# Natural Resource Allocation and Governance in the Water-Energy-Food Nexus: An Analytical Framework

**Ph.D. Thesis**

By

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**A THESIS**

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*requirements for the award of the degree*

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**DISCIPLINE OF ECONOMICS**

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# INDIAN INSTITUTE OF TECHNOLOGY INDORE

I hereby certify that the work which is being presented in the thesis entitled **NATURAL RESOURCE ALLOCATION AND GOVERNANCE IN THE WATER-ENERGY-FOOD NEXUS: AN ANALYTICAL FRAMEWORK** in the partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** and submitted in the **SCHOOL OF HUMANITIES AND SOCIAL SCIENCES, ECONOMICS, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2017 to August 2022 under the supervision of **Dr. PRITEE SHARMA**, Professor, Discipline of Economics, School of Humanities and Social Sciences, Indian Institute of Technology Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

05.12.2023.

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This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

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**SALLA NITHYANTH KUMAR** has successfully given his Ph.D. Oral Examination held on **29 NOVEMBER 2023**.

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## Abbreviations/Acronyms

| | |
|---|---|
| APWALTA | Andhra Pradesh Water, Land and Trees Act |
| AUWSP | Accelerated Urban Water Supply Programme |
| BPL | Below Poverty Line |
| CADWM | Command Area Development and Water Management |
| CBD | Convention on Biological Diversity |
| CDM | Clean Development Mechanism |
| CER | Certified Emission Reductions |
| CPCB | Central Pollution Control Board |
| CWC | Central Water Commission |
| DPAP | Drought Prone Areas Programme |
| ENGO's | Environmental Nongovernmental Organisations |
| FAO | Food and Agricultural Organisation |
| GHG | Greenhouse Gas |
| GMO | Genetically Modified Organisms |
| IAD | Institutional Analysis and Development |
| IEA | International Energy Agency |
| IFPRI | International Food Policy Research Institute |
| INDC | Intended Nationally Determined Contributions |

| | |
|---|---|
| INRM | Integrated Natural Resources Management |
| IPCC | Intergovernmental Panel on Climate Change |
| IRENA | International Renewable Energy Agency |
| ISWM | Integrated Solid Waste Management |
| IWRM | Integrated Water Resources Management |
| LDC's | Less Developed Countries |
| LPCD | Litres per capita a day |
| MIS | Micro Irrigation Systems |
| MLP | Multi-Level Perspective |
| NFSA | National Food Security Act |
| NRDWP | National Rural Drinking Water Programme |
| NWP | National Water Policy |
| OECD | Organisation for Economic Cooperation and Development |
| PDS | Public Distribution System |
| PIM | Participatory Irrigation Management |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation |
| RPF | Respect, Protect and Fulfill |
| SDG | Sustainable Development Goals |
| SNA | Social Network Analysis |
| SNM | Strategic Niche Management |
| UNDESA | United Nations Department of Economic and Social Affairs |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WCD | World Commission on Dams |
| WEC | World Energy Council |
| WEF | Water, Energy, and Food |
| WRI | World Resources Institute |
| WTO | World Trade Organisation |
| WUA's | Water User's Association |

# CHAPTER 1

## Introduction to the WEF nexus

The United Nations plan, "Transforming our World: the 2030 Agenda for Sustainable Development," adopted by 193 countries in 2015, covers a wide range of complex social, economic, and environmental challenges in the form of SDGs. The SDGs are characterized by strong interactions among them. A complex set of synergies and trade-offs make achievements in one goal without considering other goals hardly possible. Water, Energy, and Food lie among them as SDG 6, 7, and 2 respectively (Qureshi, 2021; Wydra et al., 2019). Simply put, it is the nexus formed by these three SDGs that help meet the basic needs (which are six in total i.e. SDGs 2, 3, 4, 6, 7, 11) (Zanten & Tulder, 2020). Synergies are understood as positive effects of a target achievement on ecosystem services, which in turn allow reaching other targets. While the trade-offs are understood as when environmental degradation caused by the achievement of one target limits the chances of the achievement of other targets (Fader et al., 2018). Assessing them quantitatively, significant positive and negative spearman's rank correlation (ρ) between the indicators are interpreted as synergies and trade-offs. Succinctly put, the correlation coefficient between the indicator pair with a ρ value greater than 0.6 as a synergy and with a ρ value less than -0.6 is treated as a trade-off. Furthermore, when the ρ value is between -0.6 and 0.6, such interaction is considered to be unclassified (Putra et al., 2020). The World Economic Forum (WEF) has highlighted the risk of water- energy- food nexus (WEF nexus) for the development community to shape the relationships between different departments and intertwined relationships by a holistic, operational framework. Understanding the risk of the WEF nexus systems, this issue has become an international topic for resource risk research (Chen et al., 2020). Although there is no clear definition of the term nexus so far, nexus is internationally interpreted as a process to link ideas and actions of different stakeholders from different sectors for achieving sustainable development (Endo et al., 2017). Water, Energy, and Food are vital natural resources needed to resolve critical global issues of hunger, improve health and build a sustainable and desirable economy (Shannak et al., 2018), and informed decision-making regarding climate change (Cremades et al., 2019), reducing conflicts (Abbott et al., 2017), and satisfying basic needs (Hussien et al., 2017). Water, Energy and Food are closely interlinked in many ways often termed as 'WEF nexus'. The WEF nexus aims to support a transition to a green economy in two ways i.e. achievement of greater policy coherence and higher resource efficiency (Hoff, H., 2011). The goals of the WEF nexus are outlined in the table. Besides these goals, the WEF nexus is divided into the core and peripheral nexus based on the dimensions of sustainability, drivers, extensions to the other resource systems, and challenges of the WEF nexus (Chai et al., 2020). For instance, the dimensions of sustainability (Xu et al., 2019). A similar type of understanding is also identified in the context of Urban-Rural linkages across the economic, social and environmental fronts. The core is the urban areas, where the resources from rural areas are transferred and the rural areas serve as the periphery (Sukhwani & Shaw, 2020). The nexus approach has to be investigated concerning the past integration approaches in environmental discourses such as Integrated Water Resources Management (IWRM), Integrated Natural Resources Management (INRM), and Integrated Solid Waste Management (ISWM) (Roidt & Avellán, 2019). A clear distinction between the WEF nexus and IWRM is provided by (Benson et al., 2015).

**Table 1.1 shows the comparison between IWRM and the WEF nexus Approach**

| **Item** | **Nexus Approach** | **IWRM approach** |
|---|---|---|
| Integration | Integrating water, energy, and food policy objectives | Integrating water with other policy objectives |
| Optimal governance | Integrated policy solutions, Multi-tiered Institutions | 'Good Governance' principles |
| Scale | Multiple scales | River-basin scales |
| Participation | Public-Private partnerships, Multi-stakeholder platforms for increasing stakeholder participation | Stakeholder involvement in the decision-making; multiple actors, including women |
| Resource Use | Economically rational decision-making; cost recovery | Efficient allocations; cost recovery; equitable access |
| Sustainable Development | Securitisation of resources | Demand Management |

Source: (Benson et al., 2015).

At this juncture, it is important to understand the definitions and the meanings of water, energy, and food security. All three definitions are arranged in the following table.

**Table 1.2 provides the definitions of Food, Energy, and Water Security respectively**

| Food Security | Energy Security | Water Security |
|---|---|---|
| The Food and Agriculture Organization of the United Nations (FAO) defined food security as "…when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." | Energy security has been viewed mainly in terms of the uninterrupted availability of energy sources at affordable prices. | The Global Water Partnership (GWP) (2012) has defined water security as, "Ensuring the availability of adequate and reliable water resources of acceptable quality. |

Source: (Lele et al., 2013).

Coming to integrating WEF nexus with other important sectors and resources as well are with land (Ringler et al., 2013), environment (Momblanch et al., 2019), waste (Feng et al., 2020), and ecosystems (Bekchanov et al., 2015). Given these interlinks, emphasis, and integration aspects, it is worth outlining the goals and features of the WEF nexus approach without which the framing of the issues may not address the WEF nexus effectively.

**Table 1.3 shows the Goals and Features of the WEF nexus approach**

| Goals of the WEF nexus | Features of the Nexus Approach |
|---|---|
| Achieve water, energy, and food security | Consider governance norms, institutions, organisations, and partnering private sector to improve nexus-based investments |
| Support the SDGs | Holism and Systems Approach |
| Increase resource efficiency and optimisation | Participation and inclusion of stakeholders from three sectors |
| Inform resource governance and | Provide Interdisciplinary and transdisciplinary |

| | |
|---|---|
| promote rational decision-making | methods and tools for assessment |
| Enhance policy coherence and cooperation within and between sectors | Focus on the poor and systems efficiency |
| Shift from integration within the sector to cross-sectoral integration | Reduce trade-offs and increase synergies |

Source: (Roidt & Avellán, 2019).

## 1.1 Interactions in the WEF nexus

The energy industry is water-intensive, consuming water for resource extraction, conversion, transportation, and power generation. On the other hand, the water industry is energy-intensive, consuming electricity for desalination, pumping, and wastewater treatment. This energy/water link represents a critical trade-off and possible constraint to agricultural production (MACS-G20, 2020). Furthermore, all these resources and their interactions are also interlinked with climate change (Liu, 2016).

### 1.1.1. Water for Food

Agricultural irrigation accounts for 84% of global consumptive freshwater use (Sadegh et al., 2020).

### 1.1.2. Energy for Food

The food supply chain demands up to 30% of global primary energy use (Sadegh et al., 2020).

### 1.1.3. Water for Energy

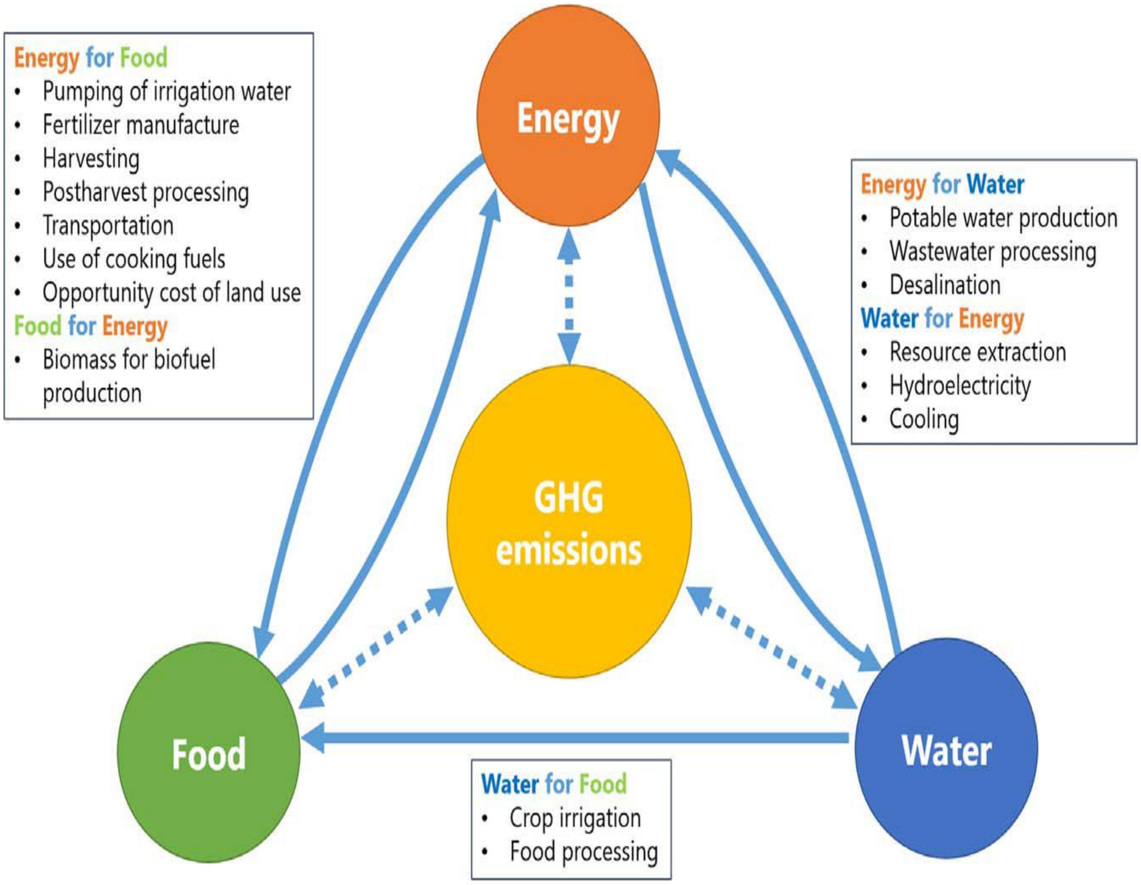
Roughly 80% of global electricity generation depends on water for cooling ≈ an average of nearly 100 litres of water withdrawn per kWh (Sadegh et al., 2020). In 2014, the energy sector accounted for 10 % of total worldwide water withdrawals and around 3% of total water consumption. About 12% of these withdrawals and 64% of the consumption were used for energy source extraction and the remaining water was used for power generation (D’Odorico et al., 2018), while (UNEP, 2016) puts the figure at 15%.

### 1.1.4. Energy for Water

Globally, 8% of the energy generation is used for pumping, treating, and transporting water, while most forms of power generation are water-intensive (UNEP, 2016). Depending on the depth, groundwater pumping is more energy-intensive than surface-water withdrawals. Additional energy is required to convey surface water when gravity flow is not an option (D'Odorico et al., 2018). Total energy consumption associated with water withdrawal as per the global average values is 0.48 and 0.37 KWh/m$^3$ for groundwater and surface water, respectively (Sadegh et al., 2020).

### 1.1.5. Food for Energy

Biofuels (biodiesel and bioethanol) can be obtained from a variety of crops, including food crops (first-generation biofuels), cellulose-rich crop residues (second generation), and algae (third generation). First-generation biofuels have a higher water footprint than fossil fuels. Thus, they compete with the food system directly (as food) and indirectly (through water) (D'Odorico et al., 2018). The interactions can be depicted in the following figure **1.1**.




Source: (Bieber et al., 2018)

## 1.2 WEF nexus paradigms

The *Global Risks Report 2011* (WEF, 2011a) has an economic standpoint, and it highlights the risks related to the WEF nexus. The report suggests that water, food, and energy securities are all likely or very likely risks, but also interconnected and driven by the same drivers. World Economic Forum also sees climate change closely linked to this nexus of risks – both as a driver for risks and influenced by the nexus stresses (Juvonen, 2015). Coming to the rise of WEF nexus's popularity in academia, the masterpiece works often cited is the background paper prepared for the conference titled "***Understanding the Nexus***' in Bonn, Germany (Hoff, H., 2011). This paper served very influentially in introducing the WEF nexus to the scientific community (de Andrade Guerra et al., 2020). The publications have shown a sharp upturn between 2015 and 2016. This upturn may be attributed to several funding calls and cross-research council initiatives launched around that time (Opejin et al., 2020). However, before it, the interlinkages and trade-offs between water, energy, and food at the global level became apparent because of the world food price crisis of 2007/08. This crisis was driven, in part, by the generation of energy from food crops contributing to a high correlation coefficient between food and oil price indexes but also by drought in key wheat-producing areas of Australia and Ukraine. Another important determinant of the close linkage between these price indexes is the increased energy intensity of agriculture and the food supply chain, particularly in some rapidly growing developing countries (Ringler et al., 2016). But the Bonn conference calls for more nexus research by listing some knowledge gaps in the nexus, especially highlighting insufficient nexus data. The report suggests that applying the nexus approach could for example help to increase resource productivity, guide the path to green growth, maintain productive ecosystems and advance poverty alleviation (Juvonen, 2015). The third European report on development 2011 'confronting scarcity: managing water, energy, and land for inclusive and sustainable growth is a type of report with a more policy and development-oriented standpoint (Juvonen, 2015), and the WEF nexus was addressed in the European policy documents such as the Blueprint to safeguard Europe's water resources (2012), and Flagship project of the European Commission's Joint Research Centre, addressing the 'water-energy-food-ecosystem nexus' in 2018 (Del Borghi et al., 2020).

## 1.3 Methods and tools in the WEF nexus

The nexus approach consists of two dimensions, that is, interdisciplinary and transdisciplinary. The first dimension addresses the complexity of linkages among water, energy, and food resources, systems, and sectors by highlighting the trade-offs and synergies between these components. The second dimension enhances cooperation with diverse groups of stakeholders and improves governance across sectors by translating systems thinking into government policy-making processes and balancing different user goals and interests (Endo et al., 2020). Qualitative methods are generally used to describe the nexus in the region of interest and include primary research methods such as Questionnaire Surveys, as well as secondary research methods such as Ontology Engineering and Integrated Maps. Quantitative methods for examining the nexus include Physical Models, Benefit-Cost Analysis (BCA), Integrated Indices, and Optimization Management Models (Endo et al., 2015). Despite researchers and practitioners have developed many tools to study the water-energy-food nexus at a variety of scales and perspectives to aid decision-making, there is a recognised lack of tools that consider these interdependent and complex interactions in an integrated fashion (Byers, 2015). The basis of the water, energy, and food nexus approach to resource management lies in accounting for interactions at the interfaces of resource systems, while holistically assessing the impact of specific scenarios or interventions from environmental, financial, and sociocultural perspectives (B. Daher et al., 2018). The tools are also characterised as simple and complex (Zhang et al., 2018). Even though some institutions and researchers have proposed some preliminary tools, they have been designed as frameworks for in-depth nexus analysis, not as simple, easy-to-use tools for conducting basic evaluations. These wide-ranging tools are intensive in terms of information, time, capacities, and funding needed (Rosales-Asensio et al., 2020). Tools that give equal weightage to water, energy, and food are not developed yet (Ringler et al., 2018). Although not exhaustive, widely used tools in analysing the WEF nexus are provided in the table below.

**Table 1.4 describes the source and content of the important tools in the WEF nexus**

| Tool | Authors | Description |
|---|---|---|
| The WEF Nexus Tool 2.0 | (B. T. Daher & Mohtar, 2015) | It is an input-output model used for analysing the national resource requirements associated with different food self-sufficiency scenarios. Users of the tool identify data inputs that provide a |

| | | |
|---|---|---|
| | | localized, contextual basis to the model: local food profile, national water, and energy portfolios, agricultural conditions, and food import-export portfolio. As a result, the tool specifies the total water, land, and energy requirements, carbon footprint, financial costs, and sustainability of the user-defined food efficiency scenario. The tool is web-accessible and open-access for users (Dargin et al., 2019). |
| CLEWs (Climate, Land-use, Energy-Water strategies) | (Howells et al., 2013) | The framework is focused on identifying Feedback across these systems use interconnections to determine how changes in one sector influence others. CLEWs have been applied to various case studies across Africa, small island developing states, and European transboundary basins with emphasis on context-specific nexus issues, such as (but not limited to) links between water availability, hydropower production, ecosystem services, and agricultural Intensification (Dargin et al., 2019). |
| MuSIASEM (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism) | (Giampietro et al., 2013) | It is a framework that builds on concepts from bioeconomics and the flow-fund model. Over the years, it has been updated to include water, energy, and food systems, simultaneously characterizing the metabolic pattern of energy, food, and water with socio-economic and ecological variables. The framework analyses the 'metabolic pattern of energy, food, and |

| | | |
|---|---|---|
| | | water' with land-use changes, population dynamics, and greenhouse gas emissions (GHG) at both national and subnational scales It has been used for both diagnostic purposes as well as to simulate scenarios defined by the user simulation purposes (Dargin et al., 2019). |
| WEAP (Water Evaluation and Planning System) and LEAP (Long Range Alternatives Planning System) | Stockholm Environment Institute 2013 and 2014 | Individually, the tools have been applied worldwide to support alternative policy measures in water resources and energy challenges. The models were integrated in 2014, becoming 'WEAP-LEAP.' The model works by exchanging parameters and outputs, such as hydropower generated or Cooling water requirements. Together, they can represent evolving conditions in both water and energy systems (Dargin et al., 2019). |
| Diagnostic tool for investment in water for agriculture and energy | Food and Agriculture Organisation of the United Nations 2013 | It provides estimates of ongoing planned investment in water resources for food and energy production projects. The tool analyses the impact of hydropower and irrigation projects on three aspects: (1) human, social, and environment (2) poverty and food security (3) health and nutrition. It also facilitates the identification of practical solutions, which reflect the institutional, legal, and policy realities of a country (Kaddoura & El Khatib, 2017; Shannak et al., 2018) |

For more elaborative nexus tools please refer to (Rosales-Asensio et al., 2020).

Given the introduction, this thesis framed its objectives surrounding governance of the water, energy, and food nexus. The first objective conceptualised the governance of natural resources which are dealt in silos employing the Earth System Governance Framework.

The second objective of the study focused on the integrated governance and integrated natural resources. As part of it, the study dealt with the global institutional architecture which impacts the allocation and access to WEF nexus. As a consequence, we used the access and allocation theoretical framework developed by (Gupta & Lebel, 2010) as part of the ESG project and takes the SDGs as a point of integration. Furthermore, we framed the analysis of allocation and access according to Rawlsian distributive Justice (Rawls, J., 1971). This study suggested decentralised governance with sectoral coordination, and the establishment of legitimacy (participation, accountability, transparency) in the governance to ensure equitable allocation of and access to WEF.

The study formed its third objective to analyse the role of institutions in the sustainable management of the WEF nexus. For this to happen, the study put forward an institutional arrangement namely- water users association as a synergy into the WEF nexus system. Furthermore, the utilised institutional arrangement i.e., water users' associations envisaged a sustainability transition toward the WEF nexus. The issue addressed is groundwater exploitation, hence energy too, for food. This objective builds on the idea of synergistic effects of the Water Users Associations (WUAs) in the WEF nexus. 'Sustainability transitions' is an emerging research field dedicated to the analysis of transitions. Sustainability transitions were used marginally in the 1990s but took pace thereafter. Coming to the methods used, the Multi-Level Perspective (MLP) is a dominant one. Despite this, MLP cannot be used as a standalone method because it requires the integration of several other frames to conduct an effective analysis. On top of this, transition studies initially were limited to a few resources such as energy, food, and housing albeit isolated. This study aims at integrating the three resources namely water, energy, and food. Within this integration, hitherto considered frameworks along with the MLP include such as technological innovation systems framework, strategic niche management, transitions management, and social practices approach. However, they are currently lagging in depicting reality. Above this, within the rules established, the role of finance and its political economy was relatively neglected so far. Further, so far, the studies about sustainability transitions are geographically focused on the global north. Accordingly, the geography of Andhra Pradesh from the global south is chosen and the Institutional Analysis and Development (IAD) framework is integrated with the multi-level governance. It was used to investigate the functioning of WUAs in the erstwhile Andhra Pradesh.

Relatively much attention to the adoption/implementation of the WEF nexus approach has been given to the legislative (laws and institutions) and executive (policies) spaces of the state. Capitalising on this gap, this study attempts to place the WEF nexus approach in the sphere of the Judiciary i.e., the third wing of the state. To this end, this study builds on the access dimension of the security concept and treats access in the WEF nexus as a 'trio' of possessing them. Further, it would also help the governance of nexus by the state holistically. This formed the fourth objective of the study. We restricted the meaning of access to WEF nexus as 'basic needs' because we place access to WEF nexus as quintessential to the survival of human beings. To this end, this study uses the 'Respect, Protect and Fulfill' (RPF) framework to analyse the WEF nexus security in India. We found that the Indian Judiciary system has already recognised the 'Right to Water'; 'Right to Electricity' and the 'Right to Food' as 'Fundamental Right' in the Indian Constitution may it be under the umbrella of the 'Right to Environment' or 'Right to Life'. So far this happened with the negative protection. Providing the same with positive protection is the key to promoting equitable access and sustainable development as well. We reached this conclusion by analysing the developments in the space of a rights-based approach to water, energy, and food hitherto in India along with the challenges to achieving the WEF nexus. Therefore, we suggest that the positive protection of these rights and the robust legal systems and instruments are vital for meeting the minimum requirements of the people.

# CHAPTER 2

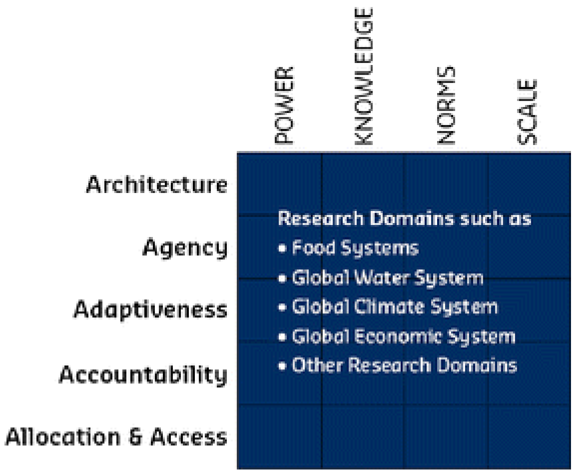
## Conceptualising Governance

Focusing on natural resources this study framed its objectives surrounding their governance. As the resources themselves are, governance as a process and outcome are also linked across the resources. To avoid ambiguity about the complexity, the mapping of governance arrangements to the resources is dealt with at first. For this to happen, conceptualising 'Governance' is the key. The success or failure of resource management is intrinsically linked to institutional structures in place. It is not uncommon to believe that most often challenges reported by many resource management paradigms such as overpopulation, environmental degradation, poverty, hunger, and deforestation to name a few are fundamentally institutional in nature.

### 2.1 Agency in the Allocation of and Access to Natural Resources

The pattern of agencies, laws, and policies that pertain to a particular resource or environmental issue is termed the institutional structure. It consists of agencies, public and private actors, and laws. Agencies need legal authority to act. The law defines what courses of action they may take. Therefore, agencies administer, make, and enforce policies within the law (Fernie & Pitkethly, 1985). The above-said process can best be included under the umbrella term 'Governance'. The means and ends of governance are abstracted from the Earth System Governance (ESG) Scholarship. Governance in ESG is conceptualised as 'The interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change, and, in particular, earth system transformation' (Biermann et al., 2009).

The schematic representation of the ESG framework is depicted in the following figure **2.1**




Source: (Biermann et al., 2009).

Its science plan operates around five analytical problems namely- Architecture, Agency, Adaptiveness, Accountability and Legitimacy, Allocation, and Access. This chapter focuses on the linkages between the analytical problems of Agency and Allocation & Access in Earth System Governance (ESG) research. The goal of the analytical question of access and allocation in the ESG research framework is focused on analysing and understanding the role and influence of state and non-state actors towards fulfilling governance functions in the context of earth system transformations (Biermann et al., 2009). However, we focus on some key natural resource domains such as water, land, forests, and Biodiversity. The two key questions this section tries to address are: (1) what is the influence of agency on the analytical problem of Allocation & Access? (2) How have the issues of equity, fairness, and justice influenced agency in the face of earth system transformations?

The problem of access and allocation understood as the process of sharing scarce resources among multiple users and resulting in an overall maximum social welfare has emerged as a dominant discourse among academics and global policymakers in the field of sustainable development, especially with the critical role of agency. The concepts are inextricably associated with efficiency criteria and pricing mechanisms playing a key role in economic development and environmental conservation. Fair and equitable allocation of benefits produced from the conservation of the environment among all stakeholders reduces inequalities and poverty and promotes sustainable livelihoods. Following its importance, studies on access and allocation are raising key questions and debates regarding the issues of Distributive and procedural justice in an uneven global political environment, and continues to generate unresolved debate in earth system discourses. For example, justice that concerns how resources are allocated and the process that resolves disputes of resource allocation remains critically unresolved in international environmental politics (Coolsaet & Pitseys, 2015; Okereke & Coventry, 2016).

Starting with the ESG–Agency Harvesting Database, we conducted a meta-analysis of the articles coded as relevant to Allocation & Access (n = 54) to explore the significant pattern of scholarship within the subset focusing on cross-cutting themes, resource systems, and geography. Our meta-analysis shows that agency in earth system governance, especially the agency of nonstate actors, has increasingly expanded to include policymaking and implementation – shaping and framing the access to and allocation of resources with a direct impact on livelihoods (Bulkeley et al., 2012). For example, ESG scholarly efforts have focused on understanding the phenomenon through the analyses of the implementation structure of Reducing Emissions from Deforestation and forest Degradation (REDD+) and its impact on the livelihood of the marginalized (Fujisaki et al., 2016), public participation by the marginalized in the governance of land use (Barau & Said, 2016; Kabiri, 2016), the implementation of Clean Development Mechanism (CDM) projects (Smits & Middleton, 2014), and the power of agency in support of policy reform that is fair, equitable, and reflects justice in developing countries (Brockhaus et al., 2014).

ESG scholars have addressed these debates by analysing the role and influence of agency in the allocation of and access to scarce resources in the context of environmental change across sectors. For example, in the forestry sector, studies have analysed the benefit-sharing regime, inclusiveness, and participation in policy implementation and its impact on livelihoods, especially in developing countries (Chhatre & Agrawal, 2009; Coolsaet & Pitseys, 2015; Dunlop & Corbera, 2016; Fujisaki et al., 2016; Mathur et al., 2014). An analysis of the Allocation & Access articles in the ESG–Agency Harvesting Database shows that 37% are focused on Forest & Land Systems; 25% are focused on Biodiversity conservation; 14% are focused on Water systems, while 21% are focused on more than one resource. Please refer to Figure **2.2**

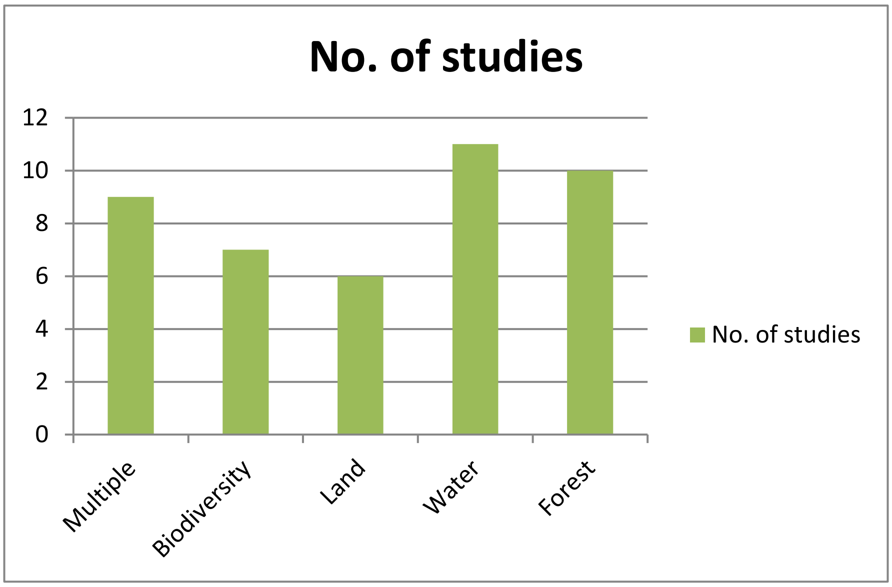



Figure 3 the focus of research articles by resource

The studies also are diverse in terms of geography (please refer to figure 4). Of particular note, there is greater coverage of earth system governance in Africa than in other areas of ESG–Agency research.

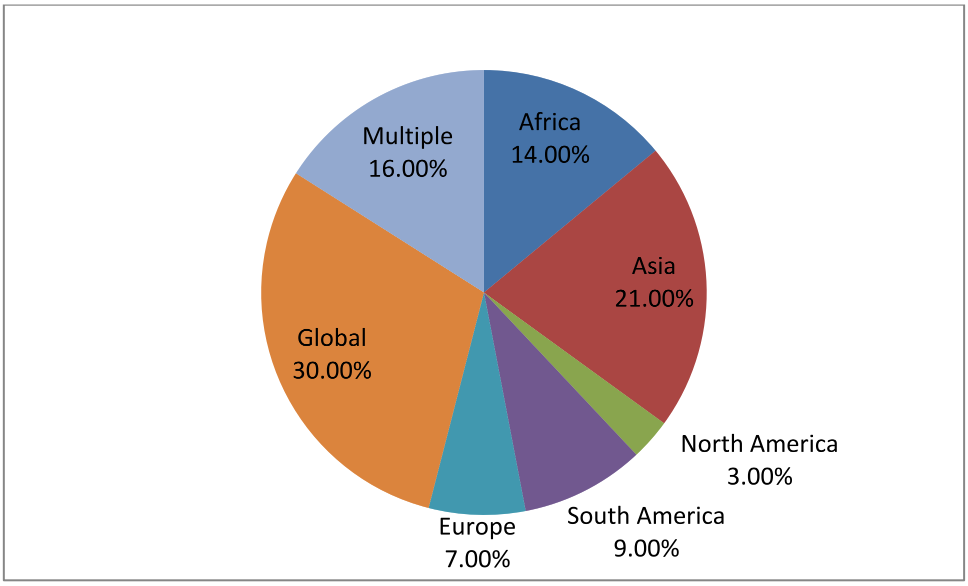



Figure **2.3** geographical distributions of research articles

## 2.2 Forest and Land Systems

Development policies related to forest systems face various constraints such as climate change in the form of greenhouse gas (GHG) emissions, deforestation, agricultural practices, biodiversity, livelihoods, human rights, and infrastructure. In the ESG–Agency research on Allocation & Access published over the past decade, we see analysis and discussion of policies related to forest systems, including REDD+, land acquisitions, and land resettlement schemes. How agency shapes these policies in the face of allocation and access is discussed here.

### 2.2.1 REDD+

REDD+ emerged from the United Nations Framework Convention on Climate Change (UNFCCC) as a central policy instrument to govern land-use–related carbon emissions from developing countries. REDD+ intends to reduce forest loss, hence reducing emissions from land-use change. REDD+ was initially designed as a market-based mechanism for conservation whereby developed country actors provide direct payments to developing countries in return for measurable reductions in carbon emissions beyond what would have occurred under a 'business as usual scenario' (Corbera & Schroeder, 2011). To qualify for financial compensation under the UNFCCC, countries have to formulate (and implement) national REDD+ strategies (Brockhaus et al., 2014). (Biermann et al., 2009) argue that REDD+ governance encompasses a range of institutions; organizations; principles; norms; mechanisms; the allocation of and access to REDD+ benefits; the effectiveness of monitoring systems; and 'good governance' principles such as transparency, accountability, and legitimacy. (Dunlop & Corbera, 2016) contend that decentralized governance can also provide a chance for local elites to capture the resources. Suitable Benefit Sharing Mechanisms (BSMs) must also be in place for the successful implementation of REDD+ in the long term.

Forests are a source of food, fuel, fibre, and various ecosystem services. The efficient and sustainable management of forests is essential for sustainable development. The drivers of deforestation and forest degradation are widely varied and country-specific. For example, they include agriculture (including large-scale forest plantations such as oil palm, small scale, subsistence); logging and mining in Indonesia; and agriculture, infrastructure, logging, fire, shifting cultivation, and migration in Vietnam (Brockhaus et al., 2014). Among these sectors, policies exist for and against REDD+. For the successful implementation of REDD+, the inclusion of all stakeholders who depend on forests and consideration of their interests has to be facilitated through public participation in decision-making.

(Newton et al., 2016) hold the view that before identifying relevant stakeholders in the forestry sector, it is important to define the term 'forest-dependent people'. Targeted beneficiaries of development or conservation policies vary according to the definition of the term. Owing to the wide range of services provided by forests, there arise many dimensions of the term. Identifying and defining exactly who counts as forest-dependent people is necessary for their inclusion in the decision-making process. A taxonomic approach, relying on the dimensions of the term and characterization of dimensions of forest–social relations helps identify forest-dependent people. Usually, the term 'forest-dependent people' is aggregated; instead, a disaggregated approach is required and it would prove successful in Mitigating trade-offs and promoting synergies in the form of effective inclusion of targeted beneficiaries in the decision-making process, whose livelihood options are affected. Otherwise, forest conservation is made possible at the cost of forest-dependent communities, infringing on their rights and affecting their livelihood options.

Environmental governance and climate change are not only technical challenges but also have serious distributional implications. The neo-liberal environmentalism approach applied to REDD+ lays special emphasis on efficiency and its principles are comparably easy to account for equity. Article 6 of the UNFCCC states that, at all levels (local, regional, national), the state has to promote and facilitate access to information, public involvement in decision-making, and access to justice. With sufficient local knowledge, forest policy decentralization reforms that transfer ownership and management responsibilities to the local forest user organization can provide social and ecological benefits together. However, public participation should not be seen only through the outcome lens because there are differences in the conceptualisation of power and influence.

Though REDD+ was emerging within the framework of UNFCCC, it was not until the Cancun Agreements of the sixteenth session of the Conference of the Parties (COP-16) in 2016 that the rights of indigenous peoples (IPs) and local communities were acknowledged as part of the social safeguards to REDD+ by taking note of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). UNDRIP recognizes IP's inherent substantive rights, including the right to self-determination; collective rights to lands, territories, and resources; and cultural rights, but also their procedural rights and the provision of Free, Prior, and Informed Consent (FPIC).

(Wallbott, 2014) finds this could be possible for IPs by ‘Importing Power’ exercising FPIC, and lobbying for rights in the community and state-level institutional spaces. (Witter et al., 2015) observe how nonstate actors influence the negotiation process by sounding alarmed, shaming, and aligning with state actors. Nonstate actors’ participation in decision-making is important, but without power is considered void. The emphasis of most research has been on non-governmental organizations (NGOs) and civil society organizations (CSOs), but there are many individuals, communities, indigenous peoples, and local communities whose interests also should be served. Often these people are marginalized through various regulatory instruments of the state.

Public participation has three facets: access to information, involvement in the decision-making process, and access to justice. For successful public participation to obtain, the three facets should be conceptualized as a package rather than in isolation (Kabiri, 2016). ‘Public’ here refers to all other actors than the state. Agency here has to ensure public participation at every phase of the policy cycle with no marginalisation in the three facets. The public satisfaction arising out of policy implementation must also be distributed equitably. These three facets are dependent on the country-specific constitution, law enforcement, and the type of government in place. They may be interlocked in the system as well. For instance, a constitution may provide the right to access information for its citizens, but the same law gives the state the right to deny the disclosure of confidential information. Therefore, the creation of institutions for public participation that particularly deals with REDD+ and environmental governance is required. Several other factors may constrain public participation, including the knowledge capacity of the participants, state bureaucracies that may not like to work with non-state actors, and infrastructure problems. REDD+ is an incentivizing program, a performance-based funding mechanism. It lays importance on the number of carbon emissions reduced. This fund can be used by the state to intimidate the other participants, which otherwise have refused the decision of the state (Sova et al., 2015).

### 2.2.2 Land Acquisition and Land resettlement

Power asymmetries are major challenges to analyse in earth system governance. Land acquisition by foreign investors in developing countries for agricultural purposes is a rapidly increasing phenomenon after the 2007–2008 world food price hikes. Land acquisition can also take place for purposes other than agricultural production. Food production not only affects land acquisition but also causes a reallocation of water and energy, which are required for food production. This leads to the reallocation of land, water, and energy resources in developing countries.

The vulnerability of the host countries may increase due to land acquisition. A study based on the socioeconomic data of households in Sierra Leone, (Yengoh et al., 2016) found that areas, where there are low levels of education, are becoming easier targets for these land investments. The areas with powerful traditional chiefs and the areas with heavy corruption are also prone to land acquisition by investors. Investors also exploit the poor economic situation of local households by making promises of development opportunities. Land investors are invited in the name of food security, fuel security, and infrastructure development. Poor governance in the local region and the marginalisation of local peoples' rights, low agricultural productivity, low level of technology used in agriculture, and the inadequate land tenure system are other factors drawing land investment to particular areas. These land acquisitions and investments affect the future and livelihoods of the locals. Many sub-Saharan African countries are presently food insecure; this gets intensified if land investors produce biofuel crops as the biofuel crops have higher market returns.

Displacement of people in developing countries due to various development projects such as dam construction, transportation, and ecosystem conservation is quite common. This affects their livelihoods adversely, and the effects can be short-term and long-term. Land resettlement schemes are present in developing countries, but not many are successful. The reasons are many, including taking away people's skillsets, introduction to new livelihood options about which they may not know, forceful expulsion from the area, and lack of political will. These were evident during the construction of the Three Gorges Dam in China (WCD, 2000).

One successful land resettlement scheme is the Federal Land Development Authority (FELDA) in Malaysia. Using the ESG analytical framework and its analytical tools combined with the path dependency approach, (Barau & Said, 2016) characterized the multidimensional aspects of the policy. FELDA was established in 1956. It served the interests of the landless population by providing them land for shelter, farming, jobs, and ownership of valorized land titles. According to the (Scudder, 1981, 1993) model, every land settlement scheme goes through four stages: (1) planning infrastructure development and recruitment, (2) transition, (3) economic and social development, and (4) handing over and incorporation. FELDA has gone through all four stages. Initially, each beneficiary received ten acres of agricultural land for the cultivation of rubber, half an acre for housing, one acre of private orchards, and a soft loan to pay back within 15 years for forest clearing expenses. In 1960, FELDA started developing land on its own throughout peninsular Malaysia (Barau & Said, 2016). In 1967, FELDA set up the Settlers Social Development Division. Its main task was to modernize settlers and introduce them to modern businesses and procedures for marketing rubber and palm oil. Lastly, in 2005, FELDA introduced a subsidiary company named the FELDA Techno Plant Company Limited. Thus, the economic nature of the institutions is introduced.

### 2.3 Water Systems

Governance of the water system is heterogeneous due to its multilevel nature including local, national, and transnational basins. The interactions between natural and built systems are evident in water governance, particularly in dealing with the quality aspect of water. ESG–Agency research on the governance of water systems includes studies on the Ramsar Convention and the role of agencies including shared river basin organizations (international, national, regional), social-ecological regime shifts, and marine protected areas management. This section discusses studies on how agents make decisions about the allocation of and access to water resources. The methods used in analysing the governance of water systems include analysis of discursive and ideological dimensions of power, semi-structured interviews, focus group interviews, historical analysis, fieldwork, local surveys, and discourse analysis. Some of the research reflects a realist view of power as well as perspectives drawn from political ecology and political economy.

#### 2.3.1 Ramsar Convention and Wetlands

The Ramsar Convention is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their services and resources. According to the Ramsar Convention of 1971, wetlands are ‘areas of marsh, fen, peatland or water, whether natural or artificial, permanent or seasonal with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six metres’. Wetlands, which are saturated and inundated for an extended period, have unique soils and vegetation, and natural cycle processes that support unique biodiversity. Many environmental hazards arising from industrial pollution, climate change, and rapid urbanization are posing threats to wetlands across the globe. Using the principles of wise use of wetlands, national conservation agencies of wetlands often place more emphasis on conservation, which restricts the rights of the public to access the ecosystem services that wetlands provide (e.g., Regulatory, Provisioning, Supporting, and Cultural services). The negative impacts of conservation range from displacement to loss of livelihood options, while the positive benefits include the opening of new livelihood options concomitant with ecotourism.

The trade-offs between conservation and livelihood options and across the various ecosystem services are illustrated in (Salisu Barau & Stringer, 2015) study of the Pulau Kukup area as a Ramsar Site. This designation has restricted people's ability to access the cultural and historical values of the site, contradicting the Ramsar Convention's principles of wise use. At the same time, the Ramsar designation has improved their livelihoods in the form of local business, fishing, hotels, and gastronomy tourism due to the influx of Eco tourists. People in the Pulau Kukup site expressed their happiness about their long-term livelihood option enabling socio-economic development.

### 2.3.2 Forms of Agency in the Water Systems

The sustainable management of water resources requires decentralized governance and public participation in decision-making. Public participation in water management is increasing, but resulting in more complexity. In their comparative study on Yaqui Valley, Mexico; Upper San Pedro Basin, USA; Ceara Basin, Brazil; and Upper Ping River, Thailand, (Jacobs et al., 2016) suggest that participatory processes are better in the context of short-term decisions such as water allocations and not for long-term, high-stakes decisions regarding infrastructure. The transaction costs of public participation processes are high and require huge amounts of time.

An integrated understanding of the problems related to the governance of water systems has to be addressed. Co-management, knowledge building, and problem-solving approaches are not common in water governance across the world. Water systems governance is dynamic in nature and hence understanding the socio-ecological regime shifts and transformations depend on water systems information. Empirical studies of Cau Hai Lagoon in central Vietnam (Andrachuk & Armitage, 2015), Chilika Lagoon in India, and Tim Giang Lagoon in Vietnam (Nayak et al., 2016) suggest that community perceptions of the social-ecological system and social relations of power and politics in periods of abrupt coastal and marine change will adversely affect the on-going efforts to predict and navigate changes to the benefit of ecosystems and human wellbeing, respectively. On the other hand, (Gerhardinger et al., 2009) find that the incorporation of fisher's local ecological knowledge and the resource user communities 'goals (irrigation, urban drinking, hydropower generation, industrial use) in governance improves the management of water resources.

Allocation problems in the water system are linked to other natural factors such as geographic position (e.g., upstream and downstream problems) and infrastructural, financial, and political power asymmetries existing between these positions. For example, (Menga & Mirumachi, 2016) find that decision-makers in Tajikistan have employed various strategies to establish the country's role as an environmental champion via international diplomacy, the mobilization of financial support through powerful allies, and the adoption of a domestic policy aimed at fostering a sense of national identity and patriotism through the Rogun Dam. 'Soft' power plays a role in transboundary water interactions through discourses that frame river basin development as attaining integrative benefits and facilitating buy-in to the proposed measures (Menga & Mirumachi, 2016). (Gabrielsson & Ramasar, 2013) emphasize that gender plays a major role in water management. Increased empowerment of widows and their collective action in the Nyanza province, Onjiko location, Western Kenya, illustrates the way to respond to water scarcity, uncertainty, and working out innovative livelihood strategies. Reforms are needed in the political, ecological, cultural, and economic spheres to empower women and understand their role in water resource management. Likewise, in marine systems, (Österblom et al., 2015) found that under globalization trends, transnational corporations are becoming the 'keystone' actors in the fishing and aquaculture industry. This power asymmetry between transnational corporations and local fishing communities further exacerbates the pressure on diverse species of marine ecosystems, besides making fishing communities vulnerable, and unemployed, and hampering their socio-economic development.

### 2.4 Biodiversity Conservation

The third issue area where we explore the links between ESG–Agency and Allocation & Access research over the past decade is biodiversity. Biodiversity is important for the planet Earth; we derive many benefits from biodiversity in the form of ecosystem goods and services. Maintaining biodiversity for the present and future generations is crucial for achieving sustainable development. In the Anthropocene era, human interactions with the environment in the areas of forest, water, agriculture, mining, and industrial pollution have huge impacts on biodiversity. In 2010, parties to the United Nations Convention on Biological Diversity (CBD) adopted the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. Access and benefit-sharing issues have evolved out of concerns for distributive injustice where the loss of access and gain of benefit arising out of biodiversity conservation is unequally distributed based on income, reallocation of resources, and shifting of livelihood options Decisions about the distribution of benefits and costs between the user and providing parties of genetic resources depend on the material, social, political, cultural, and institutional circumstances prevailing (Coolsaet & Pitseys, 2015). As a result of power asymmetries existing among participants in any environmental negotiations, better outcomes may not be always for the disadvantaged sections.

Principles of procedural justice (access to information, involvement in the decision-making process, and access to justice) are assumed to enhance fairness and equity in the outcomes regarding benefit sharing of any environmental conservation policy. The number of stakeholders involved in the decision-making process is not necessarily an efficient indicator to evaluate the effectiveness of public participation. Rather, the likelihood of their voices being able to influence the outcomes of decisions is also an important dimension to consider. Taking into account all of the stakeholders, including NGOs, CSOs, IPs, businesses, and local communities (Paloniemi et al., 2015), in making decisions regarding environmental conservation ensures the fairness of the process (Young et al., 2016). Environmental governance networks comprising state and nonstate actors can be seen as an opportunity in influencing the decision, but lobbying or threats between these actors gives scope to the state to fulfil its interests. The trust between these actors in the governance network enables the achievement of common goals (Young et al., 2016). Hence, decentralized governance coupled with community management of resources plays an important role in the allocation of and access to resources (Robinson & Makupa, 2015).

**Summary and Conclusion**

The issues of access to and allocation of natural resources are becoming central political discourses in a world with growing inequalities within and across national borders. Inequality as a contextual condition in the new ESG Science plan is interrelated with the other three contextual conditions (Transformations, Anthropocene, and Diversity) as well (Earth System Governance Project, 2018). Multiple tradeoffs and synergies are occurring in governing resources for socio-economic development along with the conservation of the environment. Conservation policies place emphasis on the protection of the environment and safeguarding ecosystem goods and services. This often leads to loss of access to the environment for the people who are dependent on environmental goods and services, such as forest-dependent people and fishing communities. Consideration of all stakeholders dependent on these resources is a promising approach for making decisions without affecting any section of society. Opportunities for future research include furthering understanding of the trade-offs and synergies in conservation policies and potential conflicts with ownership and livelihoods; the role of gender in resource management, especially in the water resources; evaluating the modes of power in which power acts; and understanding how people acquire the power.

Legitimate and transparent democratic processes can promote acceptance of environmental policies with a strong linkage to the question of access to and allocation of resources (Kalfagianni & Pattberg, 2013). Public participation in decision and policy making is an important tool towards ensuring justice in earth system governance as it empowers and mobilizes communities to seek equitable distribution of resources (Anand, 2004). However, (Atela et al., 2017) stress the quality of participation and inclusiveness in policy and decision-making in environmental governance, especially from the Global South. In addressing the question of justice in environmental governance, divergent views arise in the description of the affected as a result of interest, context, and understanding of the purpose of the resources (Newton et al., 2016). Therefore, there is a need to reinforce ESG research towards an interrogation of the role of agency in the pathway of achieving justice in the allocation of and access to resources in the face of increasing global inequality.

In closing, Across the three-issue areas studied here, the agency plays an important role in every phase of the policy cycle (decision-making, agenda-setting, problem definition, policy design, policy implementation, policy enforcement, and policy evaluation), which has a direct impact on the allocation of and access to resources.

# CHAPTER 3

## Integrated Resources and Integrated Governance

The common elements of the WEF nexus include a ‘global public goods’ element, international trade, and strong interdependencies with climate change and the environment (Bazilian et al., 2011), and hence, these must be treated in an integrated manner rather than in isolation (Hoff, H., 2011). The interrelations in the form of trade-offs and synergies can be understood by employing system-level thinking. The interrelations existing among them are further intensified as a consequence of population dynamics i.e. population growth, urbanisation, changing consumption patterns, climate change, and food waste.

Globally, 3 billion people are without access to modern fuels or technologies for cooking/heating, 900 million people lack access to safe water, 2.3 billion lack improved sanitation (UNEP, 2019), ), and 821 million people are undernourished (UNDESA, 2019). The present world population of 7.6 billion (mid-2017) is expected to reach 9.8 billion in 2050 (UNDESA., 2017) and may require a 70% increase in food production by 2050 (FAO, 2014); a 30% increase in energy demand by 2040 even if energy efficiency gains are accounted for (WEF, 2017); and more than 40% of the world population will live in river basins under severe stress (OECD, 2014). Given these interactions within the sector and between the sectors, there are a few approaches that take all three sectors in an integrated manner into account.

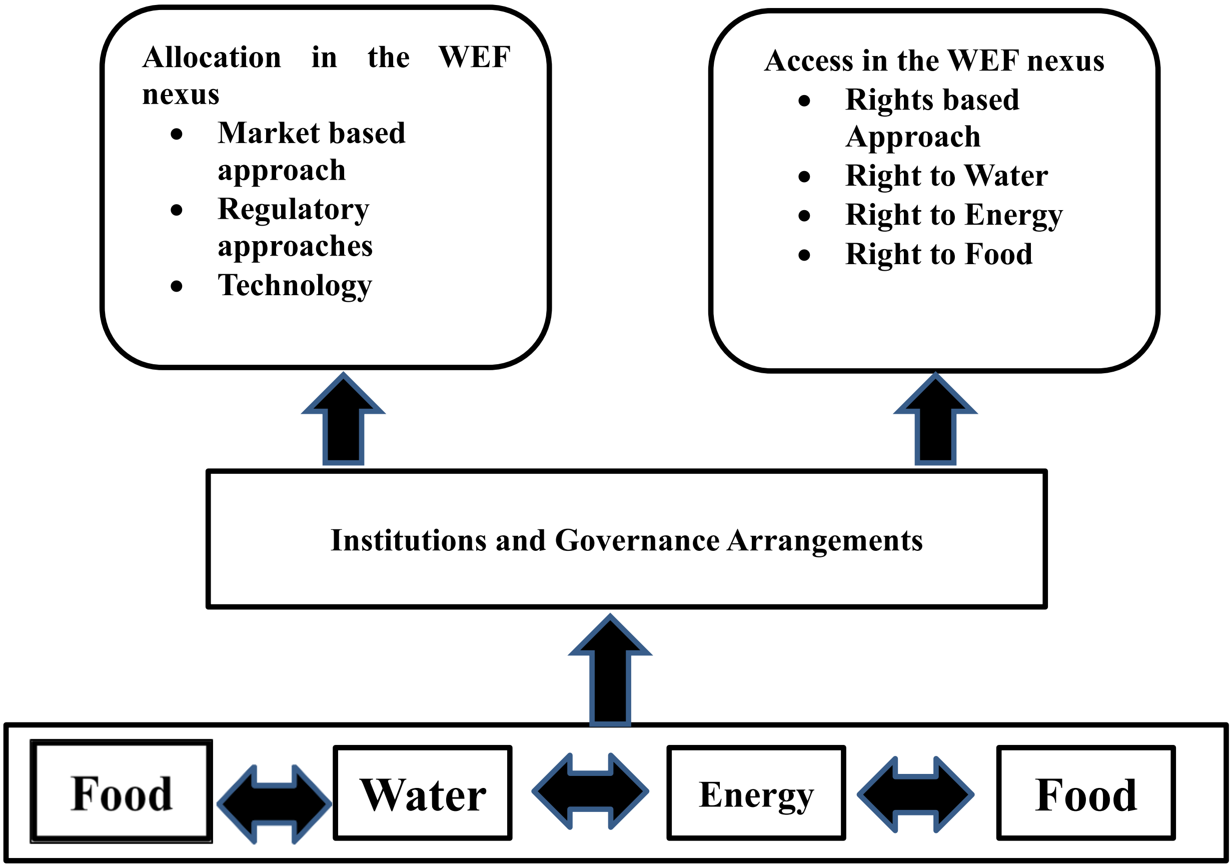
The WEF nexus accounts for all three resources. Nevertheless, many nexus papers are either water-centric or focused on dual-sector interactions which are ‘insufficiently cross-sectoral to improve coordination of policies across resource sectors and reduce unintended tradeoffs and impacts among water, energy, and food security (Albrecht et al., 2018). Governance in the WEF nexus consists of all actors and their networks that affect the consumption and production of these resources. Thus, it requires vertical (actors in each sector at various levels) and horizontal (actors across the sectors) coordination to promote synergies and mitigate trade-offs arising out of resource constraints within the WEF system (Hagemann & Kirschke, 2017); the successful implementation of the innovations across the sectors (Halbe et al., 2015); and integration with the environment (Weitz et al., 2017). The governance in each sector plays a major role in determining the effectiveness of other sectors by creating institutions, influencing institutional adaptability, and shaping the processes in each phase of the policy cycle (decision-making, agenda-setting, problem definition, policy design, policy implementation, policy enforcement, policy evaluation) (Portney, 1992).

### 3.1 The framework for allocation of and access to WEF Nexus

Allocation in the nexus literature can be understood as the distribution of each resource available within its subsectors along with all the subsectors in the other two sectors. For instance, water allocation deals with how the water is distributed for domestic purposes, irrigation and industrial purposes (within the sector), for the energy sector (coal-fired, hydropower, and virtual water in case of food that is converted to biofuels), and for food (irrigation and processing), respectively. We used the Rawlsian conception of Distributive Justice in this study. While addressing distributive issues the nexus deals with one dimension of equity. Equity in the nexus is conceptualised as the distribution of one resource as input to produce the other two resources where the net societal welfare is maximized after the externalities are internalised i.e., allocation of a resource where the proportionate benefits and costs are shared. This holds for the energy and food sectors as well. Access to the nexus means the ability to meet the minimum requirements of humans across the three resources. Covering the minimum requirements, it deals with the second dimension of equity. It seeks to ensure that the basic requirements of people are met for a resource along with the other two resources i.e., access in the nexus is achieved if all the three resources are provided as a 'bundle'. However, there is no uniform universal norm and therefore minimum requirements vary by the custom, culture, and geography and at different times within geography to ensure a minimum and decent standard of living. The decent standard of living is more comprehensive than the minimum standard of living, but the WEF nexus forms the basic requirements of the decent standard of living among other things.

This paper uses the access and allocation theoretical framework developed by (Gupta & Lebel, 2010) as part of the Earth System Governance project and takes the Sustainable Development Goals (SDGs) as a point of integration. The framework is adjusted for the WEF. Water, Energy, and Food is inextricably interlinked. The institutional arrangements in the WEF distribute the amount of the available resources to competing demands. The market-based allocation of the WEF can be drawn from the neoliberal economics literature. In this approach, the marginal cost of production is the price we pay for. The access to WEF in the market-based approach depends on the ability to pay for WEF. The other method of allocation used for the WEF is the regulatory approach. It deals with the ceiling of some resources used for specific purposes with the information on the available resources. The relative merits and demerits of alternative approaches to the allocation and access to WEF are addressed in the Discussion section. The word 'efficiency' is related to the least-cost input combination i.e., greater output for the same inputs, whereas 'effective' refers to whether the equity in the allocation and/or access is attained. It is related to the outcome. If both the dimensions of equity are attained out of the allocation and access, then distributive justice is effectively accomplished. Since efficiency is a process, laying the principles of procedural justice in the allocation and access is more likely to be effective. Efficiency contributes to equity if the redistribution mechanisms are in place. Coming to Access to WEF, we employ a rights-based approach. To ensure access to the WEF nexus people need to be provided with water rights, right to energy, and the right to food combined. The methods of allocation of and access to these resources are depicted in the following figure.

Figure **3.1** shows the governance analysis in the Allocation and Access in the WEF Nexus




Source: The basic tenet of the analysis is taken (Gupta & Lebel, 2010) and adjusted to include Energy and Food.

The further analysis ponders on the tradeoffs in the WEF nexus including those arising in the face of climate change. Climate change has impacts on water, energy, and food security (Wichelns, 2017).

### 3.2 Governance of water: Implications for energy and food

This section focuses on some of the lessons on water governance that emerge from the literature. Global Water Governance can be defined as the development and implementation of norms, principles, rules, incentives, informative tools, and infrastructure to promote a change in the behavior of actors at the global level in the area of water governance (Pahl-Wostl et al., 2008). UN-Water was founded in 2003 and has not been able to reduce the system's overall ineffectiveness in achieving water-related targets in the field of global water governance. This is because it is constrained by its institutional setup to act in the foreground and has not been able to significantly improve some structural deficiencies (Baumgartner & Pahl-Wostl, 2013). As the local environmental and social phenomena surrounding water are situated in global dynamics, management of transboundary water issues remains global in nature. The reasons are: The hydrological system is a global system and is affected by climate change, which is again a global phenomenon in nature. Furthermore, the pattern of food production in the basin is affected by global trade. The water embedded in such food production is evaluated by the concept of 'virtual water'. With very few parties having ratified and the lack of executing agencies under the UN Convention on the non-Navigational Uses of International Watercourses (UNWC 1997), it has not substantially influenced global policies on sharing water (Gupta, 2016). At the national level governance depends on social, economic, and political factors (Abu-Zeid, 2001).

Competing demands from agriculture, industry, domestic needs, and the environment are outstripping the supply of limited water supplies. Furthermore, there are limits to augmenting the supply of water in the "matured water economy" due to the dearth of financial resources, environmental impacts, the displacement of people in constructing new water infrastructure projects, and the impacts due to climate variability and change (Expósito & Berbel, 2017). Adaptive management depends on how problems are defined and by whom (variety), the learning capacity of institutions, room for autonomous change, leadership, resources, and fair governance (Gupta et al., 2010). Within the WEF framework, the governance of water for the inter-sectoral and intra-sectoral demands plays a major role in mitigating the trade-offs and tapping the synergies existing in the WEF system. The major tradeoffs existing in the WEF system for water allocation are the conflict between hydropower generation and irrigation, drinking water and irrigation, or between conventional energy and agricultural purposes as is the case of the yellow river basin in China (Xiang et al., 2017). Hence, the coordination among all the actors present in the WEF system is a prerequisite for the equitable allocation of water among the competing demands. Since the allocation takes place at decentralised levels it is where the coordination from cross-sectoral actors with no power differences existing among them plays a major role in the equitable allocation of water in the WEF system. The participatory forms of governance such as partnership, polycentric or collaborative governance paves way for the equitable allocation of the resources since all the actors in the WEF system are part of the legitimate decision-making regarding the allocation of the resources. But it is expected that none of the power dominations and lobbying takes place between them. The allocation of, and access to, water resources affect the equity of its other interlinked sectors such as energy and food, and vice-versa. However, the issues surrounding water are most dependent upon the method of allocation and pricing (Dinar & Mody, 2004; Johansson et al., 2002). Meeting the SDGs for water requires, inter alia, meeting the needs for water and sanitation for the poorest (Hurlbert, 2020).

Partnership and polycentric (collaborative approach) forms of governance in water resources exist with their own merits and demerits, depending upon the extent to which 'power' can be exercised by an actor in decision-making. (Pahl-Wostl et al., 2012) applied a generic but contextual diagnostic approach, which distinguishes between water governance regime, regime performance, and the environmental and socio-economic contexts, for 29 river basins across Latin America, Europe, Asia, and Africa (industrialized and developing countries). They provide evidence that polycentric governance regimes are characterized by a distribution of power and effective coordination structures and have higher regime performance in the sustainable management of water resources. Research suggests that collaborative approaches that include broad stakeholder inclusion, face-to-face deliberation, shared learning, willingness to reconsider assumptions, pooling of resources, the building of long-term relationships, and consensus-focused decision-making (Brisbois & Loë, 2016) may have more successful outcomes.

Despite the strengths of participatory forms of governance, it also cannot escape critique, especially from the dimensions of lack of procedural justice and the power imbalances among the stakeholders. The success and outcome of participatory governance depend on how the problem is structured (Hurlbert & Gupta, 2015). Participatory or cooperative management may not ensure the effective management of water resources, especially where issues are unstructured. Participatory approaches may be more suited for short-term rather than long-term decisions (Jacobs et al., 2016). Participation works well when the costs are properly budgeted. However, very often governance processes do not adequately take these into account (Anggraeni et al., 2019). Polycentric approaches may also be characterized by legal pluralism – where different rules apply to the same jurisdiction and this can have positive outcomes when these rules are mutually supportive or accommodating, but they can also lead to a competition where power determines the outcome (Gupta & Bavinck, 2014).

The state, private businesses, environmental NGOs (ENGOs), and citizens are actors in collaborative water governance, each with their vested interests. Employing Luke's framework of 'power' to provincial water governance in Alberta and Ontario Canada revealed how the energy sector (e.g., the petrochemical industries in Ontario and the energy sector in Alberta) dominates decision-making even in collaborative approaches to water governance (Brisbois & de Loë, 2016). Dominant industry uses instrumental, structural, and discursive power in shaping water policies. In collaborative processes, firms face challenges in engaging with diverse actors who influence the decision-making process; building relationships with other relevant actors; and are uncomfortable with the 'messy' process involving multiple actors with different perspectives, interests, and skills; and the time and resources spent in a participation process with uncertain outcomes (de Loë et al., 2016).

### 3.3 Governance in the Energy sector: Climate change and renewable energy

We now turn to lessons learned on energy governance from the literature. Energy is essential for human sustenance, livelihoods, and economic development and it has been incorporated into SDG 7. Globally, 1.4 billion people lack access to electricity and 3 billion people are without access to modern fuels or technologies for cooking/heating (UNEP, 2019). The drivers of energy include population dynamics, urbanisation, change in consumption patterns, economic growth, and climate change (UNEP, 2019).

The International Energy Agency (IEA), founded in 1974 in response to the 1973-74 oil crises, governs energy. In 1993, it adopted the goals of energy security, economic development, and environmental protection (the three E's). IEA is an adaptive institution from the perspective of 'new institutionalism' (Van de Graaf & Lesage, 2009) and has tried to integrate global energy and climate governance (Heubaum & Biermann, 2015) in partnership with the Climate Treaty regime and the International Renewable Energy Agency

(IRENA). IRENA, established in 2009, promotes the use of renewable energy and the limited literature only deals with the creation, ratification, and functions of IRENA (Urpelainen & Van de Graaf, 2015). The Clean Development Mechanism (CDM) under the 1997 Kyoto Protocol on Climate Change aimed to promote GHG emission reduction in industrialized countries by enabling them to reduce these emissions in developing countries in a cost-effective manner.

In developing countries agriculture is the significant source of demand for energy where it is needed for groundwater pumping, lift irrigation purposes, the fertilizer industry, and treatment of sewage and wastewater. The Governance of the energy sector has implications for the equitable allocation and access in the WEF system. The trade-offs existing in the WEF arise out of the energy governance mainly stem from the concerns of climate change and the improper functioning of the Water User Associations (WUA's). Under latter circumstances, the farmers resort to the abstraction of groundwater which is impossible without the provision of energy. This is one of the places where the role of coordination among actors from the cross sectors in the WEF is evident. The synergies existing in the WEF system could be reaped by the proper functioning of the WUAs in the form of energy savings (Bhaduri et al., 2015; Mekonnen et al., 2015; Shenhav et al., 2019). Climate change is yet another factor to be considered in energy governance from the WEF perspective. Since energy is a major greenhouse gas (GHG) emitter that is causing climate change. Therefore, to combat climate change, the replacement of renewable and clean energy for conventional energy sources is increasingly occurring. The energy transition is yet to take off globally, as internationally we are set to cross 1.5C by 2030 unless urgent action is taken (Michaelowa et al., 2018). The move for such renewables is not without the tradeoffs in the WEF system and affecting the equitable allocation and access to the WEF such as the use of land for biofuel (energy) crops has trade-offs with water and food (Rulli et al., 2016), the generation of hydropower requires dam construction which affects water access to downstream users and water allocation for irrigation purposes impacting food security (e.g. in the Mekong region (Smajgl et al., 2016; Smits & Middleton, 2014), and the land for the other renewable energy sources such as wind and solar energy. The distributional effects in such allocation are evident as the poor farmer's crops are converted into an affluent person's fuel for commutation. Access to food is also affected by the affordability dimension of food security due to the rise in the price of food crops for the conversion of food (i.e. increased demand) into biofuels. This violates the 'Distributive Justice' one of the three tents of 'Energy Justice'. Energy Justice deals with the application of principles of justice to the energy system as a whole. Energy justice has three tenets- distributive justice, procedural justice, and recognition justice (Jenkins et al., 2016). However, biofuel policy may have negative social and ecological impacts on exporting countries (Lima & Gupta, 2014).

In the case of CDM,  the distributional effects arise in the form of choice of developing countries, technologies, prices, and the complexities that evolve out of contexts (external) to the 'host countries. While host countries wish to address energy security, energy poverty, and reduce emissions; their investment (finance, price, and technical capacity) and policy (multi-level governance) characteristics determine CDM project approvals. In India (with the highest number of rejected CDM projects); the approved CDM projects within different states are correlated with the state's income, resources, industrial growth, and governance. Moreover, the negative social and environmental impacts associated with CDM projects, the availability of multiple sources of funding, and the lack of actor coordination have impeded its progress (Newell et al., 2011). The CDM objectives of 'Additionality' and contribution to 'sustainable development in the host countries have often been reduced to technicalities and have failed to achieve the latter (Newell et al., 2011; Smits & Middleton, 2014). Results from a non-CDM project show that the multiple sources of funding with diverse vested interests have led to, e.g., massive hydropower generation in the Mekong region transferring accountability from public to private actors where issues of food security, livelihoods, and ecosystem services may be undermined (Merme et al., 2014).

The energy transition to biofuels or other renewables involves the water or/and food embedded into it and both the resources operate at the local levels leading to increased competition for land. This again lays the importance of a decentralised form of governance with cross-sectoral and inter-sectoral coordination in the equitable allocation and access to the WEF.

The above discussion highlights the need for the incorporation of the stakeholders present in the WEF for environmental policies aiming at GHG mitigation from the energy sector to ensure equitable allocation and access to the WEF and to reduce the tradeoffs arising out of the allocation and access.

### 3.4 Governance of Food: Farm income and implications for energy and water

We now examine the lessons learned from food governance from the literature. Food Security is universally considered a primary goal for nations irrespective of their level of economic development. It is widely discussed in academic, business, and policy circles. Food security and trade policy have complex links. Though the World Trade Organisation (WTO) has embraced the norm of 'free trade', the politics and power differentials existing among competing interests have contributed to the partial and uneven application in the agricultural sector (Clapp, 2015). However, WTO's role in global food security is contested by non-governmental organisations in the wake of the global food crisis of 2008 (Margulis, 2014). Availability, access to food, use, and stability over time are the four dimensions of food security (Gross et al., 2000). As of 2017, one out of nine persons worldwide faces food insecurity (FAO, 2018). On the contrary, food waste is 33 percent of all the food produced globally, of which 56 percent is in developed countries (UNEP, 2019). SDG 2 aims to end all forms of hunger and malnourishment, respectively. Globally, agriculture accounts for 70 % and 30% use of water and energy respectively (Chang et al., 2016). Despite such use, small farmers' incomes remain static while food prices increase for consumers. The complex food system does not contribute to enhancing access to and allocation of food (Azizi, 2020) while addressing water and energy constraints. Food availability is linked to productivity as access to food is linked to affordability. The rise in food prices hurts the affordability dimension of food security affecting the poorest that spend a relatively higher proportion of their income on food than the rich. Food price rise is caused by local to global contextual issues. For instance, rising food prices in South Africa were due to rising input (water and energy) costs and in South Africa, the poorest 30% of people spent approximately 34% more of their monthly income on food than the 30% wealthiest people did (Gulati et al., 2013). The causes of the 2008 global food crises were, inter alia, 'market fundamentals', a weak USD, an unregulated agricultural commodity derivatives futures market, and the growing production of biofuels (Clapp, 2009; Rosegrant, 2008). However, the prices fell rapidly when the United States (US) (and others subsequently) tightened its regulations on the commodity futures market and swaps by imposing 'position limits' (i.e., ceiling on the number of agricultural futures contracts a single non-commercial trader is allowed to hold) on 'non-commercial' investors. This shows the importance of global financial markets and their influence on food prices (Clapp & Helleiner, 2012). At the same time, the rise of biofuel production encouraged by Roundtables can be held accountable for 30 percent of the rise in food prices (Clapp, 2009). Such biofuel production uses 2-3% of the water and land available for agriculture which could potentially feed 30% of the malnourished people in the world (Rulli et al., 2016).

Low farm incomes of small farmers limit their ability to pay their dues towards the provision of energy and water services. The situation calls either for water conservation or for the move towards non-food or commercial crops. The latter situation may pose threat to the food security concerns of the people. Water conservation efforts receive attention in two situations. The first is to decrease the amount of water being used to produce the same quantity of food i.e., water use productivity. Water conservation efforts come dearer to the farmers and may likely increase the cost of cultivation but can be compensated through increased productivity. But the initial investment required for such structures is a concern and very much contingent upon the farmer's income (Jobbins et al., 2015). In such a case, many nations provide subsidies to the water-conserving structures, but this led to inequitable allocation because the subsidies either do not signal the water scarcity signals to the farmers or put the burden on the exchequer.

The second is water conservation in the face of climate change. Agriculture is vulnerable to climate variability and change (IPCC, 2014). Adaptive agriculture is the key to promoting food security and achieving economic development. Vulnerability to climate change is not solely solved by the formation and design of institutions or policy procedures, it further depends upon the way they are implemented and operationalized in practice. Stakeholders' participation in decision-making is crucial for increasing the adaptive capacity and reducing the vulnerability of agriculture to climate variation and change. The case study of two successful adaptive governance programs (Farm Stewardship Programme and the Water Infrastructure program) in Saskatchewan in Canada found that flexible decentralised governance tailored to local geographical conditions, incorporating the perceptions of local farm producers, and establishing the trust between the government and the farmers enabled successful adaptive governance in practice (Hurlbert, 2014). However, this is less likely to happen in international agricultural adaptation regimes. Within the global climate change regime, farmers' voices are systematically under-represented, and they are unable to influence agenda-setting and decision-making and this implicitly shapes the outcomes that discriminate against poor farmers (Sova et al., 2015).

### 3.5 Discussion

Equitable allocation and access can be achieved where the principles of distributional justice and procedural justice are laid in governing the WEF system. To ensure equity, WEF is allocated on the criterion of proportionate sharing of benefits and costs even after accounting for the externalities. The potential problems with the market-based allocation are that those do not recover the fixed costs associated with the infrastructure related to the WEF nexus. Moreover, it does not meet the second dimension of equity i.e., minimum requirements of the people. Considering the externalities of resource use in the allocation mechanism in WEF, the social costs should not exceed private benefits. For this to happen, we need to internalize the externalities. But it is fraught with the heavy transaction costs involved (Markantonis et al., 2019). Instead, using quantitative regulations such as Laws, Permits, Quotas, and Rationing could serve as an alternative mechanism of allocation to overcome the resource pressures but hinder the service quality dimension of allocation. Moreover, these quantitative regulations should be tradable. Technology as an alternate form of allocation in WEF may strive for efficiency (more output with the same inputs), and reduce resource scarcity but unfortunately, many technologies within the WEF nexus are 'backstop' technologies that require consumer adoption and are deeply interlinked with the income of the people e.g., desalinated water, solar energy. Furthermore, it may not meet the basic access to WEF for poor people. However, subsidies can be given to people but may not be sustainable (Rasul, 2016). Getting 'prices right' also may not always be useful because it often leads to social unrest, violence, and increased human insecurities (Snorek, 2015). Access in the nexus literature is defined as the people's capacity to be able to meet their minimum requirements in terms of achieving water, energy, and food security. It seeks to ensure that the basic requirement of humans is met across the WEF nexus at a point of time and stable over a while i.e., water, energy, and food are to be provided for the people as a 'triplet' of goods and security over long-term because people who have access to any single resource may not be able to access the other two resources. The reason to buttress the claim is that under the 'silos' management of the WEF nexus the tradeoffs in the nexus induce resource scarcity for the other resources. Furthermore, the difference in the number of people who lack access to water, energy, and food is evident. Both the allocation and access are also deeply linked to the infrastructure-related process. For instance, providing the threshold limits of water (50 or 55 lpcd) through the piped water supply is different from the service of a hand pump and its distance from the user. The role of Recognition Justice plays a crucial role here. The burden of fetching water and fuelwood (those who lack access to clean cooking sources of energy) falls on the female gender of the rural households. The marginalisation of the people based on gender, and social and economic status needs to be recognised in the WEF nexus. The governance of the WEF nexus is desired to be inclusive of them. Besides it, the state and non-state actors (non-governmental organisations, civil society) may strive together to enhance capacity-building in the community-led management of the WEF nexus through the provision of personnel and financial capacities. Similarly, for food, the lack of storage facilities may lead to food waste. Reducing food waste can provide access to food for the people who do not have it so far or can achieve both the energy and water savings that have gone through the production process of food (Kibler et al., 2018). To govern the inequity issues in the above-mentioned alternate mechanisms of allocation we suggest that market-based allocation ignores the basic access to WEF (hence, it is inequitable allocation); the Regulatory approach can be equitable if they are tradable. In the case of technology as a form of allocation, it ignores the basic access dimension of WEF because the people whose income levels are low find it difficult to adopt such technologies. Technology to become an equitable allocation mechanism, there is a need for coordination among policy, business, and social circles. Therefore, without coordinated governance of the WEF nexus, tradeoffs between the equity dimensions of the allocation mechanism may persist. Therefore, the allocation mechanism has a bearing on access to WEF. The appropriate allocation mechanism to choose is in which the trade-off between the two dimensions of equity is minimum. The lack of policy coordination among actors in one sector has repercussions on the WEF system. The stakeholder participation, even if it exists, the lack of other features that ensure legitimacy in the governance such as procedural justice may not ensure the equitable allocation and access to WEF.

The marginalisation of farmers in the decision-making raises key issues about the allocation of and access to water and energy since agriculture is a significant consumer of energy and a major source of water demand. Often in developing countries, water and energy resources are dealt with in silos, and in several cases, within water and energy sectors there are different policies and programs for different sources of water and energy, respectively. The disconnected pricing mechanism for resource conservation from one source may lead to unsustainable exploitation of the resource from another source. For example, the fragmented policy of levying high-water prices for surface water leads to the unregulated abstraction of groundwater. Such abstraction of groundwater could not be possible if the policy coordination is in place because groundwater extraction is also not viable in long run due to huge initial investments and energy consumption (Mekonnen et al., 2015). Extraction of groundwater can be viewed as a temporary adaptive mechanism, but the environmental impacts would be huge if it is exercised at a large scale. Besides the environmental impacts, there are potential trade-offs within the uses because most people in developing countries also depend on groundwater for domestic purposes (Reddy et al., 2011). The allocation of and access to the WEF system is further determined by local contexts. These contexts are external to the domain where the WEF nexus operates. Although, the global governance structures are in place, the targets to achieve these rarely percolate to developing countries (Gain et al., 2015). The diverse interests vested in the stakeholders, the lack of good governance principles, interdependence among the stakeholders, and fragmented governance institutions together contribute to worsening the equity issues associated with the allocation and access. For instance, the impact of external funding for infrastructure-related projects in the host countries across the water, energy, and food is a 'land grabbing' phenomenon (Bizikova et al., 2013) i.e. the loss of access due to the reallocation process. (Newell et al., 2011) expounded that to seek equity in the case of CDM funding there is potential for diverting the funds to the nations which had no access to CDM so far. It can be further supported by the (Smits & Middleton, 2014) study in the case of Vietnam, criticizing the "Additionality" of CDM in the host country. Concerning transparency, as one of the aspects to explore the legitimacy in the governance, the inherent process in the implementation of CDM is "rendered technical". Hence, the inclusion of all stakeholders' participation in the decision-making, robust legal structures, and binding to the principles of procedural justice and distributive justice is the key to promoting sustainable development through participatory forms of governance. Furthermore, it reduces the trade-offs among resources, uses, and users thereby leading toward equitable allocation of and access to resources.

## Summary and Conclusion

Water, Energy, and Food Security are crucial for sustainable long-term economic development and human well-being. The equitable allocation of the WEF is complex because it involves a two-step process (both for producers and consumers). The two resources in the WEF system used as inputs in the production of the third resource depend on the mechanism of allocation. As a first step drawing from the 'neo-liberal' or market-based theory it can be said that water (or energy or food) is allocated to the production of food and energy (or water and food or water and energy) in the manner where the revenue generated is high i.e. either food or energy. The second step is water has to be allocated to either food or energy which generates more revenue within the subsectors of them. The same principle holds for any of the resources comprising WEF. The allocation must encompass both dimensions of equity to WEF.  The equity in the access to WEF resources for human security is accomplished, provided there are well-established rights for all three as fundamental rights enshrined in their respective constitutions of the nations across the globe. This further requires robust legal instruments and the structures to enforce such rights guaranteed by the constitution. The protection of such rights must not only be negative but also to be positive. To ensure access to the WEF under the rights-based approach, we propose these rights must be provided as a 'triplet' of rights. The provision of Water, Energy, and Food services to people may be provided under the social sector schemes too. In such a case, it is expected that these schemes are also implemented as rights based. The presence of robust legal structures supports the people gaining access to the WEF nexus through exercising their rights i.e., access to justice is the key to ensuring access in the rights-based approach. The benefits arising out of access to WEF are poverty alleviation (through livelihoods), sustainability (improved productivity) (Wiegleb & Bruns, 2018), and other positive consumption externalities of WEF. Governance in these resources plays a major role in creating institutions, institutional adaptability, and in every phase of the policy cycle. Since we have seen that the interactions in the WEF raise tradeoffs reel under the decision-making at a local level; we propose the decentralised governance with sectoral coordination to ensure equitable allocation of and access to WEF. The integrated governance of the WEF system allows allocating the scarce resource among multiple uses and users i.e., intra and inter-sectoral demands (Weitz et al., 2017). However, in developing countries (and many developed countries), there is a lack of coordination in policy aspects related to the WEF nexus perspective. The establishment of legitimacy (participation, accountability, transparency) in the governance of the WEF system is crucial for equitable allocation and access. The inclusion of all stakeholders with the representation of rights in the decision-making regarding WEF at all scales of governance in general and local governance, in particular, can solve the potential tradeoffs and manage the synergies. Since water, energy, and food are interconnected and interdependent, it is desired that policy coordination is in place rather than governing them in silos i.e., ministries, bureaucracies and all the actors acting upon the policy planning, regulation, consumption, and production of individual resource would share a common platform in governing these three resources in an integrated manner.

# CHAPTER 4

## The Semantic elements of the WEF nexus

Water, energy, and food security are crucial for sustainable long-term economic growth and human well-being. The three systems are entangled. Effective and sustainable management of resources requires understanding the interconnections and interdependencies in them in the production and consumption as well, here forth WEF nexus. Policies in one sector have an impact on the other, ignoring the same would not constitute equitable WEF nexus. Through the Network diagram analysis and topic trend analysis, This and the following chapter aim to delineate the appropriate meaning of 'Integration' for holistic treatment of WEF nexus, owing to WEF nexus means different things to different people. In this vein, we conducted a review of 345 articles spanning from 2011 to 2021. The term-co-occurrence analysis done through VOSviewer revealed that Institutions, Politics, Justice, and Rights are some of the areas in Social sciences which did not garner much attention posing imbalanced interdisciplinary action. This section attempts to address three underlying questions. First, what constitutes the integration and its building blocks of it? Second, WEF nexus encompasses how many sectors? And finally, dependent on the former two, what are the qualifications of a response strategy to become a cross-cutting strategy in the WEF nexus? Shaping the analysis in this way, this study contributes to a better understanding of the critique of the WEF nexus, improved comparision for earlier integration paradigms particularly Integrated Water Resources Management (IWRM), and enhanced mapping of the important stakeholders to be involved in the decision-making.

### 4.1 Perspectives on WEF Nexus

There are different perspectives in viewing the WEF nexus. These perspectives vary according to focusing on physical resource systems and interactions alone and considering the social, political, environmental, economic, and institutional dimensions of the resource systems. Some scholars opine that governance of the resource system is crucial in evaluating the impacts on human livelihoods. Besides these, there are also perspectives emphasising scale at WEF nexus is studied and their analytical approaches. The perspectives on the WEF nexus are generally laid in the following areas: Ecosystems, waste management, institutional change, trust, and the learning process (Proctor et al., 2020).

**Table 4.1 shows the perspectives on WEF research**

| Author | Perspective |
|---|---|
| (R. Lawford et al., 2013) | Emphasise incorporating environmental, economic, political, and social dimensions. |
| (de Grenade et al., 2016) | Place the nexus among interacting social and physical systems. |
| (Biggs et al., 2015) | WEF nexus approaches need to evaluate nexus impacts on human livelihoods |
| (Mwale & Mirzabaev, 2015) | The role of gender in the nexus trade-offs and synergies is mostly overlooked. |
| (Miralles-Wilhelm, 2016) | Nexus analyses are often conducted at regional or national levels |
| (Smajgl et al., 2016) | Current nexus analyses are insufficiently cross-sectorial. |
| (van Gevelt, 2020) | Introducing the element of politics to the WEF nexus is the key to understanding the complexity. |
| (M. Scott & Larkin, 2019) | The scale in the WEF nexus is vital for sustainable management of the nexus. |
| (Pittock et al., 2015) | The scale of the Tradeoffs that arise in the WEF nexus is equally important for informed decision-making. |
| (Bielicki et al., 2019) | The perspective of the stakeholders depends on the context in which the stakeholders operating in the WEF domain. |
| (Salmoral & Yan, 2018) | Advocates integrating water diplomacy with the nexus approach. |
| (F. P. L. Melo et al., 2020; Tidwell, 2016) | Advocate that 'forest security' should form a fourth foundational dimension of the WEF nexus |
| (Heal et al., 2020) | The impact of water quality on health, environment, and well-being is rarely acknowledged in the WEF nexus. |
| (Batlle-Bayer et al., 2020) | National Dietary Guidelines (NDGs) need to incorporate the integrated Life Cycle Assessment (LCA) and WEF nexus approach. In this sense, they argue the need to add a fourth system to the WEF nexus, which would be the nutrition aspect of diets. |

Source: (Albrecht et al., 2018) and the authors.

### 4.2 Spaces for trade-offs in the WEF Nexus

These are the areas where the three systems interact profoundly. These interactions are varied across the globe and specific to geography. These are the areas where future research needs to focus (Bazilian et al., 2011). They are Energy access and Deforestation (McCornick et al., 2008), Biofuels production (Debbarh, 2019; Stenzel et al., 2021; Mwale & Mirzabaev, 2015), Irrigation and food security, Desalinisation, and Hydropower generation (WCD, 2000; Al-Saidi & Elagib, 2017; McCornick et al., 2008; Zeng et al., 2017).

What has been sketched above are the basic tenets of the WEF nexus. To better understand the research that has been carried out till now, we present a network diagram below created using VOSviewer

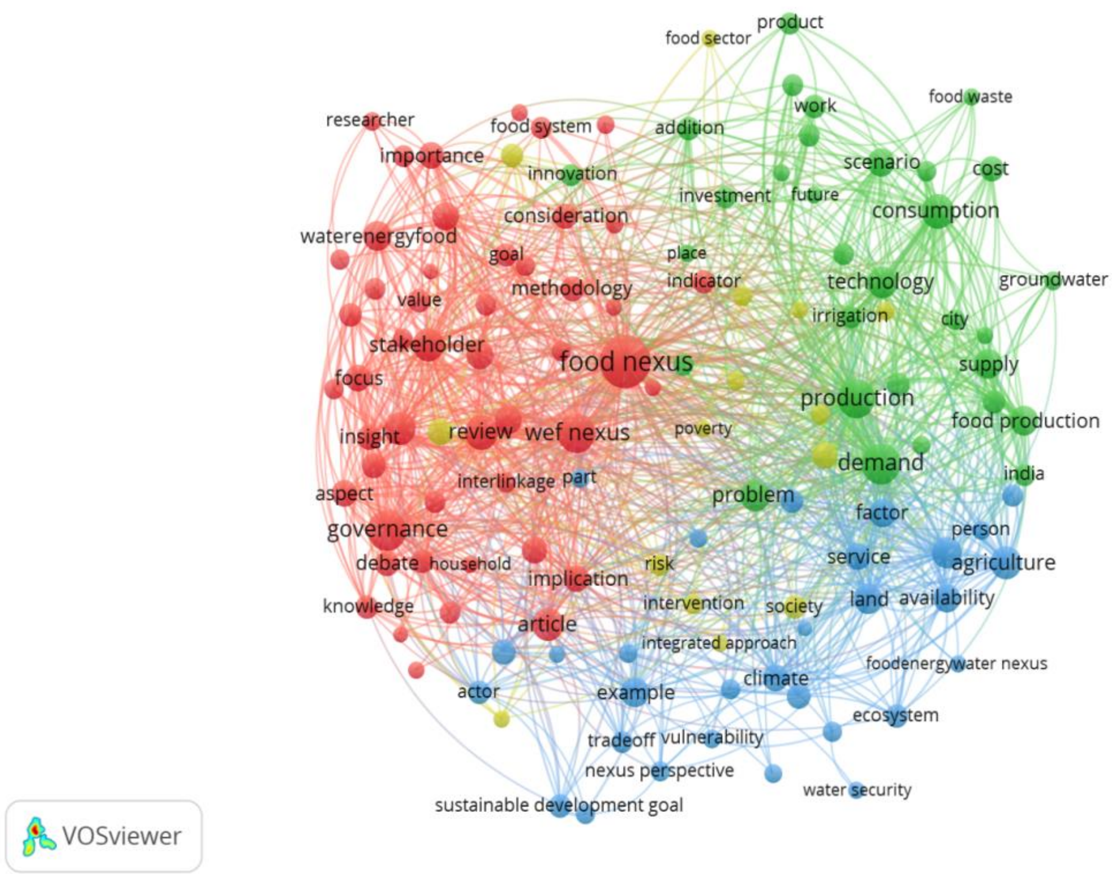



Figure **4.1**

### 4.3 Limited Data Availability

Data and Information are the keys to effective implementation and successful decision-making in the WEF nexus. However, data are missing entirely or if available, they are based on short-duration. For instance, Data on food waste and its implications for resource use efficiency; The source, use, and the fate of water used for Fracking; and the estimation of water use and water quality at local, national, and global scales have not received adequate attention (R. G. Lawford, 2019). A full understanding of all interlinkages between WEF sectors may never be possible (McGrane et al., 2018). While data collection, scientific research, and model development can improve our ability to understand the complex system in which we live and hence make better decisions (Seidou et al., 2020). Access to data is a key challenge. To carry out a proper assessment of the water, energy, and food nexus, it is necessary to have access to both data from each of these sectors and data able to express the number of their mutual connections (Rosales-Asensio et al., 2020). Furthermore, the data needs to increase if we annex externalities to the WEF nexus. Taking negative externalities as an example, the data that may be needed includes the following: the amount of sewage discharged and the area of soil pollution caused by the energy industry; the amount of water pollution caused by the use of chemical fertilizers or pesticides in food production; the area of ground subsidence caused by the over-exploitation of groundwater; and the area or ratio of soil desertification (soil salinization). In addition, since externalities include positive externalities and negative externalities, the amount of data required is larger (Yan et al., 2020).

Generally, the data needs for the nexus modeling and analysis usually exceed initial data availability and depend upon the scope of the nexus, complexity in the nexus, variability in the data, and technological alternatives (McCarl et al., 2017).

**Table 4.2 outlines the desirable types of nexus data items.**

| Sl.No. | Item Description |
|---|---|
| 1 | Regional Economies, Income distribution, and Jobs. |
| 2 | Energy, Water, and Food needs and Prices. |
| 3 | WEF production practice technology matrix. |
| 4 | Emissions of greenhouse gases, particulate matter, soil erosion, nutrients, and contaminated water. |
| 5 | Allocation of Land and Water. |

| | |
|---|---|
| 6 | Export possibilities and Import needs. |
| 7 | Water treatment requirements. |
| 8 | Stocks of groundwater, agricultural land, oil, and other fossil energy plus historic data describing depletion or increases and conditions under which that happened. |
| 9 | Potential alternative energy and water sources plus data on their cost, yield, and input usage. |
| 10 | Population location and projected growth plus associated WEF item demands. |
| 11 | Links between past and projected climate change, water supplies, and water diversions/withdrawals. |
| 12 | Aquifer elevations, reservoir conditions, and river flow as they depend on precipitation locally or in distant recharge or upstream locations. |
| 13 | Energy use by irrigation, M&I pumping, water conveyance, power cooling, hydropower, and hydraulic fracturing. |
| 14 | Water use and return flow for major diverters including energy, agricultural producers, municipal and industrial concerns plus requirements for environmental health and preservation. |
| 15 | Regional weather for at least 20 previous years. |
| 16 | Agricultural crop and livestock yields, costs, water, energy, input, and other resource usages. |
| 17 | Movement patterns for water, agricultural commodities, and produced energy. |
| 18 | Budgets give water use alternatives and their resource usage for relevant energy production enterprises including mining, oil/gas production, and thermal and hydroelectric power. |
| 19 | Enterprise locations and water withdrawal points. |
| 20 | Locations of roads, railways, rivers, reservoirs, power transmission, pipelines, and WEF processing facilities. |
| 21 | WEF governance structures and degree or potential of coherence across these sectors. |
| 22 | Utility pricing structure. |
| 23 | Possibilities for water, energy, and food conservation and potential consumer acceptance. |
| 24 | Technical possibilities for improving nexus management along with |

| | |
|---|---|
| | information on their cost, energy, water, and other input requirements. In addition, information on their robustness includes alterations in incapacity under adverse weather conditions, shock, corrosion, fouling, and operator faults. Also, information on technology scalability and potential integration with existing regional industries and infrastructure. |

Source: (McCarl et al., 2017)

Besides these, classes of relevant data include

| Sl.No. | Item Description |
|---|---|
| 1 | Water extraction and conveyance. |
| 2 | Crop/livestock mix. |
| 3 | Crop management possibilities. |
| 4 | Population growth. |
| 5 | Climate change effects. |
| 6 | Thermal, hydropower, Fracking, bioenergy production. |
| 7 | Energy conveyance mechanisms. |

Source: (McCarl et al., 2017)

### 4.4 Critique of the WEF nexus

The criticism mounted against the WEF nexus corresponds to different elements. One aspect is regarding the terminology. Terms such as "water," "food," or "energy" are regularly used to describe nexus studies. While these terms are appropriately broad in scope for the FEW nexus domains as a whole, more distinction and details are required to understand specifically what aspects of these resources are being considered in the analyses. For example, water could refer to fresh surface water, brackish groundwater, or drinking water, while energy might refer to raw fuel such as crude oil or processed fuel such as gasoline. In each case, the reference could be to either a natural resource (i.e., materials that occur in nature, such as fresh surface water and crude oil) or a finished product (i.e., goods that are available for direct human consumption, such as drinking water and gasoline). Concepts such as "energy for water" make little sense in the context of fresh surface water or brackish water since those are resources; rather, it is only when we discuss a product in terms of its end use (e.g., potable water or irrigation water) that an energy burden can be assigned. Similar confusion persists when the nexus is extended to consider land and food. Food is a product, while the land is a resource; food production requires an investment of natural resources (such as water and land) as well as products (such as diesel to operate pumps for groundwater and electricity to manufacture chemical fertilizers) (Gunda & Tidwell, 2019). (Nauditt, 2018) found that despite an increasing focus on interdisciplinary research and stakeholder participation in EU research funding during the past decades, there remains a lack of research programs that address the WEF nexus. This might be due to missing ownership of this topic among the scientific community. Furthermore, the community tends to consider the "nexus" concept as only a new term comprising the same content as IWRM.

Coming to the framing of WEF nexus, it is held that WEF nexus as a security discourse is a unique departure from other environment security discourses in that economic productivity is the main referent object rather than countries, individuals, or ecosystems. This deviation can shift authority over security away from state-centric institutions toward private sector organisations, resulting in technocratic responses to the environmental security discourse (Liebenguth, 2020). (Meisch & Leese, 2015) depicted the movement from distributive justice to the securitisation of sustainability. They have identified the WEF nexus as a double twist in the politics of sustainability. One is resource scarcity as an existential threat and second, the proposed instruments again fall under the neoliberal economic agenda.

Critique about the other integration paradigms reveals that (Wichelns, 2017) revisiting the 'United Nations (UN) Scientific Conference for the Conservation and Utilization of Resources, 1949' and 'The UN Conference on water, 1977', held them as 'nexus-plus' perspectives because they embrace labour, soils, land tenure, etc., besides WEF. (Allouche et al., 2019) hints at 'capitalocene' and 'Techno-Market' veils of framing the WEF nexus. This work also questions the role of social elements such as equity, rights, etc. in the securitisation frame of the WEF nexus. Besides these, they held little hope in achieving the success of the nexus approach vis-a-vis the IWRM.

Criticism concerning the term 'integration', (Cairns & Krzywoszynska, 2016) termed WEF nexus as a 'Buzzword'. They stressed understanding the power relations in the proposed integration. They criticised the nexus approach as the technocratic managerialism of the environment. (Allouche et al., 2015) argues it is whether integration or separation? Because farmers treat WEF nexus as isolated due to water, energy, and food were never separated as much as now. (Keulertz & Woertz, 2015) argues that technocratisation of the nexus often emphasis demand-side management and ignores supply-side factors. (Bizikova et al., 2013) warned about the Resource grab phenomenon in developing countries. Hence, they suggested an integrative framework for planning the resources.

### 4.5 The Technologies suggested in the WEF nexus

Competition for water, food, and energy has driven innovation in partnerships through ecosystems of stakeholders and technologies. Beyond numerous examples of technological innovation- precision agriculture, renewable energy, water efficiency, reuse, and recycling technologies among them (Will, 2015). However, this work extends to adding some more options. The role of technologies for Irrigation is discussed widely, but cannot be prescriptive in nature. Furthermore, the decision-making should be contingent upon the relative availability of other elements comprising the WEF nexus. For Instance, Modern Irrigation equipment such as Drip, pivot, sprinkler, and solar-powered pumps are not without trade-offs even though discussed within the WEF nexus.

The use of the drip irrigation technique not only saves large amounts of water but also drastically reduces the amounts of agricultural chemicals used per Hectare (Rogers & Daines, 2014). However, In Murray-Darling Basin (MDB) the unintended consequence is the increase in the significant amount of energy use (Ahmad & Khan, 2017), and in general (Fayiah et al., 2020). The study conducted on sugarcane production in Ethiopia to this effect confirms the argument (Hailemariam et al., 2019). Considering the social factors in adopting drip irrigation, a study focused on Morocco farmers held that equity dimensions are affected (Jobbins et al., 2015).

Similarly, Solar Pumps used to produce fruits and vegetables found that adoption of solar pumps leads to more use of water (E. Gupta, 2019). Solar Irrigation Pumps (SIPs) represent an innovative irrigation solution. Promoting SPIs reduces emissions, curbs huge oil import bills, and offers daytime uninterrupted power. On the other hand, they may accelerate groundwater depletion and ecological stress. Therefore, promoting SIPs simultaneously requires institutional or governance arrangements that monitor water resources and alternative energy sources as well. The economic drawback of SIPs is that it requires 10-12 times the capital investment compared to diesel or electric pumps. Without 70-95 percent capital subsidy, SIPs would have few takers in India. Drawing upon the seven criteria for promoting the SIPs (Shah et al., 2018) opines that “growing” one’s solar energy to run irrigation pumps as well as to sell the surplus for cash income can correct or moderate many perversities of prevailing groundwater-energy-food interlinkage. Besides these, the experiences of Solar Energy Farming (SEF) and Solar Pumping Irrigation systems (SPIs) are varied nationally and within a nation. However, both options could be used as a source of additional income for the farmers in the case of excess supply provided there are institutional and regulatory arrangements such as Power Purchase Agreement (PPA) and water allocation rules. These arrangements can be used to encourage farmers to rationalise energy use and reduce water pumping. Particularly in India, the increased abstraction of groundwater is a major challenge for SEF and SPIs across the states. The solutions offered to this challenge are linking solar farming subsidies to water harvesting and efficient irrigation, experimentation with remote monitoring, and purchase guarantees for surplus power to substitute agricultural use (Al-Saidi & Lahham, 2019).

Agrivoltaics i.e. creating a hybrid of collocated agriculture and solar PV infrastructure, where crops are grown in the partial shade of the solar infrastructure may serve to bolster the resilience of renewable energy and food production security to a changing climate. The factors included in the analysis are water, energy and food, and the physical and biological dimensions. Drawing upon them, (Barron-Gafford et al., 2019) hypothesised the cross-cutting synergy across the three sectors namely- ***water*** through maximising the efficiency of water used for plant irrigation by decreasing evaporation from soil and transpiration from crop canopies; ***Food*** by preventing depression in photosynthesis due to heat and light stress and ***Energy*** through transpirational cooling from the understorey crops lowering temperatures on the underside of the panels, which could improve PV efficiency. However, it is suggested for drylands (Ravi et al., 2016) but warrants further research in terms of geography, social impacts, species, and more (Barron-Gafford et al., 2019).

Soil mulching improves soil water storage and warmer soils. However, there are long-term damaging effects on soil quality in some mulching practices considering the decrease in organic C and the total N content of the soils. The fundamental concern regarding the innovations is their adoption of them and within this adoption; affordability is a major barrier (Scardigno, 2020). One can argue that the state can provide subsidies but they are affecting the economic dimension of sustainable development (Rasul, 2016).

Coming to the Circular economy perspective, though the water conservation efforts are in place, the relative scarcity of water resources can be solved through the new source/reuse of water but needs to be energy efficient, economically, and socially acceptable. The sources are municipal wastewater, Seawater, Agricultural run-off, Manufacturing and mining wastewater, and power plant discharge (Armstrong et al., 2018). Desalination of water may lessen the scarcity of water but consumes energy. Moreover, it is economically and environmentally costly due to it requiring substantial inputs. The affordability challenges are evident in developing countries (Keulertz & Woertz, 2015). Now the turn is for integrating Renewable Energy Sources (RES) with desalination. It can be accomplished by incorporating renewable sources into the electric grid for utilisation by desalination facilities (Rao et al., 2017). Solar energy resource has great potential for desalination in arid and high-solar insolation regions with abundant brackish or saline water reserves. Wind and geothermal sources are also promising candidates for energy sources but these sources are not as geographically abundant as solar energy (Gude & Fthenakis, 2020).

Food waste primarily appears to be problematic in developed countries but is of no less importance in developing countries too. For instance, the loss of water resources related to food waste was more than 10% of total water use in China (Liang et al., 2020). Generally, food waste is dealt with by four treatment processes: Anaerobic Digestion (AD), In-vessel composting, Incineration, and Landfilling. AD is environmentally the most sustainable option with the lowest impact on the WEF nexus. Incineration is the second-best option but has a greater impact on the health aspect than landfilling. Landfilling has the greatest influence on the water aspect and the second-highest overall impact on the WEF nexus. In-vessel composting is the worst option overall, despite being favoured over incineration and landfilling (Slorach et al., 2020). Comprehensive sustainable management of food waste will involve varied mechanisms and actors at multiple levels of governance and the level of individual consumers (Kibler et al., 2018; Falconer et al., 2020). The principal outputs are biogas, which is composed primarily of methane and carbon dioxide, and nutrient-rich digestate which is comprised of water and the remaining undigested solids. Digestate as a fertilizer for growing crops to replace mineral fertilizer can reduce the emissions associated with food cultivation, one of the main sources of emissions in the supply chain (Haltas et al., 2017). However, the consequences of the adoption of AD in the UK yielded mixed results. The energy policy of the UK was fruitful for the part of energy generation in AD and the outcome of digestate is neglected (Haltas et al., 2017). Technical, Operational, Economic, and Regulatory constraints related to the AD process as a whole have slowed its uptake and application in the UK market (Nikolaos Voulvoulis, 2015). Furthermore, within the UK, England took a decentralised approach while Scotland embraced a centralised one, there exists a trade-off between transport costs and social acceptability for AD centralised versus decentralised strategies (Falconer et al., 2020).

The other technological innovation providing the cross-sectoral solution is the waste water treatment from municipal, industrial and agricultural slurry. Energy is essential to powering the waste water systems. However, great opportunities exist to recover energy, nutrients essential for agriculture i.e. for food such as Nitrogen and Phosphorous (which would otherwise require energy to produce), and clean water from waste water streams. Ammonia, which is used in fertilizers, is produced using energy-intensive industrial processes and fossil fuels. However, in waste water treatment systems, energy is used to remove Nitrogen (N). If N can be recaptured, then energy to produce ammonia would be offset. Phosphorous (P) is a non-renewable and irreplaceable resource in food production. However, (Hoolohan et al., 2019) held that recognition of unintended consequences of sectoral support mechanisms is highlighted as a key area to assist with technological adaptation.

It is necessary to consider changes in the diet because the specific ingredients of food consumed lead to different agri-food demands and demands to the ecosystems for energy, water, and land (Irabien & Darton, 2016). The creation of meat-based diets normally needs double the amount of water when contrasted with a vegetarian diet (Mehmood et al., 2019).

## 4.6 Challenges in the WEF Nexus

Many barriers exist to the good governance of the WEF nexus. Some generic barriers include limited data availability, limited institutional capacity, insufficient funding, limited integration of other sectors, issues related to implementation, maintenance, and operations and lack of policy coherence and coordination, and difficulty to implement effective multi-level governance. The majority of the barriers are similar to the classical barriers to implementing IWRM (UNEP, 2016). The finance for building infrastructure for the WEF nexus is a major concern. Geopolitical and political-economic contexts are crucial for implementing the nexus-related approaches in general and in the Arab region particularly (Keulertz & Woertz, 2015).

The scientific challenges are primarily related to data, information, and knowledge gaps. The tools used for nexus analysis are also unable to address all the trade-offs involved in the nexus (Liu et al., 2017). Scale and data availability are the major challenges in the operationalization of the WEF nexus (McGrane et al., 2018). Moreover, the water-energy-food security nexus concept has mostly been analysed at higher scales in a top-down manner, while examples of bottom-up and local scale applications remain limited (Villamor et al., 2018).

Coming to the implementation challenges, (Varis & Keskinen, 2018) expounded that most nexus cases still have a clear water-centric viewpoint, concentrating on the classical water use/withdrawal aspects of agriculture and coupling these with specific energy-sector issues such as hydropower operation. While such water-centrism can be seen to be natural given increasing water scarcity and the critical role that water plays in energy and food production, it is also likely – besides water quality issues – to be the greatest single challenge for the nexus approach, as its Implementation requires the engagement of actors from both energy and food sectors. The challenges to the implementation of the nexus are trade-offs between sectors, difficulties of communication across the science-policy interface, the emergence of new vulnerabilities resulting from the implementation of policies, and the perception of high social and economic costs (Snorek, 2015).

# CHAPTER 5

## Socio-Economic and Political dimensions of WEF nexus

This chapter aims to highlight the issues that are eligible to discuss within the realm of the WEF nexus. This chapter acknowledges that addressing WEF nexus challenges often involves competing interests and various stakeholders. Moreover, earlier experiences in the governance of water, energy, and food sectors either in isolation or be it integrated indicate that the presence of institutional inertia would call for an effective governance framework that treats the WEF nexus holistically. This would help delineate the roles of equity, justice, markets, property rights, livelihoods, and myriad other factors.

### 5.1 Livelihoods in the WEF nexus

Sustainable Livelihoods are important to achieve sustainable development. It is termed as socioeconomic and environmental link ‘Environmental Livelihood Security’. Environmental Livelihood Security is defined as a concept that seeks a balance between natural resource supply and human demand on the environment to promote sustainability (Biggs et al., 2015). The livelihood concern in the WEF nexus takes entry point at Infrastructure or the affordability dimensions. In the latter case, it is from the demand side. Affordability is the key dimension to the security of the WEF nexus. Besides these, livelihoods are impacted by climate change too (Mabhaudhi et al., 2019).

Coming to the human sphere, (Gebreyes et al., 2020) laid emphasis on livelihoods and concludes that global and national level policies in the WEF nexus Obscure the household level perceptions, vulnerabilities, and well-being leading to trade-offs in the WEF nexus. Human security is part of the broader concept called Environment Security. This is particularly important when human livelihoods are dependent on the environment (Duncan et al., 2015). (Wolde et al., 2019) a survey conducted in Central Ethiopia found that the perceptions of the community on livelihoods in the WEF nexus are based on a single resource rather than interlinkages in it. The single resource is major food i.e. their perception is based on output rather than on Inputs. (Dach & Fleiner, 2019) advocates for a participatory approach in the governance of the WEF nexus. The normative content of the study is that the needs of the mountain people and communities are fairly addressed provided; they are viewed from the combination of livelihoods and Justice Lens. This approach highlights competing interests, and social and power relations between stakeholders.

(Spiegelberg et al., 2015) using the socio-ecological network to study the WEF nexus Interlinkages (both from production and consumption) in the Dampalit watershed area in the Philippines. They opined that to reduce trade-offs and for improved resource governance, resource users need to be brought under a centralised network. Similar to the findings from (Wolde et al., 2019), the integrated management of the WEF nexus remains elusive in this study area too.

### 5.2 WEF nexus on major river basins across the globe

River Basin Organisations play a crucial role in coordination and cooperation between water, energy, food, and the environment, across all scales, and between the public and private sectors (UNEP, 2016). (Mayor et al., 2015) studies WEF nexus in the Duero River basin in Spain. According to 2009 data, the following table **5.1** provides the interactions

| Water-Energy | Water-Food | Energy-Water | Energy-Food | Food-Energy |
|---|---|---|---|---|
| 83,874.85 $Mm^3$ withdrawal and 280.14 $Mm^3$ consumption | 3800$Mm^3$ withdrawal and 9108 $Mm^3$ consumption | 689.96 GWh | 12960 GWh | 12,34,060 tons of various crops were used to produce 1,11,200 tons of Biodiesel and 2,78,000 tons of Bioethanol |

Source: (Mayor et al., 2015)

In the Yellow River basin, the agricultural and energy sectors are competing for limited water supplies. Rapid expansion of coal-fired power generation and oil and gas production in the upper and middle reaches of the yellow basin is the major source of energy in the basin (Xiang et al., 2017). A study centered on the river basins of Danube, Indus, Ganga, Brahmaputra, Murray-Darling, Lake Winnipeg, and Yellow River (R. Lawford et al., 2013) held that the factors that influence the WEF nexus are climate change, Political and economic change, regional and economic development, demographics, urbanisation, land-use change, and basin infrastructure. None of them were significant due to the small sample size. Relationships between water-energy-food are specific to the basin. In this vein, (Kalair et al., 2019) emphasised the impact of climate change on the water resources in the Indus river basin. (Yang et al., 2016) studied the future of Water, Energy, and Food Production in the Brahmaputra River Basin (BRB) by integrating WEF nexus with climate change.

Coming to the other factors than climate change, Particularly Allocation and Access issues (Keskinen et al., 2016) studied the bidirectional links between the transboundary river basins and the WEF nexus across the Asian river basins. In Central Asia, i.e. Aral Sea basin; upstream countries are highly dependent on hydropower production which is opposed by downstream countries that are dependent on reliable quantity and quality of water. In Southeast Asia, the massive hydropower development, particularly in the Mekong river basin is raising trade-offs between fish and rice production, the staple food in the region (Harwood, 2018). Similarly, the scale of hydropower development across the upstream MRB is likely to impact the hydrology, food security, and livelihood of the people dependent on the Tonle Sap Lake in Cambodia (Keskinen et al., 2015). Focusing WEF nexus on the Great Ruaha River (GRR), Tanzania, (Yang & Wi, 2018) observes water competition between irrigation (upstream), ecological purpose (midstream), and hydropower generation (downstream) makes water resources management difficult.

Coming to political, economic, and regional factors, China, despite its recognition of the interlinkages and tradeoffs in the WEF nexus, the scale, pace, and location of hydropower infrastructure are dependent upon its economic and political power in the MRB and exercised through state-owned enterprises as an overseas development initiative. This needs to be carefully examined in terms of the impacts it has on the MRB as a whole and the hydrology dependent upon the MRB, livelihoods, fish, and food (food security of the region) (Matthews & Motta, 2015). Besides the impacts on the ecosystem and livelihoods, the three most important tradeoffs are between Hydropower-Irrigation, Hydropower-Fisheries, and Fisheries-Irrigation (Do et al., 2020). However, delineating the role of regional organisations in transboundary river basin management, (Dombrowsky & Hensengerth, 2018) guided the incorporation of effective governance with coordination in place, following the principles of international water laws and benefit-sharing mechanisms could reduce the tradeoffs in the WEF nexus.

Coming to cooperative governance, (Lebel et al., 2020) focusing on Laos and Thailand held that ***coordination*** may be hindered by competition among ministries and bureaucracies within the country and across the region. The ***anticipation*** about the links in the WEF nexus before the policies or projects proceed is underestimated. The ***inclusion*** of vulnerable and marginalised people and ecosystems is also a neglected issue. The ***attribution*** of responsibilities was also not properly delineated. The lack of coordinated approaches hinders comprehensive management and undermines opportunities to implement sustainable development options (McCartney & Brunner, 2020).

The study conducted by (Allam & Eltahir, 2019) looks into the WEF nexus in the Upper Nile Basin (UNB) within the Ethiopian borders and held that there is a clear trade-off between expanding the rain-fed agricultural potential in the UNB basin and saving the water for hydropower production at the Grand Ethiopian Renaissance Dam (GERD). (Stein et al., 2018) on the same river basin analysed how stakeholders in the WEF sectors are embedded in the social networks. (Kibaroglu & Gürsoy, 2015) in their study on historical analysis of WEF nexus in the Euphrates-Tigris (ET) transboundary basin observed that current institutions do not represent coherent, robust, and flexible structures to regulate the water demand among competing uses. Policy integration and coherence remain weak. (Zarei, 2020) are yet another study conducted on the same area and the same kind of problem. Currently, Iran requires an additional supply of water; Iraq is facing a water crisis currently due to the decrease in the quantities and degradation in the quality of the two important rivers i.e. Euphrates and Tigris; Turkey's water problems are related to maintaining water quality. In the ET basin (Ozguler & Yildiz, 2020) held that the occurrence of droughts in Syria, Iran, and Iraq affected the people in terms of Social, Economic, and Environmental dimensions. Concomitant with lowered precipitation levels, the situation is still worsened in terms of WEF security.

A study by (Chegwin & Kumara, 2018) explored the WEF nexus management in the Mahaweli River Basin, Srilanka suggests a major change in management effort and reorientation of stakeholders towards stewardship of precious water resources will be required to facilitate the implementation of the program and the achievement of its economic, social, and environmental objectives through improved water management. Yet another study that is focused on the same river basin is conducted by (Perrone & Hornberger, 2016). The authors examined competition between energy generation and paddy production using the current infrastructure of the Mahaweli basin. (Pittock et al., 2015) explored the processes that enable effective policies and practices for managing the links between water, energy, and food. As part of this, they have chosen the Walawe basin as a meso basin scale in Srilanka. The stakeholders involved are the farmers, Ceylon Electricity Board (CEB), and the Irrigation Department (ID). The negotiation effort made by the CEB in collaboration with the ID is a compensation scheme for farmers' water rights during dry seasons. The compensation amount is equal to the estimated average foregone income from rice cultivation. Though it was a win-win solution but was rejected by farmers after 2 years of inception. This is mainly because of the different values gained from farming which cannot be replaced with money. Hence transparent, integrated, and multi-objective planning is vital to maintain public trust and ensure fair and equitable access to water by different users.

Applying a Water-Energy-Environment-Food (WE$^2$F) nexus approach in the Upper Niger Basin (UNB) and the Inner Niger Delta (IND); (Seidou et al., 2020) held that despite the existence of an agency, Niger Basin Authority (NBA), the ecosystem services in the IND region are impacted by the construction of dams and climate change. The challenges faced by the NBA in implementing the WE$^2$F are similar to the challenges discussed by (Liu et al., 2017).

### 5.3 Gender in the WEF Nexus

Employing the framework of the social practice lens to assess the vulnerability of the urban poor in Kampala, Uganda (Mguni et al., 2020) observed that water is commonly fetched by children, and cooking is done by mothers and older girls in most households. Add to this, the trade-off between food and energy i.e. they avoided cooking protein-rich beans as it is energy demanding food and it takes a long time to cook. In the poorer households, water boiling practices were inconsistent due to charcoal-conservation practices. The study titled ‘Gender-specific perspectives among smallholder farm households on water-energy-food security nexus issues in Ethiopia’ by (Villamor et al., 2018) revealed that Male and Female farmers had differential access to key actors with broad scales of influence. For example, males reported access to a broader spectrum of actors involved in elements of the WEF nexus than females, particularly concerning energy, minerals, and irrigation which provide access to seeds, fertilisers, and solar panels. In Kenya, Women in both counties (Lakipia and Machakos) are often prohibited from discussing matters related to land with their husbands, and water permits are typically registered in the name of the husband yet women are in most cases the custodians of water points. Women’s voices, roles, and needs are neglected (Simon et al., 2017).

Coming to the recommendations, (Villamor, 2014) showed that there were differences between women and men in land-use decisions for food or bioenergy production. This was in addition to contested rules between the state and local communities regarding the overuse and protection of natural resources that affected environmental services and livelihoods in the forest marginal areas. Therefore, future research in the water-energy-food nexus should more often rely on sex-disaggregated data collection and analysis protocols.

### 5.4 Urban WEF Nexus

The urban WEF nexus is useful in analysing the resource nexus as well as the urban sustainability and resilience-building paradigms (Artioli et al., 2017). Urban sustainability from the WEF nexus can be understood as the available, accessible, and stable WEF supplies relative to geographical demands in an urban area without compromising the environment (Yuan et al., 2021). Conceptualising the urban WEF nexus (Schulterbrandt Gragg et al., 2018) mention Urban agriculture is an evolving and complex activity "located within (intra-urban) and/or on the fringe (Peri-urban) of a city or metropolitan region, which grows, raises, processes, and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area". While (Covarrubias, 2019) conceptualises the urban WEF nexus as an interaction between WEF provisioning in cities consisting of social and material flows using the Socio-Ecological Systems (SES) framework. The nexus is driven by either material flow or social flow. Cities are the nodes where cross-sectoral actors, resources, infrastructures, policies, and utility services come together for the provisioning of water, energy, and food.

Coming to the framework, (Zhang et al., 2019) proposed a conceptual framework for the Urban WEF nexus building on resource interdependency, resource provision, and system integration. Interpretation of urban nexus from resource interdependency is useful to measure resource efficiency and to identify trade-off loops along the production supply chains. Understanding the Urban WEF nexus from a resource provision perspective emphasises the consideration of the external environment and underpinning resource availability. System integration requires that it has to satisfy the constraints of resource provision capacity, economic cost-effectiveness, and social justice, as well as the ecological carrying capacity. Focusing on resource provision in Barcelona, Spain (Covarrubias & Boas, 2019) held that the Sustainability of food is not just determined by physical distances between its provisioning processes per se but by the specific ways in which food flows relate to connections (both physical and social) with energy and water. Similarly, (Covarrubias et al., 2019) focused their study on Amsterdam and held that networks in the provisioning process are weak. Similarly, (Giatti et al., 2019) focused on Guarulhos, a city in the periphery of Sao Paulo, Brazil, and employed social practices lens to assess the vulnerability of people in the area generally and low and variable income groups in particular for urban WEF nexus. Precarious local transportation, insufficient public street lighting from the energy front; intermittent public water supply, and poor access to sanitation from the water point of view; people end up purchasing cheaper industrialised foods available in the neighbourhood due to the lack of bigger marketing services related to food make them vulnerable. Instead, it can be called the 'nexus of exclusion' due to marginalisation both geographically and socially.

Coming to the recommendations, focusing on the four cities: Amsterdam, Eindhoven, Taipei, and Tainan; (Yuan et al., 2021) suggests renewable energy plays an important role in the WEF nexus. Infrastructure development, Technological innovation, partnership, and collaboration are viewed as solutions to the WEF nexus urban sustainability.

### 5.5 Governance of the WEF Nexus

Governance for the WEF nexus can be understood as the formal and informal processes and institutions for integrated policy- and decision-making across the WEF sectors. Governance concerns how actors (i.e. the individuals, households, communities, firms, government departments, regulators, and other organizations with interest or influence), their institutions (e.g. the norms, rules, conventions, and values shape the behaviour of such actors), and their practices (i.e. the actions of actors, such as consumption behaviours or processes of policymaking) influence outcomes in systems (Haltas et al., 2017).  At a minimum, this involves the coordination of multiple actors in each of the three sectors at all levels of governance. Effective governance requires horizontal (cross-sectoral) and vertical (between levels of the government) coordination (A. Scott, 2017). However, there is no consistent view on the meaning of integration within the WEF nexus although this idea is at the core of all nexus understandings. WEF nexus as an integrated management paradigm refers to different concepts, postulates, and methods that analyse three aspects **a)** intersectoral resource use issues, **b)** interdependence and interdisciplinarity of management decisions and **c)** interactional impacts of resource allocations. The process of integration is context-specific. It will depend on the existing resource links in a certain country or region and the purpose of the analysis. This is also called 'Issue Integration'. In short, it addresses the question of 'what the process of integration looks like?', while the second is 'Institutional and People

Integration'. Does it address the question of 'how should the integration look? If it does, in which institutions and by which actors (Al-Saidi & Elagib, 2017).

Given the difficulty of managing resources across the various sectors, the best point to start understanding the processes needed for the good governance of the nexus is the ecosystem-based approach. The ecosystem-based approach brings the elements of energy, food, and water into a single viewpoint (Snorek, 2015). (Urbinatti et al., 2020) based on a systematic literature review (SLR) in investigating the conceptual basis of the nexus governance debate, and attempting to clarify the main themes, networks, and gaps within the literature. The analysis is based on quantitative and qualitative methods, combining social network analysis (SNA) and discourse analysis (DA). The results highlighted that twenty-four governance-related concepts support this literature, breaking down into eight groups: water and basin governance; environmental and systems governance; risk and resource security governance; economic governance; global governance; urban governance; integrative and cooperative governance; and "epistemic" and transdisciplinary governance. All 24 themes are formulated in the table below.

**Table 5.2 outlines the studies carried out in governance of WEF nexus with the diverse themes**

| Concept | Authors | Focus | Correlation with nexus Governance |
|---|---|---|---|
| Water Governance (WG) | (J. Gupta et al., 2013) | Literature review on the state-of-the-art of water governance science | It needs to be a cross-sector process. |
| Transboundary Basin Governance (TBG) | (Al-Saidi & Hefny, 2018) | Analysis of regional cooperation in the Eastern Nile Basin | Useful for highlighting issues at the basin and Regional levels. |
| Integrated Water Resource Management (IWRM) | (Hagemann & Kirschke, 2017); (Benson et al., 2015) | Focuses on Relation between IWRM and nexus | Nexus aim at policy coherence and multi-level interaction. |
| Socio-Ecological System (SES) | (Giampietro, 2018); (Al-Saidi & Elagib, 2017); | Places the nexus at the interface between society | Nexus governance is the missing link in the nexus debate. |

| | | | |
|---|---|---|---|
| | (Villamayor-Tomas et al., 2015) | and the natural environment. | |
| Ecosystem Services (ES) | (Pahl-Wostl, 2019) | An analytical framework to identify coordination failures | It is instrumental in supporting transformative change in the WEF nexus. |
| Integrative Environmental Governance (IEG) | (Weitz et al., 2017); (Visseren-Hamakers, 2015) | Literature review on the IEG literature | The IEG literature offers analytical insights that could help close gaps in the nexus literature. |
| Environmental Justice (EJ) | (Middleton et al., 2015) | Mapping of the rise of WEF nexus as a research agenda, in mainland Southeast Asia. | Used to understand how the nexus is framed |
| Global Governance (GG) | (Boas et al., 2016) | It contributes to the institutionalization of a "nexus approach," | It emphasizes the importance of Partnerships in sustainable development. |
| Global Financial Networks (GFN) | (Schmidt & Matthews, 2018) | The role of global financial networks in articulating the nexus | Accounts for integrated thinking of economies, environments, and societies. |
| World Governance (WG) | (Zisopoulou et al., 2018) | Treats WEF Nexus holistically and includes proposals for holistic treatment of the nexus | Rethink the role of an actor with a new quantitative Economic Platform |
| Governance Of Global Risks (GGR) | (de Amorim et al., 2018) | Understanding how the global risks impact the nexus | Relates governance failure to WEF insecurity at all scales |

| | | | |
|---|---|---|---|
| Innovative Governance of Shared Risks (IGSR) | (Gallagher et al., 2016) | WEF nexus needs to consider dimensions of shared risks | Suggests that Externalities and shared risks across multiple scales; innovative government mechanisms are key. |
| Governance Of Nexus Security (GNS) | (Beck & Villarroel Walker, 2013) | Insights from cross-system mapping to assess the role of city governance in achieving nexus security (or not) | Governance must manage the man-environment relationship through Individualists (I), hierarchists (H), egalitarians (E). |
| Urban Governance (UG) | (Artioli et al., 2017) | 'Urbanize' the nexus agenda | Thinks about government transformations in urban areas. |
| Cooperative Governance (CG) | (Sperling & Ramaswami, 2018) | Review of urban case studies | Suggests 'budget-based' approach |
| Good Governance (GG) | (Lele et al., 2013) | Compares China and India at WEF security | It requires the involvement of all stakeholders |
| Policy Integration (PI) | (Gain et al., 2015) | Discusses the nexus in the context of Bangladesh. | Emphasises ministerial coordination in the nexus. |
| Inter-Governance (IG) | (Mohtar, 2016) | It examines the governance of the nexus, understanding capacity building, and models or tools available to support decision-makers. | Emphasises ministerial coordination in the nexus. |
| Organizational Governance (OG) | (Harwood, 2018) | It characterizes the WEF nexus in the Mekong River Basin. | Governance issues are modeled using the Viable System Model (VSM), revealing the multi-level perspective. |
| Governance Of Sociotechno-Economic Political (STEP) Nexus Solution | (Daher et al., 2018) | A framework for resource and stakeholder interactions and trade-offs, addressing | It requires truly inclusive transdisciplinary conceptualization, and quantification |

| | | | |
|---|---|---|---|
| | | governance and financing schemes | |
| Knowledge Coproduction (KCP) | (Howarth & Monasterolo, 2017) | Decision-making in response to shocks to the WEF nexus a | Participatory workshops are suggested |
| Reflexive Governance (RG) | (Halbe et al., 2015) | Accounts on transition processes in Cyprus | Argues for participatory model |
| Governance Heuristic (GH) | (Müller et al., 2015) | Relates nexus with systems of soil, water, and biodiversity. | Suggests the use of a Multi-Level perspective |
| Transdisciplinary Approaches (TA) | (Kurian, 2017) | Places the nexus in light of public policy formulation, implementation, and monitoring. | Accounts for the role of the government in shaping individual behaviour about the environment. |

Source: (Urbinatti et al., 2020)

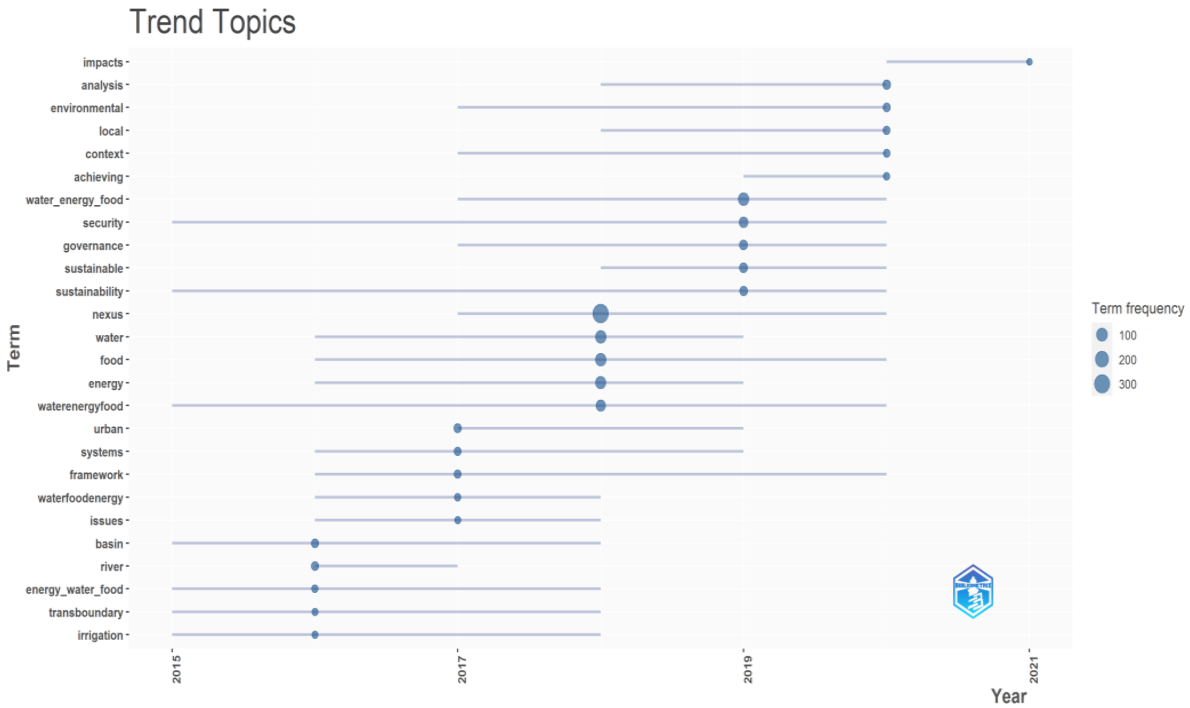
### 5.6 WEF nexus in the context of India

The most important challenge is how global ambition should be interpreted at the national level. To date, much discussion has taken place at international and regional levels but has mostly dealt with issues at the conceptual level. In most cases, policy and development choices are made on a unilateral basis, and the lack of knowledge of the WEF nexus has often led to mismatches in prioritization and decision-making, which will hinder sustainable development (Mitra et al., 2020). However, in this study, the major stakeholders identified were ministries and governmental departments, NGOs, and Academia related to the water, energy, and food sectors. (Tyagi, 2020) focusing on WEF and climate change in India concluded that neo-liberal framing is essential in the integrated management of the WEF nexus. Furthermore, he indicated that major gaps lie in (i) the quantitative assessment of inter-dependencies in WEF requiring additional data and analysis; (ii) current and projected challenges are influenced by demand and supply drivers including climate change; (iii) response options; and the (iv) an appropriate governance framework. Most of the studies done in India concerning WEF nexus are concentrated around the issue of energy used in pumping groundwater for agricultural purposes. For instance, Pro-rata pricing of electricity and jointly managing the supply of electricity with groundwater draft for irrigation is shown to achieve equity, efficiency, and sustainability of groundwater use while cushioning the state exchequer against budgetary support of loss-making state-owned energy utilities (Hanumankar, 2015). Similarly, (Barik et al., 2017) using GIS techniques pondered the Water-Energy-Food nexus from the perspective of electricity consumed for pumping groundwater at all Indian levels and suggest an integrated policy solution for the sustainable management of the WEF nexus. Another study done by (Mukherji, 2020) reports the same problem of groundwater utilisation and proposes the use of economic instruments for demand management. (Subramanian & Manjunatha, 2014) suggested Horizontal Integration in the WEF nexus for India. The focus area is the same for all the studies in India that have focused on the WEF nexus, i.e. the electricity consumed for the pumping of groundwater for irrigation.

Coming to the recommendations made in this area (Amarasinghe, 2014) with a similar perspective i.e. electricity consumed for pumping groundwater and the associated subsidies in the provision of energy services in Andhra Pradesh suggests a mechanism which is Pareto Optimal solution for all the stakeholders involved – The government, Utility companies, Farmers, and the Environment. The mechanism is a direct transfer of subsidies to the farmers. While (Beaton et al., 2019) tried to persuade the role of off-grid solar power pumps for efficient management of the WEF nexus but conceptually they are not clear what "Food" entails in the WEF nexus. In addition to this, a study done by (E. Gupta, 2019) on the adoption of solar pumps by farmers in Rajasthan found that a substantial difference in the solar pump impact on the energy-water-food nexus for a farmer depending on geographical area, the purpose for which solar pump is used, amount of landholding and amount of electric and diesel capacity possessed. In particular, it is found that for regions that use groundwater for irrigation, solar pump adoption has led to an increase in their water consumption for an average farmer. Being non-technical, (Villamayor-Tomas et al., 2015) applying Institutional Analysis and Development (IAD) framework combined with value chain analysis for Hyderabad, Telangana, India suggests demand-side management measures to reduce the impact of groundwater pumping on electricity.

Moving one step ahead in this direction (Reddy et al., 2018) suggests that there is a need to rethink the design and implementation of watershed interventions. They discussed it in the light of the first-generation problem of agricultural intensification coupled with high and imbalanced chemical fertilisers and pesticides are hampering soil fertility and the second-generation problems are in the form of water resource degradation in both qualitative and quantitative aspects because much of this applied fertiliser is washed into the river and groundwater systems through run-off and seepage. This increased use of nitrogen and phosphorous in crop production affects the water used for irrigation. In the absence of any information and knowledge on water or soil quality in developing countries of Asia, Eurasia, and South America, farmers continue to use fertilisers at an increasing rate.

To assess the topical analysis across time in the WEF nexus approach, the following diagram **5.1** is presented with the help of the R biblioshiny package




## Summary and lessons learned

The conclusion of our study makes two important caveats. We aim to delineate the meaning of integration based on the sectors including the actors. Insofar as the studies have defined solely the latter. The precise 'integration' would be the horizontal integration of WEF sectors and both the horizontal and vertical integration of actors in the WEF sectors at all levels. Coming to the aspects, it can be integrated into any aspect such as rights, justice, livelihoods, etc. The offered Innovations in the WEF nexus such as Anaerobic Digestion, Desalination of Seawater or Brackish water used for Irrigation purposes, Solar Irrigation Pumps, Micro Irrigation, Sustainable Diets, Roof top solar panels, Municipal waste water treatment, and nutrient recovery have to surpass two tests for holistic WEF nexus. ***First,*** the Innovations must be cross-cutting across the three sectors i.e. synergies/co-benefits in the dual sector interactions may become a complex integration process. ***Second,*** they must qualify the sustainability dimensions: Social acceptance, Economic viability, and environmentally sound and friendly without jeopardising equity. This requires the ‘institutionalisation’ of the nexus and improved coordination between the actors.

# CHAPTER 6

## Institutions and Sustainable Management of the WEF nexus

Since the 1990s, the concept of community-based natural resource management (CBNRM) has come to the forefront of rural development policy in developing countries. These include programs in individual sectors such as forestry, irrigation, wildlife management, and myriad other resources with or without donor support, with emphasis on conservation or local livelihoods, with statutory backing or in an ad-hoc manner, through state actors or non-state actors. Broadly speaking, the emphasis is on involving, if not privileging, local communities are essential for successful natural resources management and that doing so can simultaneously ensure environmental sustainability, social justice, and development efficacy (Menon et al., 2007). Civil society associations are generally understood to embody a larger role of community-based collaborations as a substitute for flawed government programs. A better description of it is provided by the Frankfurt school theorists especially Horkheimer, Adorno, and Marcuse. They concluded that the aspiration of the enlightenment to the creation of a society of freedom and happiness through reason had gone seriously wrong and that 'reason' as embodied in science and rational organisation had turned into monsters that had come to enslave humanity in what Max Weber had called the 'iron cage' of modernity. In other words, the public sphere has been diminished with ever more technocratic management and people making ever fewer decisions on matters affecting their lives. This technocratic management is supposedly value-free social science. Modern government has sought to treat problems of a political and moral nature as technical ones that require the application of the technique to solve them. Unlike earlier Frankfurt school theorists, **Jürgen Habermas** opines that science and technology are legitimate human projects. It is the illegitimate extension of scientific/ technological rationality into the other spheres that have to be restricted. The notion of community has an overriding influence on the notion of civil society. Building a civil society refers to a situation when a community-based association is not voluntarily created by its members but is formed as an initiative by the government and funding agencies. Thus, community as an arena 'for consensus' or 'of conflict'; are the constitutive aspects of shaping a community.

The Consensual foundations include a collective society that existed on the totality of shared beliefs, rules, morals, and sentiments (**Emil Durkheim**). The continuity of community is ensured by passing down shared norms, customs, and traditions from generation to generation

(**Emil Durkheim and Talcott Parsons**). Community is synonymous with a traditional society based on the relations of trust that are replaced with relations of contracts with the advent of modernity (**Ferdinand Tonnies**). Civil associations are voluntary and serve a larger social purpose by harmonising conflicting demands of individuals and the common social good (**Alexis De Tocqueville**). The conflict theory's emphasis is on the clashes of interests rather than the consensus of values. Communities are formed of various interest groups always ridden with conflicts (**Karl Marx and Max Weber**). However, development policy for the formation of community-based associations gives overriding importance to consensus. **Jürgen Habermas**, in his deliberative democracy model, proposed that through arguments and counter-arguments (communicative rationality) – deliberations – rational and reasoned consensus could be built among the opposing viewpoints. To accomplish this task, it is important to institutionalise appropriate procedural means so that various opposing views can be expressed and a better argument can then come into play.

By now, it is clear that procedural justice has a role to play. The governance seen as a process and outcome can well be interplayed in this dichotomy. Within the scope of governance, we now describe the institutions and water.

Water Law, Water Policy, and Water Administration are the three pillars of institutional analysis in the water economy. However, if an institutional change is about how societies adapt to new demands, its study must go beyond and incorporate civil society institutions in the ambit of institutional analysis.

According to New Institutional Economics (NIE), institutions are conceptualised as ‘formal rules, informal constraints (norms of behaviour, conventions and self-imposed codes of conduct) and the enforcement characters of both, and also ‘if institutions are the rules of the game, organisations are the players’ (North, 1991). NIE also distinguishes institutional arrangements and institutional environments. The institutional environment includes various government agencies at different levels that directly or indirectly deal with water, international agencies, governments, water policy, and water-related laws. The institutional arrangement refers to aspects like groundwater markets, tube-well cooperatives, and Water Users Associations (WUAs) (Vishwa Ballabh, 2008). Thus, it is clear that WUAs, Prices, Markets, Property rights, and institutional arrangements come into one sphere of analysis.

Before we ponder on the above description through the decentralised water governance and institutions, we now present the range of institutions that span across the three resources namely- water, energy, and food sectors. One good reason to do this is the integrative nature of the nexus formed by the three sectors.

**Table 6.1 represents Ministries and public institutions involved in the implementation and monitoring of agricultural policies in India**

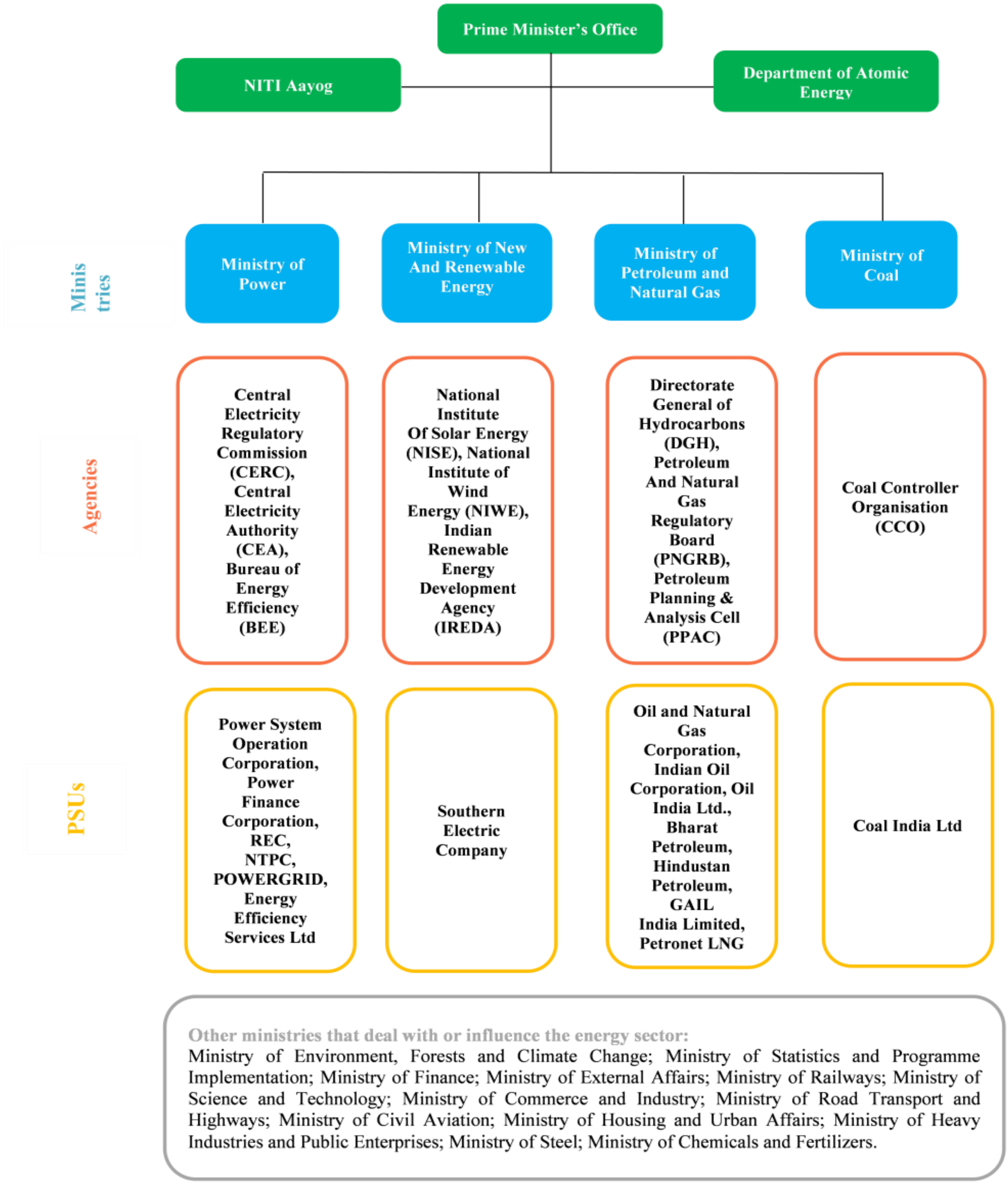
| Particulars | Agencies at the central level | Agencies at the regional/state level |
|---|---|---|
| Production | Ministries of Agriculture, Food Processing, Water Resource, Energy, and the ICAR | Ministries of Agriculture, Horticulture, Food Industry/ Processing, Irrigation, Power, SAUs |
| Prices | Ministries of Agriculture, Food Processing, Commerce, and Commission on Agricultural Costs and Prices | Ministries of Agriculture and Finance, SAUs |
| Marketing | Ministries of Agriculture, and Rural Development, APEDA, Directorate of Marketing and Inspections, NAFED, Food Corporation of India (FCI), Cotton Corporation of India (CCI), Central Warehousing Corporation (CWC), Jute Corporation of India (JCI), National Dairy Development Board (NDDB), Special marketing/processing corporations, Commodity Boards | Ministry of Agriculture, Directorate of Agricultural Marketing, State Level - Agricultural Cooperative Marketing Federation, State Level – Agricultural Marketing Boards, Primary, Central, and State level marketing societies/unions, Special marketing/processing societies, Tribal Cooperative Marketing Federation (TRIFED) |
| Credits | Ministry of Finance, Reserve Bank of India, and National Bank for Agriculture and Rural Development (NABARD) | Ministry of Finance, State Level Bankers Committee, Regional Offices of NABARD, Commercial Banks, Credit Cooperatives, Regional Rural Banks |
| Trade | Ministry of Commerce, Commodity Boards, Agricultural and Processed Food Export Development Authority(APEDA), National Agricultural Cooperative Marketing Federation | Agri Export Zones (AEZs), Ministry of Agriculture |

| | | |
|---|---|---|
| | (NAFED) | |
| Research | Indian Council of Agricultural Research, Veterinary Council of India (VCI), Indian Council of Forest Research (ICFR), Central Agricultural Universities, Deemed Universities | State Agricultural Universities, Private Agricultural Colleges, Private Institutions, and Autonomous Institutions |
| Education | Indian Council of Agricultural Research, Indian Institute of Management, Central Agricultural Universities, MANAGE, IRMA, NIAM | State Agricultural Universities, Private Colleges, Agribusiness Management Institutes (e.g. CABM) |
| Extension | Ministry of Agriculture, Indian Council of Agricultural Research | State Agricultural Universities, Krishi Vigyan Kendras, Krishi Gyan Kendras, State Government Departments |

Source: (Arora 2013).

While the energy sector agency is shown in the following Figure **6.1**

**Governance of the energy sector by Central Government in India**




***India has multiple bodies in central government with a range of energy-related competencies and functions.***

Source: IEA (2021)

Coming to the agency in the water sector, the following two tables show the agency at the central and state government level

**Table 6.2 shows the agency in the water sector at the central government level**

| Name of Agency | Functions |
|---|---|
| Ministry of Water Resources, River Development, and Ganga Rejuvenation | Is a nodal central level ministry. It is in charge of the overall planning and administration of water assets in the nation. |
| Central Water Commission | Provides overall technical support to the ministry |
| Central Groundwater Board | |
| National Water Development Agency | |
| Central Water and Power Research Station | Provides research and training support to the ministry |
| Central Soil and Materials Research Station | |
| National Institute of Hydrology | |
| NITI AAYOG | Grants project clearance and allow and authorizes the financial allocation to various water projects within the country |
| Irrigation Department under the Ministry of Agriculture | Influences the water sector through the Ministry of Water Resources, River Development, and Ganga Rejuvenation |
| Pollution Control Boards under the Ministry of Environment and Forest | |
| Ministry of Housing and Urban Development | |
| Ministry of Drinking Water and Sanitation | Is the nodal department for the overall policy, planning, funding, and coordination of programs for drinking water and sanitation in the country |
| National Water Resources Council | Is the apex policy organ which is chaired by the Prime Minister and includes the Union Minister of Water Resources, Chief Ministers, and Governors of all states and Union Territories |
| National Water Board | Is the executive arm of the National Water Resources Council which is chaired by the union Secretary of Water Resources and the chief secretaries and top bureaucrats of the states and Union Territories |

**Table 6.3 shows the agency in the water sector at the state government level**

| Name of Agency | Functions |
|---|---|
| Water Resources Department | Policy formulation, holistic planning, funding, and coordination of water resources at the state level |
| Water and Land Management Institutes | Capacity building, Research and Development, and Training at the state level for water and land management |
| Agricultural Universities | |
| Water Authorities and State Water Boards | For the effective regulation and monitoring of water resources at state levels |
| Water Supply and Sewerage Board | Caters to the public the water, wastewater, solid waste management, and stormwater management services within the state |
| Municipality/ Nagar Palika | |
| Gram Panchayats | |
| State Pollution Control Board | Have the responsibility for water quality aspects |
| Irrigation Department | Regulates operates and manages the provisions of irrigation within the state |
| Public Works Department | Construction, maintenance, and management of water projects and schemes |

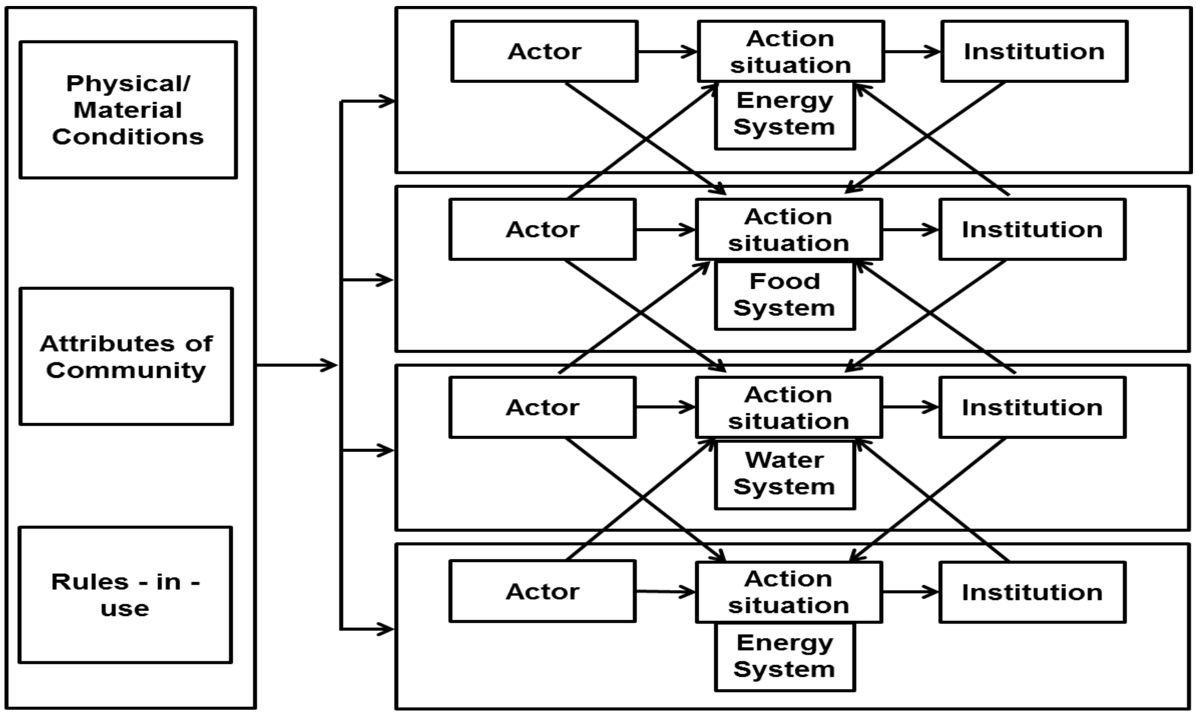
Source: (Bhatt & Bhatt, 2017)

Of the above arrangements, we choose WUAs as the institutional arrangement. The decentralised form of governance of water resources acquired two names: Irrigation Management Transfer (IMT) and Participatory Irrigation Management (PIM). Though these terms are often used interchangeably, slight differences exist as to the degree of farmers involved in the system (Dinar, 1997). IMT refers to programs that shift responsibility and authority from the state to non-governmental bodies; thus, it implies a rolling back of the boundaries of the state (Vishwa Ballabh, 2008). Whereas PIM refers to programs that seek to increase farmers' direct involvement in the system management, either as a complement or substitute for the state role. It refers to the involvement of irrigation users in all aspects of irrigation management, at all levels. Within the decentralised water governance, in the 1970s emphasis was on crafting institutions, in the 1980s emphasis was on farmers' participation addressed by Sociologists and Anthropologists, and in the 1990s emphasis was on Self-Governance addressed by Political Scientists and New Institutional Economists (Vishwa Ballabh, 2008). Till now we are clear about three things i.e. WUAs as institutions, their evolution deserves multi-level perspective interrogation and their governance can be seen as a process and outcome.

Although the WEF nexus entails many system boundaries, groundwater abstraction is the cross-cutting theme for the studies that concentrate on Indian geography (Barik et al., 2017; Fujita & Fukumi, 2020; Gaddam & Sampath, 2022; E. Gupta, 2019; Mukherji, 2020; Tyagi, 2020). This chapter provides an account of the growing groundwater use, hence energy, for irrigation in India. This chapter builds on the idea of the synergistic effect of the Water Users Associations (WUAs) in the WEF nexus system. The abstraction of groundwater for irrigation across the world is granted, provided the lack or limitations of irrigation infrastructure such as dams, tanks, canals, etc. But the presence of infrastructure with improper functioning of the WUAs has an impact on the sustainable management of the WEF nexus (Bhaduri et al., 2015; Mekonnen et al., 2015; Shenhav & Domullodzhanov, 2017). The link is clear in the sense that farmers resort to groundwater sources in the case of improper functioning of WUAs. But the abstraction of groundwater is deeply linked to the energy policies and property regimes existing. Hence the WUAs make the case for the WEF nexus to act upon from the institutional aspects. Furthermore, groundwater abstraction has environmental impacts too. Therefore, this study aims to analyze the drivers and barriers in the functioning of WUAs from a multi-level governance perspective and suggests that policy coordination among the actors in the WEF nexus is the key to capitalising on the synergies existing in the WEF nexus particularly arising out of WUAs. The Institutional Analysis and Development Framework (IAD) adjusted for the multi-level governance perspective is used to investigate the functioning of WUAs in the erstwhile Andhra Pradesh, India as an illustrative case. The results obtained by the framework suggest that the policy coherence in the fragmented sources of just one of the resources in the WEF as well as the policy coordination in all the resources in the WEF system is essential for the sustainable and holistic management of the WEF system. This paper also suggests that the effective implementation of regulatory instruments existed (such as WALTA (Water, Land and Trees Management Act) and KUSUM (Kisan Urja Suraksha evam Utthan Mahabhiyan)) that aim at integrating the WEF sectors into the decision-making contributes to the equitable allocation of resources and the resource security in the WEF system. The simple correlation results suggest that there is a significant relationship between the electricity consumed and the Gross Irrigated Area (GIA) from the wells. The Wilcoxon Signed-Rank test shows that there is a significant decrease in the financial recovery of the irrigation water post-WUAs implementation in Andhra Pradesh. This section concludes that regulatory instruments for demand-side management (pricing the resources that send scarcity signals to the uses and users) coupled with effective water governance and promotion of renewable energy sources to pump groundwater equitably for irrigation is the key to sustainable management of the WEF nexus.

This chapter adopted the tailored Institutional Analysis and Development (IAD) framework for holistic management of the WEF nexus (Märker et al., 2018), though the base of it was developed by Elinor Ostrom in the 1980s (Ostrom, 2008). This framework is used to analyse the collective choice in WUAs and the allocation of other resources (Dhakal et al., 2018). See figure 8. The interdependence among transactions for pursuing WEF securities by actors in the different action situations generates a need for coordination in changing or sustaining institutions, policy goals, and policy instruments that guide actions leading to sustainable outcomes (Srigiri & Dombrowsky, 2021). The actors comprise all the users, uses, and bureaucracy who deal with the available resources and have a stake in the sustainable management of the resources. An institution is a set of formal or informal rules, regulations, and organization that work toward a common objective. The existing system (Physical/material conditions, attributes of community, and rules-in-use) determines together with the (actors, action situations, and Institutions) in one sector, say food, energy, or water along with the (actors, action situations, and Institutions) of the other two sectors the IAD framework. The movement from 'silos' to integrated management of the resources is realized, provided the bidirectional interactions are embraced in the decision-making (Märker et al., 2018).

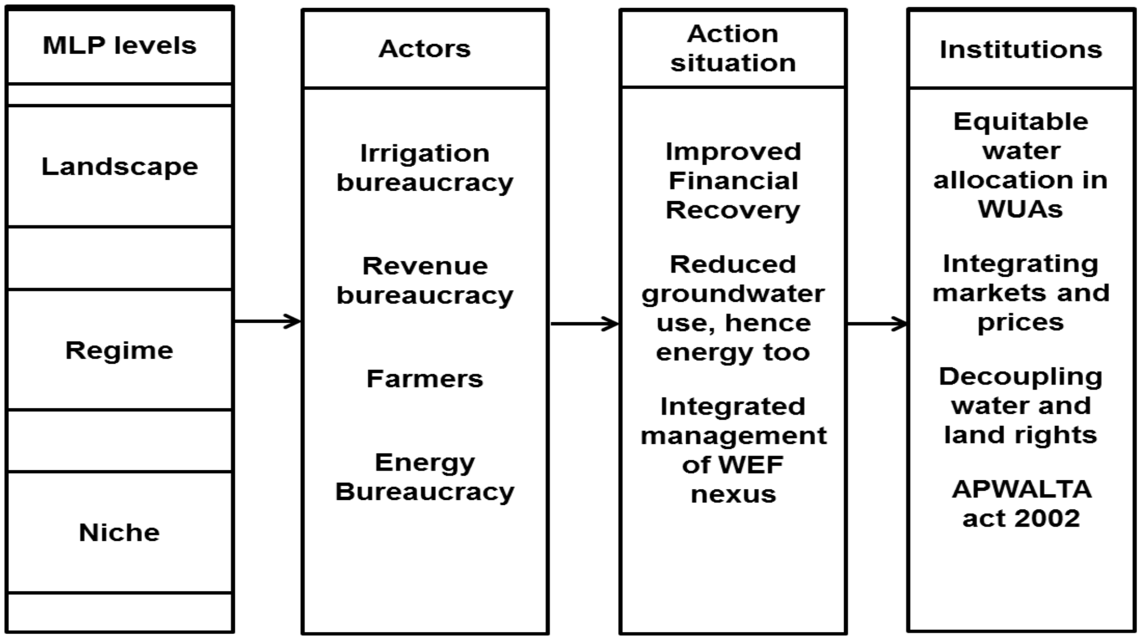
**Figure 6.2 The IAD framework of the WEF nexus**




**Source:** (Märker et al., 2018).

Furthermore, we integrated the IAD framework with the Multi-Level Perspective (MLP) in analysing the governance of WUAs. The MLP framework consists of three nested levels that are central to the explanation of transitions, namely- niche, regime, and landscape (Kaweesa et al., 2021; Raven et al., 2012). MLP argues that transitions come about through dynamic processes within and between three analytical levels: 1) niches, which are protected spaces and the locus for radical innovations; 2) socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and 3) exogenous socio-technical landscape developments (Bilali, 2019; Köhler et al., 2019). The levels of governance in MLP interact with the IAD framework and work through transition pathways for sustainability (Bilali et al., 2017; Geels & Schot, 2007). See figure 10.

**Figure 6.3 MLP framework integrated with the IAD**




**Source:** Authors

The analysis of Landscape, Regime, and Niche levels in the governance of WUAs is a promising approach in combination with the IAD framework because the IAD framework interacts with MLP levels. For example, the reform of the Irrigation Management Transfer (IMT transition) in developing countries is majorly induced by the donor agencies such as The World Bank i.e., a landscape in MLP (Geels, 2011). This study contributes to the literature on sustainability transition frameworks in two important ways. One is the integration of MLP with the IAD framework to analyse the processes that aim at sustainability transitions. To achieve the same, hitherto, MLP is often integrated with other than the IAD framework such as Social Practices Approach (SPA), Technological Innovation Systems (TIS) Approach, Transition Management (TM), and Strategic Niche Management (SNM) (El Bilali, 2020). However, Transition studies essentially consisting of TIS, MLP, SNM, and TM do not match the realities of current research activities anymore (Truffer et al., 2022). Second, this paper takes the cognizance of 'geography of sustainability transitions' i.e., accounting for the issues related to geographical diversity, and multi-scalarity of the actors (Truffer et al., 2015). Hence, Andhra Pradesh, India from the global south has been chosen for the study. This paper also strives for holistic treatment of the sustainability transition by moving beyond the processes i.e., outcome oriented. In this vein, the Wilcoxon signed-rank test is used to assess the improvement of financial recovery through the water fees received from the farmers in Andhra Pradesh. Furthermore, the data we used for analysis is the secondary one. Along with this, the quantitative analysis used in this study is a simple correlation. The Pearson correlation analysis is conducted between the Gross Irrigated Area from Groundwater and the electricity consumption for agriculture from 1985-86 through 2013-14 because both the variables are measured on a ratio scale. Electricity consumption for agriculture can be used as a proxy for energy usage in agriculture (Barik et al., 2017). The proxy used in this study for groundwater withdrawal in agriculture is the Gross Irrigated Area (GIA) from the wells. The institutional aspects of the WEF are to be incorporated into the decision-making to capitalize on the synergy in the WEF system particularly arising out of WUAs. The MLP framework along with the aspects covered in the IAD framework such as rules in use, attributes of the community, and material conditions of the system portrays the factors that determine the functionality of the WUAs.

### 6.1 The MLP description of the case

The use of MLP is the key to understanding the formation and functioning of WUAs. Finance has not been a priority focus of transition studies. This is surprising provided its role in supporting experimentation, innovation, scaling, diffusion, and system transformation. The role of finance should receive more attention in transition research because the sums required to meet SDGs or climate goals are very large (Turnheim et al., 2020). The **Landscape** description follows that the transitions require a huge amount of financial support as a transaction cost (Barbier, 2011). The external funding assistance came timely with the support of $ 141 million (approximately 512 crore INR at the prevailing exchange rate of 1 US $ = 36.31 INR) as a loan under the Andhra Pradesh Economic Restructuring Project (APERP) from World Bank in 1997-98 and is essentially designed to support the WUAs (Raymond Peter, 2001). The loan amount was nearly half of the Working Expenses spent for the same year on the irrigation sector in the state. Moreover, they are increasing every year. The loan amount was spent on the reform process rather than on strengthening the institutions (P. P. Reddy & Reddy, 2008). On top of this, external aid is granted in the manner that it is linked to the presence of a set of principles in the host country. The five principles for the ‘Bank villages’ i.e. villages in which water users associations are created by the World Bank are a). The provision of adequate and reliable water supply b). The water users' associations are formed on a ‘hydraulic’ basis, rather than an administrative basis c). Enabling the water users associations’ rights to collect water fees d). The pricing of water should be

‘Volumetric’ e). No interference from the local government (Wang et al., 2010). These principles serve to create pressure opportunities in the Regime (El Bilali, 2019; Kungl & Geels, 2018). The transaction costs in the irrigation reforms of Andhra Pradesh mainly stem from the election of WUA presidents in the state. Despite these principles, generally one has to evaluate the external aid against its odds. For example, external funding seeking to help the projects in host countries may result in grabbing the resources from the host countries. For instance, one such is the ‘Land grab’ phenomenon as exemplified by (Bizikova et al., 2013), and the political economy of those interventions (Newell et al., 2019). The poor understanding of community participation and institutional development by project staff in donor-supported irrigation projects results in the poor performance of WUAs in enhancing participation in irrigation systems (Yami, 2013).

In recent years, the theoretical conceptualization of the socio-technical regime has undergone an institutional turn (Fuenfschilling & Truffer, 2016). Scholars have increasingly drawn on concepts from institutional theory to describe the norms and rules that stabilize a socio-technical system (Geels, 2004). Coming to the **Regime level** of the case, the Andhra Pradesh government has also capitalised on the benefit from the Government of India for the implementation of the reform. Under the restructured Command Area Development and Water Management Programme (CADWM), more emphasis is being given to the participatory approach in India. Under this Programme, the payment of central assistance to states is linked with the formation of WUAs (Arun et al., 2012). The period (1997-98) marked by reforms has remarkably taken approximately 40 crore INR from the scheme (National Institute for Transforming India AAYOG, 2015).

**Table 6.4 year-wise loan taken by Andhra Pradesh from the CADWM program in INR lakhs**

| Year | Amount in INR Lakhs |
|---|---|
| 1974-75 | 46.28 |
| 1975-76 | 95.93 |
| 1976-77 | 173.78 |
| 1977-78 | 227.24 |
| 1978-79 | 378.12 |
| 1979-80 | 136.26 |

| | |
|---|---|
| 1980-81 | 166.44 |
| 1981-82 | 351.77 |
| 1982-83 | 550.79 |
| 1983-84 | 459.36 |
| 1984-85 | 366.58 |
| 1985-86 | 631.99 |
| 1986-87 | 494.78 |
| 1987-88 | 135.68 |
| 1988-89 | 204.98 |
| 1989-90 | 160.18 |
| 1990-91 | 50.19 |
| 1991-92 | 100.02 |
| 1992-93 | 134.84 |
| 1993-94 | 119.84 |
| 1994-95 | 182.91 |
| 1995-96 | 190.81 |
| 1996-97 | 99.40 |
| 1997-98 | 3839.57 |

**Source:** (National Institute for Transforming India AAYOG, 2015)

The source of the data is (National Institute for Transforming India AAYOG, 2015) and the data from the period 1998-99 through 2013-14 are zero. It is evident from the data that the political will is so strong for implementing the reforms as stressed by Raymond Peter (Raymond Peter, 2001), the then Secretary of Irrigation in GoAP. Regarding the Implementation process i.e., a technical system in MLP jargon (El Bilali et al., 2021). GoAP has followed the 'Big Bang' approach i.e., creating a mass number of WUAs at a time. Although done by duly incorporating the implications from earlier pilot-based studies conducted in 1995-96, more than 10000 WUAs were formed within one year post the reforms were initiated. The 'area of operation' under the 10790 WUAs is 4800000 Ha. But the area irrigated at the highest from canals and tanks stood at 3258510 Ha and the lowest stood at 1906220 Ha (Swain & Das, 2008). The state believed that the sudden handover of operation and management responsibilities to farmers is unwieldy because the expenses were to the tune of thousands of crores. So, the big bang approach is implemented gradually with the plow-back scheme of water rates that were received by the farmers in the sector. Before handing it over fully to the farmers, the government sought to plow back 100 percent of water fees into the system in the first year, 66 percent in the second year, 33 percent in the third year, and finally to the farmers. However, Andhra Pradesh's big-bang approach has lost ground given that after the first term of the WUAs, their function was taken over by the state department (Vishwa Ballabh, 2008), and after the first-term elections to the WUA presidents, the elections were not conducted for the second-term due to the drought as a cited reason (Doraiswamy et al., 2003). The effective functioning of physical systems in the irrigation system depends upon financial sustainability because of the large requirements of funds for operation and maintenance activities such as repairs, and desilting mud. The inequity in allocation among the tail-end farmers (i.e., location disadvantage) and the design properties of the system (i.e. seepage) in the head-end farmers, pricing of irrigation water has an impact on the recovery ratio in the irrigation system of the state (Jairath, 2001). The farmer's income also plays a prominent role in the financial sustainability of WUAs because it shows their ability to pay the water fees and contribute to the well-functioning of the irrigation systems (Narayanamoorthy, 2018).

### 6.1.1 Linking energy policies and property regimes to groundwater abstraction

We now turn to describe the **regime-regime** and **regime-sub regime** interactions. In other words, the interplay of institutions is particularly important because they have aligned with the established rules in case of the intersection of sectors (Wirth et al., 2013). Since our analysis of WUAs span three sources namely- water, energy, and food/agriculture, we aimed to study the interplay of institutions. The account on the **regime- sub regime** follows that the pricing of water in Andhra Pradesh is not 'Volumetric' but rather based on the 'Acreage'. The proposition of 'Volumetric' pricing of water further intensifies the transaction costs of the reforms because of the rise in administration costs and the implementation costs associated with it. Moreover, it requires the installation of water meters for audit purposes. However, efficient water pricing need not be based on 'Volumetric'. Sometimes, the acreage pricing of water outperforms the volumetric pricing of water (Tsur & Dinar, 1997). Moreover, the ballpark figure for implementation costs that should not exceed works out to be 7.5 percent of the cost of provisioning water service. But, we propose that the installation of water meters may be good for Andhra Pradesh because the present recovery ratios raised from water fees are at least 90 percent less than the cost of provisioning water. The further advantage in doing so is ensuring equitable allocation of water because there may be no information asymmetries in the allocation mechanism.

The **regime-regime** interactions considered in this paper are grounded in the factors that seek integration from various regimes for the effective management of the WEF nexus. The energy link to agriculture we discuss here is solely the electricity consumption for agriculture and does not include the diesel consumption for farm mechanization and fertilizer consumption. The electricity consumption is due to pumping the groundwater for irrigation purposes. The production of electricity, in turn, requires water in the various stages of energy generation with the emissions as a byproduct contributing to climate change. Climate change further impacts agriculture in the form of floods and droughts (Shah, 2009). Therefore, we provide a case for the benefits of the efficient management of surface water over environmental sustainability with reduced dependence on groundwater and energy. As far as surface water allocation for the irrigation purpose is considered, i.e. tanks and canals; the decentralized mechanism of allocation is generally suggested in the policy circles and development initiatives (MacDonald, 2019).

The level of groundwater abstraction for agriculture can be better understood through the gross area irrigated from wells. The link between surface water and the groundwater is so complex in the sense that the seepage from canal water contributes to the recharge of the nearby aquifer to some extent (Narayanamoorthy, 2018) inter-alia, the return coefficient of the crop irrigated (Kumar et al., 2011) and generally, it hovers around 25 percent at the distributary level in the irrigation system (Mekonnen et al., 2015) which is abstracted by the usage of electricity. Groundwater is the major source of irrigation in Andhra Pradesh with 49 percent of the net irrigated area in the state being from wells (Amarasinghe et al., 2008). Despite the huge initial costs associated with groundwater extraction (i.e. for digging the well or bore well, the electricity charges for pumping the water) and the environmental impacts such as saltwater intrusion, it became the alternative and more reliable supply source of water. See **Table 6.5**. The data contained in **Table 6.5** is collected from the Indiastat database.

**Table 6.5 Year-wise and Source-wise GIA in Andhra Pradesh in 1000 Ha**

| Year | Area Irrigated from Canals in ‘000’ Ha | Area Irrigated from Tanks in ‘000’ Ha | Area Irrigated from Wells in ‘000’ Ha | Total Gross Area Irrigated in ‘000’ Ha |
|---|---|---|---|---|
| 1980-81 | 2129 | 977 | 1125 | 4342 |

| | | | | |
|---|---|---|---|---|
| 1981-82 | 2190 | 1201 | 1160 | 4678 |
| 1982-83 | 2252 | 955 | 1197 | 4518 |
| 1983-84 | 2441 | 1266 | 1212 | 5058 |
| 1984-85 | 2326 | 856 | 1149 | 4470 |
| 1985-86 | 2200 | 846 | 1161 | 4337 |
| 1986-87 | 2244 | 825 | 1165 | 4360 |
| 1987-88 | 2099 | 742 | 1322 | 4298 |
| 1988-89 | 2458 | 1263 | 1540 | 5440 |
| 1989-90 | 2469 | 1149 | 1647 | 5454 |
| 1990-91 | 2311 | 1107 | 1760 | 5370 |
| 1991-92 | 2212 | 1035 | 1929 | 5378 |
| 1992-93 | 2202 | 788 | 1904 | 5085 |
| 1993-94 | 2220 | 701 | 1912 | 5020 |
| 1994-95 | 2184 | 769 | 2016 | 5185 |
| 1995-96 | 2056 | 839 | 2203 | 5304 |
| 1996-97 | 2199 | 969 | 2391 | 5782 |
| 1997-98 | 2048 | 614 | 2306 | 5158 |
| 1998-99 | 2286 | 928 | 2644 | 6092 |
| 1999-00 | 2208 | 719 | 2596 | 5746 |
| 2000-01 | 2202 | 798 | 2693 | 5916 |
| 2001-02 | 2089 | 634 | 2618 | 5548 |
| 2002-03 | 1452.01 | 454.21 | 2478.59 | 4536.2 |
| 2003-04 | 1513.43 | 537.6 | 2572.75 | 4780.69 |
| 2004-05 | 1730.41 | 514.91 | 2563.32 | 4986.71 |
| 2005-06 | 2231.15 | 761.79 | 2796.08 | 5996.46 |
| 2006-07 | 2298.45 | 695.81 | 2891.63 | 6069.57 |
| 2007-08 | 2249.69 | 668.87 | 3174.28 | 6284.78 |
| 2008-09 | 2375.44 | 726.21 | 3417.03 | 6740.57 |
| 2009-10 | 1864.61 | 370.55 | 3342.53 | 5763.95 |
| 2010-11 | 2503.03 | 755.48 | 3672.13 | 7152.86 |

| | | | | |
|---|---|---|---|---|
| 2011-12 | 2215.6 | 601.29 | 3755.78 | 6784.51 |
| 2012-13 | 1683.41 | 558.66 | 3841.43 | 6268.31 |
| 2013-14 | 1900 | 661 | 3958 | 7260 |

Source: Indiastat database

In Andhra Pradesh, the average percentage of GIA from canals to the total GIA during the period 1980-81 to 1986-87 is 49% which has declined to 38% during 1987-88 to 2012-13. Similarly, in the case of tanks, it decreased from 21.7% to 13.7% during the same period. Despite, the increase in the GIA much of it has come from groundwater. The contribution of GIA from wells to the total GIA, on average, has increased from 25.7% during 1980-81 to 1986-87 to 44.7% from 1987-88 to 2012-13.

The energy use of such groundwater abstraction is evident in **Table 6.6.** The electricity consumption for agriculture data is collected from the EPWRF time-series database, whereas the data on GIA from wells and surface water (sum of area irrigated from canals and tanks) is collected from the Indiastat database.

**Table 6.6 Year-wise Electricity consumed for Agricultural purposes and GIA from wells in Andhra Pradesh**

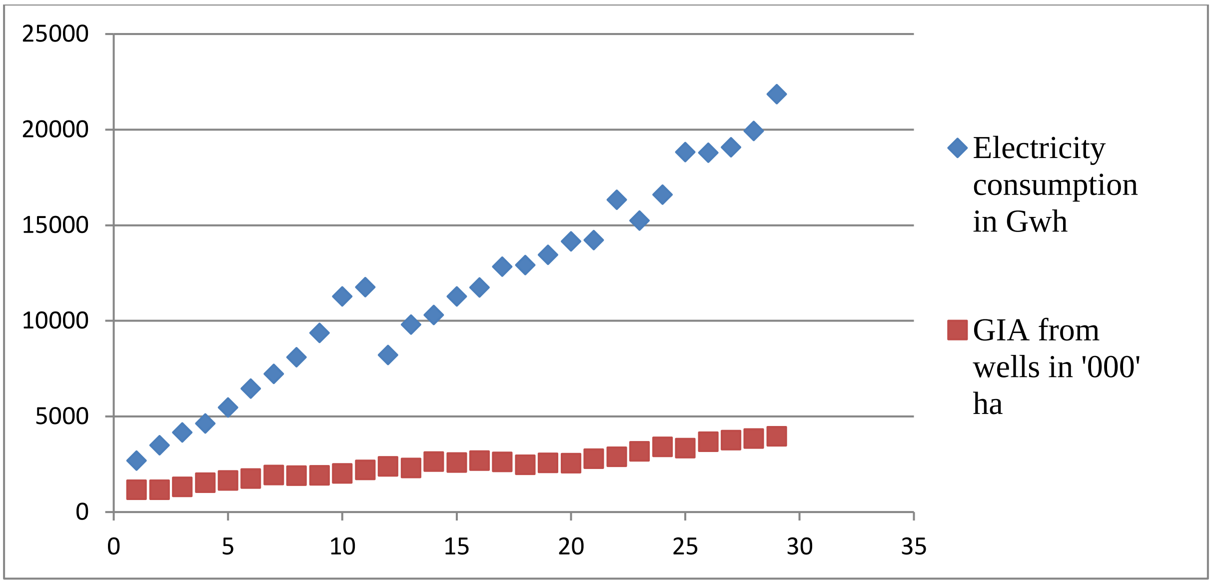
| Year | Electricity consumption in Gwh | GIA from wells in '000' ha |
|---|---|---|
| 1985-86 | 2697.52 | 1161 |
| 1986-87 | 3501.25 | 1165 |
| 1987-88 | 4155.63 | 1322 |
| 1988-89 | 4629.58 | 1540 |
| 1989-90 | 5477.01 | 1647 |
| 1990-91 | 6459.68 | 1760 |
| 1991-92 | 7218.94 | 1929 |
| 1992-93 | 8094.58 | 1904 |
| 1993-94 | 9366.8 | 1912 |
| 1994-95 | 11269.75 | 2016 |
| 1995-96 | 11757.42 | 2203 |
| 1996-97 | 8210.44 | 2391 |
| 1997-98 | 9798.78 | 2306 |
| 1998-99 | 10307.21 | 2644 |

| | | |
|---|---|---|
| 1999-00 | 11285.1 | 2596 |
| 2000-01 | 11748 | 2693 |
| 2001-02 | 12828.92 | 2618 |
| 2002-03 | 12912.1 | 2479 |
| 2003-04 | 13448.19 | 2573 |
| 2004-05 | 14160.72 | 2563 |
| 2005-06 | 14226.2 | 2796 |
| 2006-07 | 16327.92 | 2892 |
| 2007-08 | 15241.05 | 3174 |
| 2008-09 | 16604.57 | 3417 |
| 2009-10 | 18825.02 | 3343 |
| 2010-11 | 18798.57 | 3672 |
| 2011-12 | 19076.05 | 3756 |
| 2012-13 | 19935.79 | 3841 |
| 2013-14 | 21857.35 | 3958 |

Source: EPWRF time series and Indiastat databases.

Using the data contained in **Table 6.6** we conducted the Karl Pearson simple correlation coefficient between the electricity consumption in agriculture and GIA from wells because both are on a ratio scale. It is found to be 0.96. It depicts the strength of the linear association between the GIA from wells and the electricity consumed. The two variables vary together in a positive direction. The co-movement of the two variables is shown in **Figure 6.4**. The high correlation of 0.96 signifies interdependence and is not to be concluded as synergy along the lines of (Fader et al., 2018; Putra et al., 2020) while the latter studies used the correlation between the indicators of the WEF sectors to classify them as either synergies or tradeoffs.

**Figure 6.4 Scatterplot between GIA from wells and the electricity consumed for Agriculture**




The increase in electricity consumption for water withdrawal can depend on the rainfall (Barik et al., 2017), the increase in the area irrigated, and the increase in the depth of water to pump as well.

The next **Regime-Regime** interaction which deserves attention is the subsidy regime. The subsidy regime is an incentive structure of regulatory rule in the regime (Bilali & Probst, 2017). The use of groundwater for irrigation is made possible with low or no tariffs for electricity and surprisingly for water itself (Shah et al., 2018). Moreover, in Andhra Pradesh, electricity is supplied free for seven hours a day (Kondepati, 2011). The result of such subsidies leads to the competitive digging of bore wells and more water usage than necessary. However, the direct transfer of the electricity subsidy to farmers for reducing electricity consumption can be viewed as a Pareto improvement for all the stakeholders involved namely- farmers, power utility companies, government, and most important environment. This is due to the marginal loss of gross value of output due to a reduction in electricity consumption is far less than the increase in subsidy for that amount of electricity consumed (Amarasinghe, 2014) and along with the renewable integration to the groundwater abstraction points out to be the place where the policy coordination in the WEF system arises.

Another **Regime-Regime** interaction stems from fragmented sources of a resource. The public trust doctrine is embodied for surface water but not for groundwater (Ananda & Aheeyar, 2020). Many colonial acts have not yet been superseded and the basic structure of common law rights linking water rights and land rights has not yet been comprehensively reworked, however, the changes are underway (Cullet, 2018).

The recognition of the competitive digging of the bore wells by the government made it enact the regulatory (Command and control approach) legislation namely- Andhra Pradesh Water, Land, and Trees Act in 2002. The APWALTA, Act aims to put bans on the digging of new bore wells. The Act explicitly says that ‘Any person shall obtain permission for drilling a new bore well (other than drinking purposes) within 250 meters of a public drinking water source.’ (Ramachandrula, 2008). APWALTA act works similar to law 10-95 in Morocco's water policy to address the issue of groundwater overexploitation. In Morocco, water deeper than 40 meters below the soil surface is restricted from pumping, but this is very rarely enforced (Meir et al., 2021). However, the implementation of the APWALTA act is not satisfactory. The competitive digging of the bore wells is intensified due to policies such as free power supply and subsidies for the agro wells and a lack of demand management policies (Villamayor-Tomas et al., 2015). There is also no effective legislation to control it due to the establishment of strong links with local authorities and the politicians by the users helps to bypass the law (Prakash et al., 2015).

### 6.1.2 Niche level description

**The niche-**level description provides us an opportunity to dwell upon breakthroughs of a sustainable transition and delve into outcomes as well. In the MLP, transitions are crucially dependent upon activities within niches (Smith et al., 2010). Coming to the outcome, the major backdrop against which WUAs were initiated in Andhra Pradesh was to bring financial sustainability into the system. The recovery ratio which is equal to the percentage of gross receipts to the working expenses is an indicator of the financial performance of the irrigation projects in developing countries (V. R. Reddy, 2009). Accordingly, we took the data from (CWC, 2015) for major and medium irrigation projects only because the major chunk of both the plan and non-plan expenditure of the government on irrigation goes into it. See **Table 15**. While the data on recovery ratio from the period 1979-80 to 1989-90 are excerpted from (GoI, 1992) and the EPWRF time-series database.

**Table 6.7 Financial aspects of Major and Medium Irrigation projects in Andhra Pradesh**

| Year | Working Expenses in Rs crore | Gross Receipts in Rs crore | Percentage Recovery |
|---|---|---|---|
| 1979-80 | 26.10 | 1.98 | 7.6 |
| 1980-81 | 29.88 | 2.09 | 7 |

| | | | |
|---|---|---|---|
| 1981-82 | 33.94 | 2.24 | 6.6 |
| 1982-83 | 35.76 | 2.39 | 6.7 |
| 1983-84 | 40.32 | 4.91 | 12.2 |
| 1984-85 | 42.27 | 9.21 | 21.8 |
| 1985-86 | 38.88 | 14.35 | 36.9 |
| 1986-87 | 30 | 3.42 | 11.4 |
| 1987-88 | 134.64 | 5.44 | 4.03 |
| 1988-89 | 490.98 | 5.44 | 1.1 |
| 1989-90 | 315.54 | 35.21 | 11.15 |
| 1990-91 | 360.32 | 48.78 | 13.54 |
| 1991-92 | 392.1 | 13.82 | 3.52 |
| 1992-93 | 430.41 | 65.72 | 15.27 |
| 1993-94 | 504.42 | 76.79 | 15.22 |
| 1994-95 | 613.78 | 103.8 | 16.91 |
| 1995-96 | 711.82 | 94.61 | 13.29 |
| 1996-97 | 820.1 | 64.77 | 7.90 |
| 1997-98 | 944.39 | 6.33 | 0.67 |
| 1998-99 | 1111.91 | 5.11 | 0.46 |
| 1999-00 | 1053.18 | 4.05 | 0.38 |
| 2000-01 | 1295.39 | 11.43 | 0.88 |
| 2001-02 | 1342.13 | 10.27 | 0.77 |
| 2002-03 | 1574.47 | 8.47 | 0.54 |
| 2003-04 | 1726.56 | 15.52 | 0.90 |
| 2004-05 | 1772.31 | 56.27 | 3.17 |
| 2005-06 | 2470.94 | 47.82 | 1.94 |
| 2006-07 | 3026.51 | 68.81 | 2.27 |
| 2007-08 | 4541.49 | 42.03 | 0.93 |
| 2008-09 | 3797.6 | 38.33 | 1.01 |
| 2009-10 | 5116.54 | 81.88 | 1.60 |
| 2010-11 | 6092.56 | 65.32 | 1.07 |
| 2011-12 | 6349.33 | 72.27 | 1.14 |

| | | | |
|---|---|---|---|
| 2012-13 | 8394.21 | 193.25 | 2.30 |
| 2013-14 | 8370.12 | 206.82 | 2.47 |

To analyse the improvement in the financial recovery from the irrigation systems from the pre and post reforms a Wilcoxon signed-rank test is used on the recovery ratio variable. The results are shown below

```
Test for difference between post-WUAs and pre-WUAs
Wilcoxon Signed-Rank Test
Null hypothesis: the median difference is zero

Difference     rank      signed-rank

  -0.38          1              -1
  -0.74          2              -2
   1.17          3               3
   1.81          4               4
   3.02          5               5
   4.35          6               6
  -4.52          7              -7
   5.36          8               8
   6.82          9               9
   9.04         10              10
 -10.45         11             -11
  42.38         12              12
  52.85         13              13
  63.37         14              14
  68.06         15              15
  89.45         16              16
 112.21         17              17

n = 17
W+ = 132, W- = 21
(Zero differences: 0, non-zero ties: 0)
Expected value = 76.5
Variance = 446.25
z = 2.6036
P (Z > 2.6036) = 0.00461257
Two-tailed p-value = 0.00922515
```

The results suggest that the test performed allows reject the null hypothesis of the median difference is zero i.e. the recovery ratio in the post-WUAs implementation period performs relatively better than in the pre-WUAs period in most periods. Initially, we tried to assess the difference in recovery ratio using a dummy variable but the data does not follow a normal distribution. Then we tried to do the same with a paired t-test, albeit the differences between pre and post-reform groups do not follow a normal distribution. To overcome such probability distribution-related problems, we resorted to a non-parametric test known to be the Wilcoxon Signed-Rank test. It is an alternative to the paired t-test.

However, at the niche level in the WUAs, the two major actors that play crucial roles are the Revenue Department and the Irrigation Department. It is the revenue department officials who collect the water rates from the farmers. The niche level of power and social relations are important factors determining the transitions. The rural ‘elite capture’ hurdle the participation among farmers in the WUAs (P. P. Reddy & Reddy, 2008; Swain & Das, 2008). The ‘elite capture’ can be on the grounds of social, economic, and political grounds. The power relations between the bureaucracy and farmers (and within the bureaucracy and the farmers) that control the quantum and time of water lead to the inequitable allocation of water to farmers. The Inequity in the water allocation between the tail-end and head-end farmers is one of the reasons for the low recovery ratio in the irrigation sector and also for the abstraction of groundwater for irrigation purposes. Hence, the equity in the water allocation in the WUAs helps to reduce the reliability of groundwater and thereby on the electricity too. The increased demand for water and energy exerts pressure on the ecosystem's structure and function. It is where the WUAs have wider impacts on the WEF nexus including the environment.

**Summary and Conclusion**

The synergies highlighted in the WEF nexus so far by the literature are more technocratic in nature. This study analyses the synergies arising out of WUAs from an institutional perspective and hints at one of the opportunities for the sustainable management of the WEF nexus at a decentralised level. Although reforms were implemented in Andhra Pradesh, the increase in GIA from the wells (i.e. with a concomitant increase in electricity consumption) as emphasized above is worth mentioning to address the coordination and the other is financial returns did improve). These are for and against the sustainability dimensions of the WEF nexus. To tackle the groundwater over-abstraction in Andhra Pradesh APWALTA act has been designed. Even if technology is to be deployed, institutions matter. For example, the Government of India came up with a program called ‘Kisan Urja Suraksha evam Utthaan

Mahaabhiyan' (KUSUM) scheme which will support the installation of (i) stand-alone off-grid solar pumps to replace existing diesel pumps; (ii) decentralized ground or stilt-mounted, grid-connected solar power plants (~0.5–2.0 MW) by an individual or group farmers, WUAs, cooperatives or *panchayats* (Local Self Governments) based on expressions of interest issued by distribution companies (DISCOMs) and available sub-station surplus capacity; and (iii) "solarizing" existing grid-connected pumps by outfitting them with solar panels, and allowing owners to sell excess electricity back to DISCOMs. But mere integration of renewable energy to irrigation alone would not suffice the sustainable and effective WEF nexus management because they are to be evaluated in two dimensions. *First*, greening the energy source also has to take care of the monitoring of water resources, otherwise, overdraft of groundwater resources may become an important problem in terms of water quality and quantity. *Second,* the price of water and energy should also signal the scarcity of resources. On top of this, it would be very unlikely to switch across the sources when cheaper substitutes are available. The applied Multi-level perspective framework to the analysis of the WUAs in Andhra Pradesh suggests the importance of policy coordination for the effective governance of the WEF nexus and the sustainable management of the WEF resources. The policy coherence among the fragmented sources of a single resource along with the policy coordination among all the resources in the WEF system namely- water, energy, and food are essential for decision-making to mitigate the trade-offs and tapping the synergies. For a sustainable transition to be successful, integration would emerge from all three levels in MLP. Succinctly put, niche level coordination, regime-sub regime, regime-regime, and landscape integration are key for a sustainable transition process to be effective as well. Unfortunately, Andhra Pradesh state does not have electricity prices for farmers. Thus this paper suggests that integrated governance and institutions play an equivalent role as the technocratic management does in the WEF nexus.

# CHAPTER 7

## Water-Energy-Food Nexus in India: Allocation Perspective

This chapter tries to quantify the dual interactions existing in the WEF nexus namely- water to food, energy to food, food to energy, energy to water, and water to energy based on the data from India. The data used in this study is a secondary one and most of the data points over the years are taken from the EPWRF time-series database. The datasets used range from 1950-51 through 2021. The important institutions related to the WEF nexus in India include the Central Water Commission (CWC), Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR RD & GJ), Central Pollution Control Board (CPCB), Central Electricity Authority (CEA), and websites of Ministry of Agriculture but this list is not exhaustive. This study also used the country-specific and recent reports published by the International Energy Agency (IEA) and the United States Department of Agriculture (USDA). After obtaining the data, this work utilised the log-linear model to assess the trends in the data which may seem most useful to understand the interdependency among the WEF sectors. The log-linear model yields us the annual instantaneous growth rate over the period.

### 7.1 Energy-water link

The energy-water link envisaged in this paper to the Indian context deals with the electricity consumption for public waterworks and sheds light on the treatment of wastewater. While this link in the global context is widely understood i.e. energy requirements of pumping, treating, and transporting water resources including desalination (Gençer & Agrawal, 2018). Globally, 8 % of the energy generation is used for pumping, treating, and transporting water, while most forms of power generation are water-intensive (United Nations Environment Programme, 2016). On top of this, the energy used for pumping groundwater for irrigation is discussed under the water-Food link.

**Table 7.1 shows electricity consumed by public waterworks at the Indian level**

| Year (1) | All India's energy consumption by Public Water Works (GWh) (2) | All India Total Electricity Generation by Utilities (GWh) (3) | Percentage Share (2/3)*100 |
|---|---|---|---|
| 1957-1958 | 366 | 11369 | 3.21 |
| 1958-1959 | 393 | 12994 | 3.02 |
| 1959-1960 | 434 | 15033 | 2.88 |

| | | | |
|---|---|---|---|
| 1960-1961 | 436 | 16937 | 2.57 |
| 1961-1962 | 480 | 19670 | 2.44 |
| 1962-1963 | 531 | 22365 | 2.37 |
| 1963-1964 | 557 | 25498 | 2.18 |
| 1964-1965 | 601 | 29563 | 2.03 |
| 1965-1966 | 625 | 32990 | 1.89 |
| 1966-1967 | 705 | 36376 | 1.93 |
| 1967-1968 | 710 | 41195 | 1.72 |
| 1968-1969 | 837 | 47433 | 1.76 |
| 1969-1970 | 880 | 51989 | 1.69 |
| 1970-1971 | 1017 | 55828 | 1.82 |
| 1971-1972 | 1009 | 60925 | 1.65 |
| 1972-1973 | 1094 | 64546 | 1.69 |
| 1973-1974 | 1217 | 66689 | 1.82 |
| 1974-1975 | 1227 | 70191 | 1.74 |
| 1975-1976 | 1327 | 79231 | 1.67 |
| 1976-1977 | 1444 | 88333 | 1.63 |
| 1977-1978 | 1504 | 91369 | 1.64 |
| 1978-1979 | 1428 | 102523 | 1.39 |
| 1979-1980 | 1408 | 104627 | 1.34 |
| 1980-1981 | 1534 | 110844 | 1.38 |
| 1981-1982 | 1674 | 122101 | 1.37 |
| 1982-1983 | 1757 | 130274 | 1.34 |
| 1983-1984 | 1828 | 140177 | 1.30 |
| 1984-1985 | 2065 | 156859 | 1.31 |
| 1985-1986 | 2106 | 170350 | 1.23 |
| 1986-1987 | 2561 | 187714 | 1.36 |
| 1987-1988 | 2945 | 202093 | 1.45 |
| 1988-1989 | 3253 | 221396 | 1.46 |
| 1989-1990 | 3391 | 245438 | 1.38 |
| 1990-1991 | 3643 | 264419 | 1.37 |
| 1991-1992 | 4449 | 287029 | 1.55 |
| 1992-1993 | 4377 | 311362 | 1.40 |
| 1993-1994 | 4838 | 324050 | 1.49 |
| 1994-1995 | 5037 | 350490 | 1.43 |
| 1995-1996 | 5278 | 379867 | 1.38 |
| 1996-1997 | 5569 | 395867 | 1.40 |
| 1997-1998 | 6084 | 421747 | 1.44 |
| 1998-1999 | 6561 | 448544 | 1.46 |

| | | | |
|---|---|---|---|
| 1999-2000 | 7109 | 481055 | 1.47 |
| 2000-2001 | 7044 | 501204 | 1.40 |
| 2001-2002 | 7370 | 517439 | 1.42 |
| 2002-2003 | 7899 | 532693 | 1.48 |
| 2003-2004 | 9219 | 565102 | 1.63 |
| 2004-2005 | 9618 | 594456 | 1.61 |
| 2005-2006 | 10258 | 623820 | 1.64 |
| 2006-2007 | 10331 | 670654 | 1.54 |
| 2007-2008 | 11791 | 722626 | 1.63 |
| 2008-2009 | 12191 | 741168 | 1.64 |
| 2009-2010 | 12552 | 799851 | 1.56 |
| 2010-2011 | 13673 | 844748 | 1.61 |
| 2011-2012 | 14950* | 922451 | 1.62 |
| 2012-2013 | 16226 | 964489 | 1.68 |
| 2013-2014 | 19187 | 1026649 | 1.86 |
| 2014-2015 | 18837 | 1116850 | 1.68 |
| 2015-2016 | 20122 | 1167584 | 1.72 |
| 2016-2017 | 19411 | 1235358 | 1.57 |
| 2017-2018 | 20872 | 1303455 | 1.60 |

Source: EPWRF database.

The data reveals that the energy consumption for waterworks is ever increasing. To analyse the trend in the variable we have used a log-linear model of the form

$$\ln Y = a + bt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

We divided the sixty years of data into six time periods with each period containing 10 years to analyse the trend.

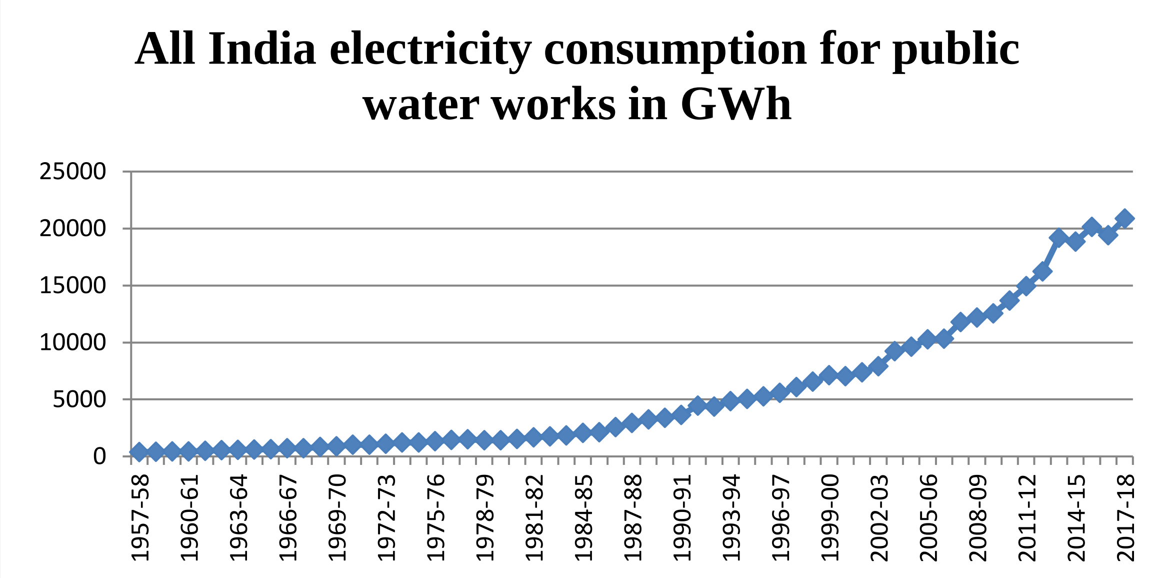
**Table 7.2** provides the growth rates

| Period | Growth Rate |
|---|---|
| 1958-68 | 6.8% |
| 1968-78 | 7% |
| 1978-88 | 6.8% |
| 1988-98 | 7.1% |
| 1998-2008 | 6.4% |
| 2008-2018 | 6.3% |

All the coefficients are significant at the 5% level

We have applied the above model (1) based on the scatter plot shown below.

**Figure 7.1** Depicts the scatterplot on electricity consumed by public waterworks by the time




India desalinates only 0.0006 $KM^3$ of water (Rakitskaya, 2021). Coming to wastewater treatment in India, only 10 percent of the generated wastewater is treated (Never, 2016), However in Hyderabad, India, the figure hops to 40% (Miller-Robbie et al., 2017). As per World Resources Institute, the treatment capacity for generated wastewater in India stands at 37%, while dealing with it in capacity terms is a necessary condition but not sufficient. Please refer to the following table 20 for this effect.

**Table 7.3 provides the Sewage generation data in India**

| State/Union Territory | Sewage generation in MLD | Installed capacity in MLD | Operational treatment capacity in MLD |
|---|---|---|---|
| Andaman & Nicobar islands | 23 | 0 | 0 |
| Andhra Pradesh | 2882 | 833 | 443 |
| Arunachal Pradesh | 62 | 0 | 0 |
| Assam | 809 | 0 | 0 |
| Bihar | 2276 | 10 | 0 |
| Chandigarh | 188 | 293 | 271 |
| Chhattisgarh | 1203 | 73 | 73 |
| Dadra & Nagar Haveli | 67 | 24 | 24 |
| Goa | 176 | 66 | 44 |
| Gujarat | 5013 | 3378 | 3358 |

| | | | |
|---|---|---|---|
| Haryana | 1816 | 1880 | 1880 |
| Himachal Pradesh | 116 | 136 | 99 |
| Jammu & Kashmir | 665 | 218 | 93 |
| Jharkhand | 1510 | 22 | 22 |
| Karnataka | 4458 | 2712 | 1922 |
| Kerala | 4256 | 120 | 114 |
| Lakshadweep | 13 | 0 | 0 |
| Madhya Pradesh | 3646 | 1839 | 684 |
| Maharashtra | 9107 | 6890 | 6366 |
| Manipur | 168 | 0 | 0 |
| Meghalaya | 112 | 0 | 0 |
| Mizoram | 103 | 10 | 0 |
| Nagaland | 135 | 0 | 0 |
| NCT of Delhi | 3330 | 2896 | 2715 |
| Orissa | 1282 | 378 | 55 |
| Pondicherry | 161 | 56 | 56 |
| Punjab | 1889 | 1781 | 1601 |
| Rajasthan | 3185 | 1086 | 783 |
| Sikkim | 52 | 20 | 18 |
| Tamilnadu | 6421 | 1492 | 1492 |
| Telangana | 2660 | 901 | 842 |
| Tripura | 237 | 8 | 8 |
| Uttar Pradesh | 8263 | 3374 | 3224 |
| Uttarakhand | 627 | 448 | 345 |
| West Bengal | 5457 | 897 | 337 |

Source: (Central Pollution Control Board, 2021) and status is as on 30.06.2020

Generally, it is assumed that 80 % of the supplied water returns as sewage (Reddy et al., 2011). Additionally, sewage consists of 90 % water (Central Pollution Control Board, 2021). The 2001 Census found that 74 percent of urban India had access to sanitation; 46 percent of urban Indians had water closets. But it did not specify whether these flush toilets were connected to septic tanks or underground networks or open drains. The 2011 Census has corrected this anomaly as its datasheet differentiates between toilets and disposal systems. It is important to note that Census 2011 shows that only 32.7 percent of urban Indians are connected to a piped sewer system and 12.6 percent – roughly 50 million people – still defecate in the open (M. Shah, 2016). The National Urban Sanitation Policy of 2008 recommends a minimum of 20% reuse of wastewater in every city. Social acceptances, not in my backyard (NIMBY), and land acquisition are some barriers identified for wastewater treatment sectors in Kochi, Delhi, and Nashik (Never, 2016). Centralised wastewater treatment entails high Operation & Maintenance costs (On average, Rs. 30000 per MLD per month). In India, the Activated Sludge Process (ASP) is the most commonly employed technology which requires 2.6 KW of electricity per MLD sewage treatment (Sahasranaman & Ganguly, 2018). In 2009-10 as per the 2001 census, there are 498 class-I and 410 class-II cities present in India. The wastewater scenario is described in the following table.

**Table 7.4 provides the wastewater data on India**

| Category | No of cities | Population | Total water supply in MLD | Wastewater generation in MLD | Treatment capacity in MLD |
|---|---|---|---|---|---|
| Class-I | 498 | 143083804 | 44769.05 | 35558.12 | 11553.68 |
| Class-II | 410 | 30018368 | 3324.83 | 2696.7 | 233.7 |
| Total | 908 | 257754640 | 48093.88 | 38254 | 11787.38 |

Source: (Central Pollution Control Board, 2010). A class-I city is identified as having a population of more than 1, 00,000, while a class-II city is identified with a population of 50,000 to 1, 00,000.

Given the gap between generation and treatment, the nutrient recovery synergy in the WEF nexus from the Life Cycle Assessment perspective works out to be as follows: The average nitrogen, Phosphorus, and potassium contents in municipal wastewater from Indian Cities are computed as 30 mg/l, 7.50 mg/l, and 25 mg/l respectively. To assess the economic value of sewage in terms of nutrient contents, the Municipal nutrient value, varied from Rs. 75/Ha/Annum to 400/Ha/ Annum for application-level of 500 cm in depth /Ha/Annum. From this, the average sale price of wastewater generated from the coastal cities and towns is Rs. 76.32 million/Annum. While 347.56 tonnes /day and the total cost of nutrients contained in the wastewater is assumed at Rs. 8000/ ton of nutrients work out to be Rs. 1014.88 million/annum (Central Pollution Control Board, 2010).

### 7.2 Water-Energy link

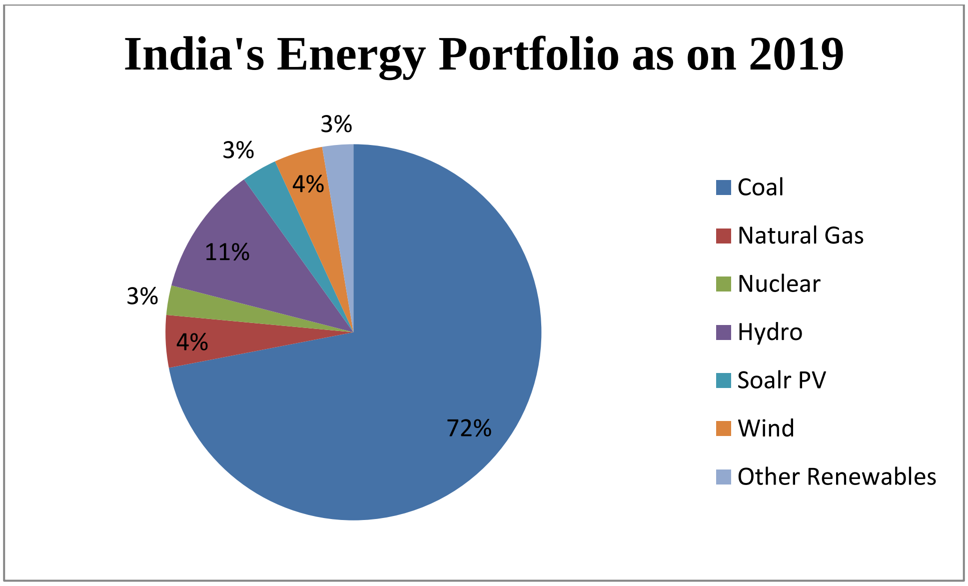
Before pondering over the link it appears to be important to first discuss the energy portfolio of the country because different sources of energy have different implications for the WEF nexus and the Environment (Srinivasan et al., 2018). Roughly 80 % of global electricity generation depends on water for cooling i.e. an average of nearly 100 litres of water withdrawn per KWh (Sadegh et al., 2020). In 2014, the energy sector accounted for 10% of total worldwide water withdrawals and around 3 % of total water consumption. About 12 % of these withdrawals and 64 % of the consumption were used for energy source extraction and the remaining water was used for power generation (D'Odorico et al., 2018) while the (UNEP, 2016) puts the figure at 15 %. Around 9% of electricity generation in India comes from hydropower generation. Today, the energy sector in India withdraws roughly 30 Billion cubic Meters (BCM) of water (the volume of water removed from a source) and consumes almost 6 BCM (the amount withdrawn but not returned to a source). Coal-fired power generation accounts for 80% of the water withdrawals made by the energy sector, with the water being used mainly for cooling and ash disposal. The energy sector accounts for less than 5% of India's total water withdrawals and less than 2% of consumption, but water availability is nonetheless essential for India's energy security (IEA, 2021).

**Table 7.5 displays the energy portfolio of India as of 2019**

| Source | Electricity in TWh |
|---|---|
| Coal | 1135 |
| Natural Gas | 71 |
| Nuclear | 40 |
| Hydro | 175 |
| Solar PV | 48 |
| Wind | 66 |
| Other renewables | 42 |
| Total | 1583 |
| Source: (IEA, 2021). | |

Coal plays a predominant role in India's energy sector (Bhattacharjee, 2017). However, India is making great strides in the adoption of renewable energy. As part of this, India's Intended Nationally Determined Contributions (INDC) to the Paris agreement, negotiated by the twenty-first Conference of Parties (CoP-21) Under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) envisages a 40 percent share of non-fossil fuels in power generation capacity by 2030, commitment to reducing the emissions intensity of its Gross Domestic Product (GDP) by 33-35 percent from the 2005 level by 2030, setting a mammoth target of 175 GW of renewable energy capacity (100 GW from solar energy; 60GW from the wind; 10GW through bio-power and 5GW from small hydro) by 2022 are to name a few (Mitra, 2019).

**Figure 7.2** represents the share of the respective sources of energy generation




Given the energy mix of India, it can be understood that emissions also make India shift its attention towards renewables. GCO2/KWh from the energy in India is estimated to be 725 (IEA, 2021). Thermal Power Plants are reported to be accounting for 87.8% of total industrial water consumption in the country. The average consumptive water requirement for coal-based plants with cooling towers in India is about 5-7 $m^3$/h per MW. As such, thermal power production in the country is consuming at least 16.8 million $m^3$ of water per day at an 80% load factor, which is equivalent to the per capita water requirement of about 20% population of the country (TERI, 2017). Taking cognisance of the issue, The GoI through its Ministry of Environment, Forests and Climate Change (MOEFCC) came up with a set of regulations namely- All plants with once-through cooling (OTC) shall install cooling tower (CT) and achieve specific water consumption of 3.5 $m^3$/MWh within two years of notification; all existing CT based plants shall reduce specific water consumption up to a maximum of 3.5 $m^3$/MWh within a period of two years of notification; and new plants to be installed after January 1, 2017, shall have to meet specific water consumption of 2.5 $m^3$/MWh and achieve zero water discharge (Luo et al., 2018). Water consumption for energy production is an indicator used for the water-energy link and is often interpreted as specific water consumption if expressed in units i.e. ratio of units of water consumed to the units of energy produced (Spang et al., 2014). Based on the primary study conducted by (TERI, 2017), India is classified into various geographical units such as western, eastern, central, southern, northern, and northeastern at prima facie and subsequently analyse the water requirements of the power generation in the respective areas. Please refer to the following table. Overall the specific water requirements vary from 1.7 - 8.0 $m^3$/MW. This mainly depends on the size, age, and the type of the plant (either coal-based or gas-based), type of water circulation (i.e. once-through system or cooling tower-based), dry ash handling system or wet ash handling system, provision for ash water recycling, etc. (TERI, 2017). For instance, the consumptive water requirement for old thermal power plants with the cooling tower is as high as around 8-9 m3/h per MW without ash water recirculation and 5 $m^3$/h per MW with ash water recirculation. Recently, TPPs have been designed with consumptive water requirements in the range of 3.5 - 4 $m^3$/h per MW (Chaturvedi et al., 2018).

**Table 7.6 shows region-wise electricity generated and water demanded as a percentage of total regional water demand**

| Region (1) | Electricity generated in GWh (2) | % share of water demand from electricity generation in regional water demand |
|---|---|---|
| Western | 94229.96 | 2.6 |
| Southern | 66066.44 | 1.7 |
| Central-Northern | 69564.75 | 0.8 |
| Eastern | 104209.37 | 2.2 |
| North Eastern | 1732.17 | 5.7 |

Source: EPWRF database

Note: Zone classification is followed differently by CEA and (TERI, 2017)

However, the study concluded that concerning water consumption for energy production, different regions can be ranked as Western>Southern>Eastern> Northern> Central>>North-Eastern, while the greater being consuming more water for power generation.

### 7.3 Water-Food interlink

Globally, agriculture accounts for 70% and 30% withdrawal of water and energy respectively (Chang et al., 2016). Agricultural irrigation accounts for 84% of global consumptive freshwater use (Sadegh et al., 2020). India is no exception. 90% of water withdrawn in India is used for agriculture, mainly for irrigation. The current information on her water resources is provided in the following table.

**Table 7.7 provides the water resources information for India**

| | |
|---|---|
| Average Annual Rainfall (1985-2015) | 1105mm (3880 BCM) |
| Annual Rainfall (2018) | 1074 mm |
| Mean Annual Natural Run-off | 1999.2 BCM |
| Total Utilisable Water | 1122 BCM |
| Estimated Utilisable Surface Water Potential | 690 BCM |
| Total Replenishable Ground Water Resources (2013) | 432 BCM |
| Net Ground Water Availability (2013) | 411 BCM |
| Ultimate Irrigation Potential | 139.9 Mha |
| From Surface Water | 76 Mha |
| From Ground Water | 64 Mha |
| Per capita water availability | 1720.29 cum |
| Storage available due to completed Major and Medium Projects (including live capacity less than 10 Mecum) | 253 BCM |
| Estimated additional likely live storage available due to projects under construction/consideration | 155 BCM |

Source: (CWC, 2020).

The data shown in the table reveals that India is not water insecure (Ramaswamy R Iyer, 2008). The per capita water availability in India is 1720.29 cubic metres, which is more than the standard of 1700 cubic metre emphasized by (Falkenmark, 1989). But the water availability is contingent upon many factors and varies with time and space (Gleick, 2003) and governance as well. To this effect, as per WRI (World Resources Institute), 54 % of the area in India is under water stress. Given the current status, the future projections of water demand for different uses in India through 2050 in BCM are provided in the following table.

**Table 7.8 provides the water demand by various sectors in India**

| Sector | Standing sub-committee of MoWR, RD & GJ | | | NCIWRD | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2010 | | 2025 | | 2050 | |
| | 2010 | 2025 | 2050 | Low | High | Low | High | Low | High |
| Irrigation | 688 | 910 | 1072 | 543 | 557 | 561 | 611 | 628 | 807 |
| Drinking water | 56 | 73 | 102 | 42 | 43 | 55 | 62 | 90 | 111 |
| Industry | 12 | 23 | 6 | 37 | 37 | 67 | 67 | 81 | 81 |
| Energy | 5 | 15 | 130 | 18 | 19 | 31 | 33 | 63 | 70 |
| Other | 52 | 72 | 8 | 54 | 54 | 70 | 70 | 111 | 111 |
| Total | 813 | 1093 | 1447 | 694 | 710 | 784 | 843 | 973 | 1180 |

Source: (CWC, 2015). This requirement is based on the assumption that irrigation efficiency will increase to 60 % from the current level of 35 - 40 %.

In this vein, GoI came up with a program on 1st July 2015 namely- Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) with a Micro Irrigation Scheme (MIS) as a part of it. It is an envelope of all earlier schemes existing including the Drought Prone Areas Programme (DPAP) and Desert Development Programme (DDP). The main objective of the scheme is to bring more area under irrigation equitably and to enhance the water use efficiency in the agricultural sector. The payment of subsidy to the beneficiary under the scheme will be 55% for small and marginal farmers and 45% for other farmers which will be met by both the Central Government and State Government in the ratio of 60:40 for all states except the North Eastern and Himalayan states. In the case of these states, the ratio of sharing is 90:10. For the Union Territories, the funding pattern is 100% granted by the Central Government. The subsidy payable to the beneficiary will be limited to an overall ceiling of 5 hectares per beneficiary. The achievements of the scheme year-wise are detailed in the following table

**Table 7.9 shows the area covered under drip and sprinkler irrigation systems**

| Year | Area covered under drip irrigation in Ha | Area covered under sprinkler system in Ha | Total in Ha |
|---|---|---|---|
| 2015-16 | 346936.49 | 204650.29 | 551586.78 |

| | | | |
|---|---|---|---|
| 2016-17 | 487390.8 | 352573.33 | 839964.13 |
| 2017-18 | 541467.79 | 507473.34 | 1048941.13 |
| 2018-19 | 575500.14 | 582993.66 | 1158493 |
| 2019-20 | 608910.40 | 549579.55 | 1158489.95 |
| 2020-21 | 178636.75 | 275333.16 | 453969.91 |
| Grand Total | 2738842.37 | 2472603.33 | 5211445.70 |

Source: https://pmksy.gov.in/mis/rptAchievement.aspx accessed on 03/18/2021.

However, drip and sprinkler irrigation saves water but uses more energy than furrow irrigation (Fayiah et al., 2020). This is one of the cases from which the trade-offs arise in the water-energy-food nexus. To tackle the trade-off we need to integrate renewable energy such as solar irrigation pumps. But the evidence from Rajasthan shows that under this scenario, farmers tend to use more water (Gupta, 2019) in particular and in India in general (T. Shah et al., 2018). Hence, this case provides a classic example of the integrated governance can play in the sustainable management of the WEF nexus (Al-Saidi & Elagib, 2017). Therefore, all the sectors are to be monitored effectively such as water pricing (Parween et al., 2020); energy saving (Hagerty & Zucker, 2019), and food waste (Haltas et al., 2017). Mere technocratic management of the WEF nexus would not suffice (Liebenguth, 2020) but it has to incorporate varied perspectives (Proctor et al., 2020) at various scales (Pahl-Wostl et al., 2020). Working out the statistics into geographically classified India in a similar fashion as table 23 in this study, the region-wise water demand for agriculture can be shown in the following **Table 7.10**

| **Region (1)** | **States (2)** | **% share of the region's water demand from Agriculture (3)** |
|---|---|---|
| Western | Rajasthan, Gujarat, Maharashtra, Goa | 85.36 |
| Southern | Kerala, Tamilnadu, Andhra Pradesh, Telangana, Karnataka | 82.39 |
| Central Region | Madhya Pradesh, Chhattisgarh | 91.2 |

| | | |
|---|---|---|
| Eastern | Bihar, Jharkhand, West Bengal, Odisha | 82.5 |
| Northern | Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Uttar Pradesh | 93.9 |
| North Eastern Region | Assam | 49.3 |

Source: (TERI, 2017).

### 7.4 Energy-Food link

As mentioned earlier that the energy consumed for irrigation is an indirect link for energy for food the direct link is concerning water. Globally, this link is envisaged as the energy for mechanized farming in the form of diesel, petrol, human power, agricultural food processing, and fertiliser production, including the energy needed for pumping irrigation water. This paper deals with the latter two and the rest are beyond the scope of this paper. The food supply chain demands up to 30% of global primary energy use (Sadegh et al., 2020). First, we dwell on the fertiliser sector of India.

**Table 7.11 shows the electricity consumed by the fertiliser industry in India**

| Year | Electricity consumption for fertiliser Industry in GWh | % share in total Agricultural Electricity Consumption |
|---|---|---|
| 1989-90 | 5252.8 | 11.92 |
| 1990-91 | 4906.23 | 9.74 |
| 1991-92 | 5012.69 | 8.56 |
| 1992-93 | 5469.39 | 8.63 |
| 1993-94 | 5700.27 | 8.06 |
| 1994-95 | 6203.05 | 7.82 |
| 1995-96 | 5946.41 | 6.93 |
| 1996-97 | 7212.75 | 8.58 |
| 1997-98 | 6586.81 | 7.21 |
| 1998-99 | 6440.3 | 6.62 |
| 1999-00 | 6448.72 | 7.09 |

| | | |
|---|---|---|
| 2000-01 | 6437.21 | 7.59 |
| 2001-02 | 6793.88 | 8.31 |
| 2002-03 | 6847.65 | 8.1 |
| 2003-04 | 4825.39 | 5.54 |
| 2004-05 | 5138.61 | 5.8 |
| 2005-06 | 4526.32 | 5.01 |
| 2006-07 | 3880.06 | 3.91 |
| 2007-08 | 3490.83 | 3.35 |
| 2008-09 | 3602.33 | 3.34 |
| 2009-10 | 3952.23 | 3.3 |
| 2010-11 | 4077.45 | 3.22 |
| 2011-12 | 4016.79* | 2.84 |
| 2012-13 | 3956.14 | 2.68 |
| 2013-14 | 4191.48 | 2.74 |
| 2014-15 | 4234.03 | 2.5 |
| 2015-16 | 4247.16 | 2.45 |
| 2016-17 | 4713.28 | 2.46 |
| 2017-18 | 4704.58 | 2.36 |

Source: EPWRF database

The data displayed in the above table only shows a partial picture. Similar to the virtual water concept there is an energy trade involved in the Indian fertiliser sector i.e. import of Nitrogen, Phosphorous, and Potassium (NPK) fertilisers may fulfill the discussion. With the advent of a green revolution in India, fertiliser consumption and groundwater resources played a major role in making India self-sufficient in food (Mukherji, 2019). But we will return to the problem of over-reliance on groundwater later in this text.

**Table 7.12 provides the consumption, production, and imports of fertilisers in India**

| Year | Total NPK fertiliser consumption in Lakh tons | Total NPK fertiliser production in Lakh tons | Total NPK fertiliser imports in Lakh tons |
|---|---|---|---|
| 1981-82 | 60.64 | 40.93 | 20.41 |
| 1982-83 | 63.88 | 44.04 | 11.32 |
| 1983-84 | 77.1 | 45.33 | 13.55 |
| 1984-85 | 82.11 | 51.80 | 36.24 |
| 1985-86 | 84.74 | 57.56 | 33.99 |
| 1986-87 | 86.45 | 70.7 | 23.1 |
| 1987-88 | 87.84 | 71.31 | 9.84 |
| 1988-89 | 110.40 | 89.64 | 16.08 |

| | | | |
|---|---|---|---|
| 1989-90 | 115.68 | 85.43 | 31.14 |
| 1990-91 | 125.46 | 90.45 | 27.58 |
| 1991-92 | 127.28 | 98.63 | 27.69 |
| 1992-93 | 121.53 | 97.36 | 29.08 |
| 1993-94 | 123.66 | 90.47 | 31.67 |
| 1994-95 | 135.64 | 104.38 | 29.65 |
| 1995-96 | 138.77 | 113.35 | 39.55 |
| 1996-97 | 143.08 | 111.55 | 22.06 |
| 1997-98 | 161.88 | 130.62 | 31.74 |
| 1998-99 | 167.98 | 136.24 | 31.45 |
| 1999-00 | 180.69 | 142.89 | 40.75 |
| 2000-01 | 167.02 | 147.07 | 20.91 |
| 2001-02 | 173.59 | 146.28 | 23.99 |
| 2002-03 | 160.94 | 144.65 | 17.57 |
| 2003-04 | 167.99 | 142.66 | 20.18 |
| 2004-05 | 183.99 | 154.03 | 27.52 |
| 2005-06 | 203.4 | 155.75 | 52.53 |
| 2006-07 | 216.51 | 160.95 | 60.8 |
| 2007-08 | 225.7 | 147.07 | 75.83 |
| 2008-09 | 249.09 | 143.34 | 101.51 |
| 2009-10 | 264.86 | 162.21 | 91.47 |
| 2010-11 | 281.22 | 163.78 | 123.63 |
| 2011-12 | 277.9 | 163.6 | 130.02 |
| 2012-13 | 255.36 | 157.35 | 86.98 |
| 2013-14 | 244.82 | 160.92 | 67.31 |
| 2014-15 | 255.76 | 162.69 | 91.35 |
| 2015-16 | 267.53 | 178.1 | 100.09 |
| 2016-17 | 259.49 | 179.49 | 78.35 |
| 2017-18 | 265.91 | 181.09 | 85.3 |
| 2018-19 | 273.75 | 179.38 | 104.97 |

Source: EPWRF time-series database.

Electricity plays a major role in Indian irrigation. As a consequence, extreme depletion of groundwater is a concern and has reached a tipping point (Tyagi & Joshi, 2019). Besides electricity, diesel pumps play a major role in the irrigation of Eastern India (Mukherji, 2020). Since coal plays a major role in electricity generation in India, climate change is yet another challenge (Zaveri et al., 2016). The existing subsidies for electricity to farmers aggravate the problem (Reforming Energy Subsidies, 2009). Electricity consumption subsidies stood at

INR 63,778 crore in FY 2019 though it is not for farmers alone (Garg et al., 2020). India is the largest user of groundwater in the world (Fishman et al., 2015) and most people rely on groundwater for drinking purposes (Chindarkar & Grafton, 2019).

**Table 7.13 displays the electricity consumed for agricultural purposes**

| Year | Electricity for Agricultural purposes in GWh | % share of agricultural consumption to Total consumption |
|---|---|---|
| 1982-83 | 17817 | 18.64 |
| 1983-84 | 18234 | 17.82 |
| 1984-85 | 20960 | 18.38 |
| 1985-86 | 23422 | 19.04 |
| 1986-87 | 29444 | 21.66 |
| 1987-88 | 35267 | 24.22 |
| 1988-89 | 38878 | 24.27 |
| 1989-90 | 44056 | 25.11 |
| 1990-91 | 50321 | 26.44 |
| 1991-92 | 58557 | 28.2 |
| 1992-93 | 63328 | 28.7 |
| 1993-94 | 70699 | 29.63 |
| 1994-95 | 79301 | 30.54 |
| 1995-96 | 85732 | 30.95 |
| 1996-97 | 84019 | 29.98 |
| 1997-98 | 91242 | 30.75 |
| 1998-99 | 97195 | 31.38 |
| 1999-00 | 90934 | 29.07 |
| 2000-01 | 84729 | 26.76 |
| 2001-02 | 81673 | 25.33 |
| 2002-03 | 84486 | 24.88 |
| 2003-04 | 87089 | 24.13 |
| 2004-05 | 88555.35 | 22.93 |
| 2005-06 | 90292 | 21.92 |
| 2006-07 | 99023 | 21.73 |
| 2007-08 | 104182 | 20.75 |
| 2008-09 | 107776.09 | 20.43 |
| 2009-10 | 119492 | 20.98 |
| 2010-11 | 126377 | 20.48 |
| 2011-12 | 140960 | 20.95 |

| | | |
|---|---|---|
| 2012-13 | 147462 | 20.8 |
| 2013-14 | 152744 | 20.31 |
| 2014-15 | 168913 | 20.74 |
| 2015-16 | 173185 | 20.06 |
| 2016-17 | 191151 | 20.91 |
| 2017-18 | 199247 | 20.47 |

Source: EPWRF database.

The data in the above table signifies the role of energy in food production. Moreover, 90 percent of the energy consumed for agricultural purposes is used for pumping water for irrigation (Barik et al., 2017). On average, 5% of the electricity is consumed by the fertiliser industry. The meagre 5 % left may justify the immature food processing industries because India currently processes less than 10% of its Agri output roughly around 2% of fruits and Vegetables, 6% of poultry, 21% of meat, 23% of marine, and 35% of milk (CII, 2019). Moreover, the Total energy consumption associated with water withdrawal as per the global average values is 0.48 and 0.37 KWh/m$^3$ for groundwater and surface water, respectively (Sadegh et al., 2020).

**Table 7.14 shows the source wise Net irrigated area in India**

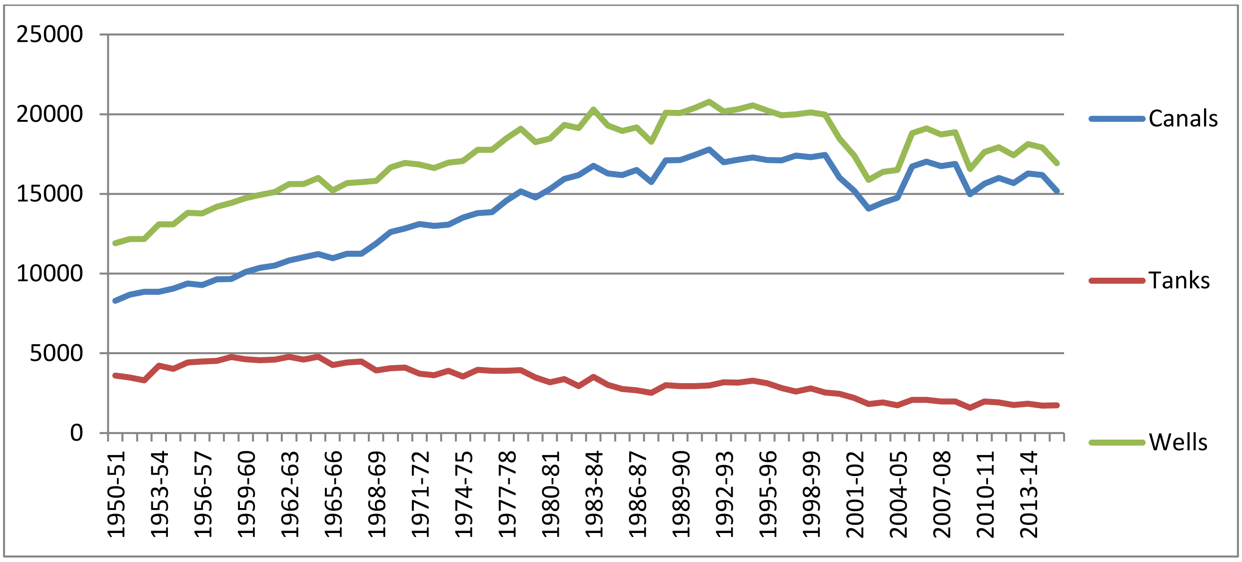
| Year | Total Net Irrigated Area in '000' Ha | Total Gross Irrigated Area in '000' Ha | Net Irrigated Area from Canals in '000' Ha | Net Irrigated Area from Tanks in '000' Ha | Net Irrigated Area from Wells in '000' Ha |
|---|---|---|---|---|---|
| 1950-51 | 20853 | 22563 | 8295 | 3613 | 5978 |
| 1951-52 | 21049 | 23180 | 8683 | 3489 | 6517 |
| 1952-53 | 21122 | 23305 | 8861 | 3303 | 6521 |
| 1953-54 | 21869 | 24363 | 8859 | 4228 | 6685 |
| 1954-55 | 22088 | 24948 | 9067 | 4025 | 6726 |
| 1955-56 | 22758 | 25642 | 9385 | 4423 | 6739 |
| 1956-57 | 22533 | 25707 | 9273 | 4492 | 6566 |
| 1957-58 | 23156 | 26628 | 9652 | 4536 | 6818 |
| 1958-59 | 23401 | 26948 | 9670 | 4759 | 6686 |
| 1959-60 | 24037 | 27454 | 10114 | 4631 | 7083 |
| 1960-61 | 24661 | 27980 | 10370 | 4561 | 7290 |
| 1961-62 | 24884.3 | 28460 | 10502 | 4612 | 7352 |
| 1962-63 | 25665 | 29453 | 10832 | 4781 | 7649 |
| 1963-64 | 25888.3 | 29707 | 11022 | 4599.2 | 7784 |
| 1964-65 | 26600 | 30705 | 11223 | 4780 | 8075.1 |
| 1965-66 | 26344 | 30901 | 10958 | 4258 | 8653.1 |
| 1966-67 | 26907 | 32683 | 11247 | 4424 | 9195.3 |
| 1967-68 | 27193 | 33207 | 11243 | 4493 | 9111.2 |
| 1968-69 | 29009 | 35483 | 11892 | 3926 | 10801 |
| 1969-70 | 30197 | 36974 | 12605 | 4059 | 11177.4 |
| 1970-71 | 31103.4 | 38195 | 12838 | 4112 | 11887 |
| 1971-72 | 31546 | 38430 | 13115 | 3734.1 | 12280.3 |

| | | | | | |
|---|---|---|---|---|---|
| 1972-73 | 31834.4 | 39055 | 12996 | 3619 | 12964 |
| 1973-74 | 32546 | 40283 | 13065 | 3900 | 13283 |
| 1974-75 | 33708.8 | 41741 | 13513.7 | 3544.3 | 14229.2 |
| 1975-76 | 34593 | 43363 | 13791.2 | 3972.2 | 14444 |
| 1976-77 | 35149.1 | 43552 | 13860.8 | 3901.3 | 15087.5 |
| 1977-78 | 36546 | 46080 | 14576 | 3904 | 15584 |
| 1978-79 | 38059 | 48307 | 15149 | 3937 | 16429 |
| 1979-80 | 38524 | 49214 | 14774 | 3481 | 17864.1 |
| 1980-81 | 38720 | 49775 | 15292 | 3182 | 17695 |
| 1981-82 | 40503 | 51412 | 15946 | 3376 | 18737 |
| 1982-83 | 40691 | 51830 | 16185 | 2936.3 | 19347 |
| 1983-84 | 41949 | 53824 | 16764 | 3533 | 19392 |
| 1984-85 | 42145 | 54529 | 16275 | 3021 | 20394 |
| 1985-86 | 41865 | 54283 | 16179.6 | 2765 | 20418.3 |
| 1986-87 | 42569 | 55759 | 16494.8 | 2677 | 20822.2 |
| 1987-88 | 42892 | 56036 | 15746 | 2523 | 21796 |
| 1988-89 | 46148 | 61125 | 17102 | 2996 | 23214 |
| 1989-90 | 46702 | 61852 | 17124 | 2941 | 23886 |
| 1990-91 | 48023 | 63204 | 17452.7 | 2944 | 24694.5 |
| 1991-92 | 49867 | 65680 | 17791.2 | 2991 | 26037 |
| 1992-93 | 50296 | 66761 | 16986 | 3179 | 26920 |
| 1993-94 | 51339 | 68254 | 17138 | 3170 | 27596 |
| 1994-95 | 52999 | 70646 | 17279 | 3276 | 28911 |
| 1995-96 | 53402 | 71352 | 17120 | 3118 | 29697 |
| 1996-97 | 55112 | 76026 | 17109 | 2821 | 31795 |
| 1997-98 | 55210 | 75670 | 17397 | 2597 | 32111 |
| 1998-99 | 57436 | 78670 | 17311 | 2795 | 34000 |
| 1999-00 | 57531 | 79216 | 17440 | 2539 | 34639 |
| 2000-01 | 55205 | 76187 | 16012 | 2466 | 33818 |
| 2001-02 | 56936 | 78371 | 15202 | 2196 | 35197 |
| 2002-03 | 53897 | 73055 | 14073 | 1811 | 34354 |
| 2003-04 | 57057 | 78042 | 14458 | 1916 | 36384 |
| 2004-05 | 59229 | 81078 | 14766 | 1734 | 35191 |
| 2005-06 | 60836.8 | - | 16717.52 | 2083.1 | 36069.79 |
| 2006-07 | 62743.44 | - | 17026.62 | 2078.19 | 37639.86 |
| 2007-08 | 63188.58 | - | 16748.11 | 1973.16 | 38360.32 |
| 2008-09 | 63637.38 | - | 16881.38 | 1980.55 | 38755.44 |
| 2009-10 | 61944.55 | - | 14974.72 | 1585.42 | 38360.4 |
| 2010-11 | 63665.42 | - | 15645.76 | 1978.61 | 39171.68 |
| 2011-12 | 65707.16 | - | 16008.23 | 1916.87 | 40537.06 |
| 2012-13 | 66286.96 | - | 15677.18 | 1751.49 | 41305.5 |
| 2013-14 | 68117.07 | - | 16283.09 | 1841.51 | 42439.36 |
| 2014-15 | 68383.57 | - | 16183.6 | 1723.2 | 42959.87 |
| 2015-16 | 67300.29 | - | 15178.17 | 1735.85 | 43117.27 |

Source: EPWRF time-series database.

The extent of the groundwater problem cannot be ascertained based on the Net Irrigated Area but can be better understood through Gross Irrigated Area. Tanks play a major role in the Southern part of India. However, they too served little as time passed. Several states have also made attempts to restore them (Kumar & Vedantam, 2016; Reddy et al., 2018).

**Figure 7.3** shows the source-wise Net Irrigated Area in India




The scatter plot Depicts that the Net irrigated area from wells is the largest across all the periods concerned. The subsidised or free electricity is not the only reason for the overexploitation of groundwater. Groundwater is excessively used due to an increase in productivity and a sense of ownership (Kumar, 2005). The public trust doctrine is embodied for surface water but not for groundwater (Ramana, 2009).

### 7.5 Food-Energy link

The Food-Energy link establishes the role of biofuels in the WEF nexus. In 2008, 40 percent of the maize produced was converted into biofuels (OECD, 2014) causing a rise in food prices at least to the extent of 30 % (Clapp, 2009) across the world and leading to a debate called the 'perfect storm' (Rosegrant, 2008). Bioenergy is a renewable energy source derived from biological sources. Bioenergy is an important source of energy, which can be used for transport using biodiesel, electricity generation, cooking, and heating. Electricity from bioenergy attracts a large range of different sources, including forest by-products such as wood residues; agricultural residues such as sugar cane waste; and animal husbandry residue such as cow dung. One advantage of biomass energy-based electricity is that fuel is often a by-product, residue, or waste product from the above sources (Owusu & Asumadu-Sarkodie, 2016). Succinctly put, Biofuels (biodiesel and bioethanol) can be obtained from a variety of crops, including food crops (first-generation biofuels), cellulose-rich crop residues (second generation), and algae (third generation). First-generation biofuels have a higher water footprint than fossil fuels. Thus, they compete with the food system directly (as food) and indirectly (through water) (D'Odorico et al., 2018). Despite these benefits, biofuels are not without tradeoffs. For instance, biofuel production uses 2-3% of the water and land available for agriculture which could potentially feed 30% of the malnourished people in the world (Moioli et al., 2018).

**Table 7.15 provides a glance at the biofuels sector in India from 2011 through 2020 (provisional)**

| Year | Ethanol in Million Litres | | | | Biodiesel in Million Litres | | | |
|---|---|---|---|---|---|---|---|---|
| | P | C | N | E | P | C | N | E |
| 2011 | 1681 | 1715 | 61 | 119 | 111 | 113 | 0 | 0 |
| 2012 | 2154 | 1955 | 5 | 177 | 126 | 125 | 0 | 0 |
| 2013 | 2057 | 1932 | 108 | 233 | 132 | 128 | 0.3 | 3.9 |
| 2014 | 2002 | 2000 | 193 | 180 | 138 | 102 | 1.7 | 41.5 |
| 2015 | 2292 | 2345 | 204 | 165 | 152 | 118 | 0.8 | 33.1 |
| 2016 | 2061 | 2290 | 432 | 136 | 158 | 119 | 2.7 | 41.7 |
| 2017 | 1671 | 2230 | 722 | 141 | 170 | 165 | 7.1 | 7.6 |
| 2018 | 2693 | 3120 | 607 | 129 | 185 | 180 | 25.2 | 23.1 |
| 2019 | 2552 | 3370 | 704 | 50 | 230 | 185 | 7 | 54 |
| 2020 | 2976 | 3620 | 870 | 40 | 225 | 180 | 2 | 58 |

Source: (USDA, 2020). Where P, C, N, and E stands for Production, Consumption, Imports, and Exports respectively and the data about 2020 are forecasted values.

The GoI has set an ambitious target of reducing 10 % crude oil imports by 2022. In this vein, the National Policy of Biofuels was formed in 2018. The main objectives are to increase the biodiesel blending percentage in diesel to 5 % by 2030 and the ethanol blending percentage in petrol to 10 % by 2022 and further to 20 % by 2030. However, the ethanol blending percentage has been dismal until now with only 3.5 % blended in 2015-16 and 2.07 % in 2016-17 (Das, 2020).

**Table 7.16 Depicts the WEF nexus aspects of the Indian biofuels for the year 2013**

| Year | Source | Consumption in $10^3$TJ/year | Water for biofuel in $10^6 m^3$/year | Area cultivated for biofuels in $10^3$Ha | People who could be fed in $10^6$ |
|---|---|---|---|---|---|
| 2013 | Bioethanol | 9 | 1097.4 | 60.7 | 1 |
| 2013 | Biodiesel | 1.9 | 198.3 | 40 | 0.4 |

Source: (Rulli et al., 2016). TJ stands for TeraJoules.

Having touched on all potential conflicts i.e. tradeoffs in the WEF nexus and the respective response options i.e. synergies, the last we would like to account for is the problem of Food Waste. Anaerobic digestion (AD) is the synergy in the WEF nexus often mooted by research arising from the food-energy link (Falconer et al., 2020). AD can be performed with wastewater, crop residue, municipal solid waste, industrial waste, and animal waste as feedstocks. The latter two are beyond the scope of this paper. India annually generates 62 MMT of municipal solid waste (USDA, 2020). The methane generation from the organic fraction is about 100 $m^3$/ton (Thomas et al., 2017) and on average, the organic fraction in Indian municipal solid waste is 42.19% and biogas can be generated at the rate of 95 $m^3$/ton of solid waste (Rao et al., 2010). Coming to crop residue, on top of using it for animal feed, direct use as fuel, or organic fertiliser, the surplus fraction of crop residue itself is estimated to contribute to an energy potential of approximately 41,50,000 TJ/year (Hiloidhari et al., 2014). In toto, as of 2018, the total biogas production in India stands at 2.07 billion $m^3$/year. This is quite low compared to its potential, which is estimated to be in the range of 29–48 billion m3/ year (Mittal et al., 2018).

**Summary and Conclusion**

The Allocation of the resources in the above discussion is followed by access to the WEF nexus in India. In India, 660 million people do not have access to clean cooking fuels, nearly 2 lakh Indians die each year from a lack of access to safe drinking water, 40 percent of Indians do not have an improved drinking water source available, only less than 10 percent of people do not have electricity access but for those who have access, reliability is still a question (IEA, 2021). India is ranked 102 of 117 countries in the Global Hunger Index 2019 (IFPRI, 2019). As of 2016, over 190 million people were reported undernourished and the percentage of children who are stunted and wasted is 33 and 20 percent respectively (George & McKay, 2019). Coming to Clean Cooking fuels, The Pradhan Mantri Ujjwala Yojana is an energy welfare program launched in May 2016 by the Ministry of Petroleum and Natural Gas. Under this scheme, the Below Poverty Line (BPL) families are provided with free Liquefied Petroleum Gas (LPG) connections in the women's name of the household. Absence of which rural households used to increasingly rely on traditional biomass cooking sources such as firewood, crop residue, coal, and coke. Switching to clean cooking fuels reduce direct emissions, reduce deforestation, improve biodiversity, and contribute to women empowerment. Often these burdens fall disproportionately on the female gender (Mehra & Bhattacharya, 2019). This scheme not only provides clean cooking fuel but intends to curb the ill effects of traditional biomass cooking fuels on the masses. The above-mentioned two schemes have challenges. One is gender issues involved within the household level (Spears, 2019). Despite the Access provided, Adoption and use of the same are still far from distant. The reasons include affordability of refills, cultural or behavioural beliefs, and issues with supply chain and access. Furthermore, beneficiaries are unable to gauge when their LPG cylinder is close to being empty. As a result, they are not able to make financial plans for their next purchase. Similarly, the expansion of distribution infrastructure has also been slow compared with the increasing consumer base, thus becoming another hurdle in the smooth delivery of services (Palit et al., 2020). In short, the main problem is affordability, and this is evident from the people’s refilling capacity (Gould & Urpelainen, 2018). The adoption of LPG fuel for cooking is also attributed to social spillovers and need not be restricted to socio-economic factors (Srinivasan & Carattini, 2020). Even in the case of allocation also the existing subsidies in the promotion of micro irrigation systems and the integration of renewable energy into irrigation severely question the sustainability from the economic dimension and the role of community in the environmental management.

# CHAPTER 8

## Access to the Food-Water-Energy Nexus: Human Rights-based approach for India

Water, Energy, and Food are essential for human sustenance. Access to the WEF nexus is contingent upon availability and affordability, which in turn are affected by several factors such as geopolitics, climate change, population dynamics, poverty, etc. This chapter treats access in the WEF nexus as a 'trio' of possessing goods and services. Further, we restricted the meaning of access to WEF nexus as 'basic needs' because we place access to WEF nexus as quintessential to the survival of human beings. This study uses the 'Respect, Protect and Fulfill' (RPF) framework to analyse the WEF nexus security in India. Analysing the developments in the space of rights-based approach to water, energy, and food hitherto in India along with the challenges to achieving WEF nexus and the challenges it poses; we suggest that the positive protection of these rights and the robust legal systems and instruments are vital for promoting the sustainable development and meeting the minimum requirements of the people. Since investment also seems necessary for providing access to the WEF nexus, the Government is expected to be a facilitator, promoter, and regulator in the case of collaborative management of the nexus because privatisation may infringe the rights to the WEF nexus through either greater resource scarcities or price pressures or negative externalities.

### 8.1 Background against which rights are important to WEF nexus

Although researchers agree broadly on the importance of incorporating the concept of WEF nexus into policy strategies and decision-making, the assessment system for how governance methods can improve the provision of these three essential services is relatively blank (Yuan et al., 2021). Despite there being many studies that lay importance to the affordability dimension of the WEF security aspects, this particular study ignored it. For the WEF system to be sustainable, it must be able to provide Availability, Accessibility, and Utilisation (AAU) of energy, water, and food for human well-being, whilst at the same time safeguarding the extent and diversity of the planet's ecosystem in space and time. Broadly this requires sustainable and efficient resource use and fairness in the distribution of benefits and costs in the economic and social balance (Irabien & Darton, 2016). This study also ignores the affordability dimension of security. Food, energy, and water are at the top of Maslow's needs hierarchy. But, there are inequalities in accessing them. For example, as of 2012, average household expenditures spent on food in India are 35.4%, whereas it is just 6.2% in the case of the US. Moreover, given these ratios, US households consume double the amount of food (in terms of Kilocalories) per capita than the Indians do (Rogers & Daines, 2014). Household income is a significant driver impacting per capita WEF consumption because it reflects the probability of affordability and accessibility (Abulibdeh & Zaidan, 2020). In India with a deficient cash reserve, the communities are incapable of fulfilling the demand for energy and safe drinking water (Katekar et al., 2020). It has been demonstrated that limited attention is given to the local level where communities, households, institutions, and small businesses face substantive challenges in simultaneously meeting water, energy, and food needs (Terrapon-Pfaff et al., 2018). A few researchers addressed this issue through the energy justice lens (Olawuyi, 2020), precarious consumption patterns (Mguni et al., 2020), and the growing inequalities between peripheries and the core of cities (Giatti et al., 2019). From a purely human perspective, a certain minimum threshold to meet basic human needs may be defined as basic human security. Security is a dynamic concept that is dependent on changing ecosystems, human perceptions, political economy, and regional trade (Sood et al., 2019). In current policy debates, the idea to foster nexus implementation primarily via a national planning approach (that is, top-down) seems popular. However, to what extent this is feasible in developing countries is an open question (Never, 2016). According to Global Water Partnership (GWP), Effective adoption of the Nexus approach is also a promising instrument for promoting social cross-cutting issues, such as gender empowerment, stakeholder engagement, human rights, and combatting poverty, by safeguarding the rights of socially and economically vulnerable groups. These groups are affected the most by resource insecurity, as they depend on the most -and spend the largest share of their income- on basic needs in the form of water, food, and energy (https://www.gwp.org/en/GWP-Mediterranean/WE-ACT/Programmes-per-theme/Water-Food-Energy-Nexus/ ).

### 8.2 Respect, Protect, and Fulfill framework

The study employs the well-known and widely used 'Respect, Protect, and Fulfill' (RPF) framework of Human Rights (Richards, 2012). Respect means 'refraining from interfering with the enjoyment not 'suffering' of the right'. Protect means 'enacting laws that create mechanisms to prevent rights violations/encroachment by second/third parties' and Fulfill means 'to take active steps to put in place institutions, budgetary, judicial, and procedure to both respect and protect thereby causing the progressive realisation of the rights'. These three are the core obligations of the state in the arena of Human Rights discourse (Rubenstein, 2004). These are to be promoted as indivisible and complement each other for the effective realisation of the rights. The potential strength of the RPF framework is it could resolve the 'positive/negative' dichotomy of rights and ground them in uniformity (Koch, 2005). We agree such positive protection leads to resource-intense policies or programs but it is where we integrate the element of 'Distributive Justice' through equitable access (Rawls, J., 1971). Our argument also lies within the ambit of minimum requirements. Given the inequalities between Urban and Rural; Wealthy and Poorer; and the social inequalities based on caste and gender to provision (by the self or by the state) in the access to WEF nexus, we propose a rights-based approach for the WEF nexus. Furthermore, Human rights work with principles such as participation and inclusion, non-discrimination and equality, and accountability (Broberg & Sano, 2018).

In India, all three rights are recognised by the apex court/High courts already but with negative protection. The executive through (policies, schemes, and programs) are already underway long ago for people to make access to WEF nexus. Hence, there is also no problem of overlapping powers (Waldron, 2013). Coming to the materials used in the study are the analysis of the various judgements of the Indian courts that fall in the WEF resources either independently or/and integrated. Moreover, this chapter sets out the discussion of the existing policies and the programs of the Indian government in providing access to the WEF nexus within the context of SDGs.

### 8.3 Right to Food

Food Security refers to a situation when 'all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for active and healthy life (FAO, 1996). India is ranked 102 of 117 countries in the Global Hunger Index 2019 (IFPRI, 2019). As of 2016, over 190 million people were reported undernourished and the percentage of children who are stunted and wasted is 33 and 20 percent respectively (George & McKay, 2019).

Internationally, The Right to Food is recognised by the following bodies. Universal Declaration of Human Rights (UDHR) provides under Article 25 clause (1) that, everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food, clothing, housing, and medical care and necessary social services and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control (UNHCR, 2008). The International Covenant on Economic, Social, and Cultural Rights (ICESCR) recognizes under Article 11 paragraph (2), the right of everyone to be free from hunger as a fundamental right. The article also provides measures to be adopted individually or collectively by States to achieve the above-mentioned objective. Article 12 of the Convention on the Elimination of all Forms of Discrimination against Women (CEDAW) provides the right of pregnant and lactating women to special protection concerning adequate nutrition. Article 14 of the same convention incorporates the right of rural women to equal access to land, water, credit and other services, social security, and adequate living conditions (Menon & Dixit, 2014).

Coming to the Indian context, The Right to Food is recognised as an entailment of the broader version called 'Right to Life'. The Constitution of India has secured its citizen's right to life as a fundamental right under the provisions of Article 21. The Supreme Court of India is the watchdog of the constitution. Thus, it is vested with many legal instruments to interfere in matters where the abrogation/infringement/encroachment of the rights occurs. The Supreme Court of India has envisaged the Right to Food in delivering the following Judgements - Chameli Singh v. State of Uttar Pradesh (1996)[1], Shantistar Builders v. Narayan Khimala Totame and Ors (1990)[2], Olga Tellis and Ors v. Bombay Municipal Corporation, and Ors (1985)[3], Samatha v. State of Andhra Pradesh (1997)[4] and the most prominent one People's Union for Civil Liberties v. Union of India and Ors (2001)[5]. The mere recognition of the Right to Food is not sufficient for an effective outcome. For this to happen, the networked governance helping the implementation, compliance, and enforcement of the rights is essential (Chitalkar & Gauri, 2017). 'Right to Food campaign' is one such important organ in the network governance for food security in India. It has succeeded in radical legal claim-making but could not attain greater social mobilisation at the grass-root level because of its emphasis being on *respect* rather than to *protect* and the lack of diverse thinking within it (Hertel, 2015). The Right to Food is entailed in the broad umbrella Right called 'Right to Life'. The discussion so far rested on the Human Rights or Fundamental Rights perspectives. Besides these, the strengthening of social rights is also of paramount importance. In India

[1] AIR 1996 SC 1051 https://indiankanoon.org/doc/64823282/ Accessed on 31 May 2020
[2] AIR 1990 SC 630 https://indiankanoon.org/doc/1813295/ Accessed on 04 June 2020
[3] 1986 AIR 180https://indiankanoon.org/doc/709776/ Accessed on 05 June 2020
[4] AIR 1997 SC 3297 https://www.escr-net.org/caselaw/2020/samatha-vs-state-ap-and-ors-air-1997-sc-3297-jt-1997-6-sc-449-1997-4-scale- 746 Accessed on 07 June 2020
[5] WRIT PETITION (CIVIL ) No. 196/2001 https://indiankanoon.org/doc/411836/ Accessed on 07 June 2020

typically there is a social construction of issues related to food, particularly meat. Coming to the Obligation, The state intervention to ensure Food Security is better understood through Public Distribution System (PDS) and the National Food Security Act (NFSA) 2013. These are the two major steps taken to reduce food insecurity (Pillay & Kumar, 2018). The NFSA confers the Right to Food on the people of India. However, both have their barriers and limitations. As far as PDS or Targeted PDS is considered methodological inadequacies in the compilation of Below Poverty Line (BPL), lack of purchasing power for certain items (sugar and kerosene), lack of capacity to adequately store the agricultural products, lack of trained staff, and equipment and the diversion of commodities (Banik, 2016). Returning to NFSA-the cost of implementation is deeply debated, Incongruence of preferences between federal governments, neglect of nutritional security, and the negative impact on farm incomes (Banik, 2016).

### 8.4 Right to Water

Water is essential for human existence and also for other species. Goal 6 of the SDGs is 'universal and equitable access to safe and affordable drinking water for all humans by 2030 (Malagó et al., 2021). In India, nearly 820 million people are facing high to extreme water stress situations. Annually two lakh deaths are due to inadequate water, sanitation, and hygiene. 70 percent of its water is contaminated. As of 2018, India is ranked 120 among 122 countries on the water quality index. (75 percent of households do not have drinking water on-premise. 84 percent of rural households do not have piped water access NITI AAYOG (GoI), 2019). Water stress is understood as when annual per capita water availability is less than $1700m^3$ (Falkenmark, 1989).

On 28 July 2010, United Nations General Assembly (UNGA), followed by (30 September 2010) Human Rights Council (HRC) recognised "the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of the right to life and all human rights (Obani & Gupta, 2014). Before the 2010 UNGA and HRC, the human right to water at the international echelon is recognised by the International Covenant on Economic, Social and Cultural Rights (ICESCR) 1976, Article 14(2) (h) of the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) 1981, and Article 24(2) (c) of the Convention on the Rights of the Child (CRC) 1990 (Chowdhury et al., 2011). Acknowledging 'The Human Right to Water' to sufficient water and appropriate quality to meet basic needs has the advantage of realising the obligations of local communities, local governments, and the national governments (Gleick, 2003).

Briefly looking at the governance of water and its treatment under the constitution of India revealed that it is an ancient civilisation and had been ruled by several dynasties including colonial rule. Many colonial acts have not yet been superseded and the basic structure of common law rights linking water rights and land rights has not yet been comprehensively reworked (Cullet & Gupta, 2009), however, the changes are underway (Cullet, 2018). The public trust doctrine is embodied for surface water but not for groundwater. The interest in water law and policy formulation can be ascribed to increasing water scarcity, increasing water pollution, competition among users for a finite resource, progressively changing economic policies at the national and international levels, and new water policy priorities at the international level (Ahmed & Araral, 2019). The constitution of India vests the power over the administration of water in the State Government. Schedule 7 of the constitution provides for the division of administrative provisions into three lists namely- List I (Union List), List II (State List), and List III (Concurrent List). Accordingly, Entry 24, 25, 56, and 57 of List I read as Shipping and navigation on national waterways, Maritime shipping and navigation, Regulation and development of interstate rivers and river valleys, and Fishing and fisheries beyond territorial waters respectively are dealt with by the Government of India (GoI). Besides these, Article 262 also empowers the GoI to adjudicate disputes relating to waters of inter-state rivers or river valleys. Whereas Entry 17 and 21 of List II read as Water, that is water supplies, irrigation and canals, drainage and embankments, water storage and water power, and Fisheries respectively are dealt with by the state government. Generally, only where water resources are sustainably protected and water infrastructure is adequately financed, and operating in a thrifty and efficient manner is possible to ensure a Right to Water for all in the long term. But, it is in the realm of water management as a whole in principle and is fundamentally different from Human Right to Water. The human right to Water lies in the Social Sphere which involves trade-offs with and within the principles of economic efficiency, ecological sustainability, and refinancing objectives (Gawel & Bretschneider, 2017).

Returning to the Recognition of Human Right to Water in the Indian context, The Supreme Court of India and various High Courts of States, in their several judgments implied that the Fundamental Right to Water is implied and derived from the ‘Right to Life’ which is guaranteed by the constitution and is existed in all the civilised societies and nations. Article 21 of the constitution read: No person shall be deprived of his life or personal liberty except according to procedure established by law. The Specification and obligations of the Right to Drinking Water are as follows, In Lucknow Grih Swami Parishad v. State of U.P. and Ors (2000)[6] the High Court of Allahabad ruled that 'it is the bounden duty of the State to assure the supply of the sufficient amount of qualitative drinking water to its people. The sufficient amount of water for domestic use is generally understood as 50 or 55 litres per capita a day (lpcd). Similarly in Vishala Kochi Kudivella samrakshana Samiti v. State of Kerala (2006)[7], the Kerala High Court specifically provided that the government 'is bound to provide drinking water to the public and that this should be the foremost duty of the government. Additionally, the judges ruled that the failure of the State to 'provide safe drinking water to citizens amounted to a violation of Article 21 of the Constitution' (Cullet, 2010). In Prof. M.V. Nayudu (Retd) and Ors v. A.P. Pollution Control Board (1999),[8] the Supreme Court of India asserted that the Right to drinking water is a fundamental right of the people (Ramachandraiah, 2001).

With the changing nature of the Judiciary in the post-liberalisation era (Bhushan, 2004) the water quality in the courtrooms in India is yet another concern. Water quality is a key component in the WEF nexus (Heal et al., 2020) and also received very scant attention (Varis & Keskinen, 2018). Hamid Khan v. State of Madhya Pradesh and Ors (1996)[9] was the crucial verdict related to drinking water quality. The case was filed against the gross negligence of the Government for not making "safe" drinking water provisions for citizens, which was detrimental to public health. The hand pump sunk by government agencies for drinking water supply had excessive fluoride content in the water, which caused serious health implications, such as skeletal fluorosis and dental fluorosis to thousands of people. However, the court concluded based on Articles 47 and 21 of the Indian Constitution that the State has a duty "towards every citizen of India to provide pure drinking water." (A. Sharma, 2017). On the whole, the drinking water-related case law in India is vast in scope but has not contributed to the development of any fully-fledged body of principles in this area. This is unfortunate in the context of something as basic as drinking water, given that the courts have not hesitated to

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[6] 2000 (3) AWC 2139 https://indiankanoon.org/doc/272751/ Accessed 07 June 2020
[7] 2006 (1) KLT 919 https://indiankanoon.org/doc/665405/ Accessed 08 June 2020
[8] Appeal (civil) 368-371 of 1999 https://indiankanoon.org/doc/1543623/ Accessed 09 June 2020
[9]AIR 1997 MP 191 https://indiankanoon.org/doc/1955514/ Accessed 10 June 2020

enter the policy arena in various contexts where the government or the legislature has failed to take the initiative. It is particularly noteworthy because of the absence of a framework piece of drinking water legislation (Cullet, 2010). This problem is also not new for India alone but instead to the whole world (Cullet, 2011). It has not received adequate attention in the global discussions on water quality (Tortajada & Biswas, 2017). Furthermore, reliable and representative water quality data are not available in the vast majority of countries of the world. Globally, at least four billion people do not have access to water that is safe to drink, or that is perceived as not safe to drink without point-of-use treatment systems (Biswas & Tortajada, 2019). The current indicators available globally are heavily dependent upon the 'Improved water sources' in assessing access to water. Improved water source does not necessarily translate into safe water because they can present inadequate microbial quality and contain toxic chemicals and these are emerging on a time-to-time basis (Martínez-Santos, 2017). Water quality is an attribute of water quantity (Haie, 2016).

Until 2006, existing water laws (based on the principle of Decentralisation and participation; regulatory instruments) largely fail to operationalize the human right to water and fail to effectively address social challenges in the water sector. Proposed water sector reforms spearheaded by the international community, The World Bank as well as Governments at the center and state levels are not effectively addressing these challenges. They are likely to contribute to increasing inequalities in access to and control over water (Cullet, 2006). Further, the three versions of the National Water Policy (i.e. 1987, 2002, and 2012) have failed to make any perceptible difference in the water management in India and all three were just 'feel good' documents and nothing more. Despite it ensuring the participation from broad stakeholders, such participation merely served as a necessary but not a sufficient condition. The reasons cited are river basin is not used as a unit of management, superfluous words and non-specific suggestions, the phrase 'Should be' should be banned, and the phrase 'Needs to be' needs to be dropped. What needs to be done and can be done must be emphatically stated (Pandit & Biswas, 2019).

Despite the above discussion on the lack of a proper legislative framework, India has made progress through various programs and schemes of the Government i.e. through the executive wing. After the announcement of the Sustainable Development Agenda in 2015, The Indian Government took a plethora of initiatives related to SDG 6. These include the Water Framework Law of India 2016, National Rural Drinking Water Programme (NRDWP), Accelerated Urban Water Supply Programme (AUWSP), Namame-Gange, and National Water Policy (Ahmed & Araral, 2019).

### 8.5 Right to Energy

Energy Economics Community for decades has ignored energy poverty. Meeting basic human needs, such as food and shelter, must be at the heart of any strategy to alleviate poverty. Modern energy services help enable those needs to be met. In practice, concrete improvements in human welfare can be realised quickly at a modest short-term cost. Strong political will and commitment on the part of the governments of the world's poorest countries will be crucial (Birol, 2007). In this paper, we restrict Energy poverty to the definition outlined by the International Energy Agency (IEA) in its World Energy Outlook 2010 as a lack of household access to electricity and clean cooking facilities (IEA, 2010). By 2018, India has 64 million people who do not have access to electricity making it the third-largest electricity access deficit country in the world (IEA et al., 2020).

India is Energy insecure and Energy Dependent country. Its energy consumption needs are mainly met through oil imports over 80 percent of consumption. Furthermore, Geopolitics and relations with neighbour countries has also an impact on the energy security of the Nation (Maj Gen A K Chaturvedi, 2013) and require strong domestic measures and friendly foreign policy (A. Sharma, 2019). Currently, increased debates linking energy production and use with climate change throws several challenges before India. The International Renewable Energy Agency (IRENA) has taken the centre stage in determining the energy mix of a country. She cannot move ahead with the earlier energy mix.

SDG 7 states that Ensure access to affordable, reliable, sustainable, and modern energy. Recognition of the ‘Right to Electricity’ unlike Food and Water is understudied and under-recognised in India. In 2013, Justice S Manikumar (Madras High Court) in an erudite judgment ruled that lack of electricity affects education and health and is a cause of the economic disparity, and consequently, inequality in society leading to poverty. In directing the Tamil Nadu Electricity Board to provide power to 180 families of launderers, the court held that access to electricity should be construed as a human right (Agarwal, 2018). “Denial of it,” said Justice Manikumar, “would amount to a violation of human rights.” Similarly, in

Madan Lal and Ors v. State Of Himachal Pradesh and Ors (2018)[10], the Division Bench of the High Court of Himachal Pradesh held that 'Potable water or Electricity is an integral part of Right to Life and within the meaning of Article 21 of the Constitution. These are necessities for human beings and can well be termed as essentials of human rights' (S. Sharma, 2018). The judicial activism of the Supreme Court of India in Chameli Singh v. State of Uttar Pradesh (1995) caused recognition of 'Right to Electricity' as a fundamental right under the 'right to life and liberty as specified in Article 21 of the constitution.

Rural electrification is important for rural development as energy security is for the economy. But, there exist inequalities in the access to electricity in the villages based on economic and social factors. (Dugoua et al., 2017) find that number of upper caste households in a village is a sufficient predictor of electricity access than the number of lower caste households. Wealthier villages have better access to electricity compared to the poor villages (based on the average expenditure). Within the same village i.e. comparisons among households indicate that lower caste households are about 15 percentage points less likely to have an electricity connection than upper caste households. Besides these, there are differences between access to electricity in Rural and Urban areas also (Urpelainen, 2014).

**Summary and Conclusion**

Water, Energy, and Food form the essentials for the survival of the human race. Often the nexus implementation is thought of from a top-down approach. Such a centralised view may lead to the under-representation of local scales – household or individual scales. However, it is at these scales most resource insecurity is experienced. Governance seen as an outcome tends to require fairness in distribution, broader stakeholder participation, and inclusive, alleviating of poverty. Yet procedural justice also plays a key role in determining the outcome. The above description makes it clear that the Indian Judicial system has already recognised the three rights in its verdicts. Moreover, the executive policy in India has also recognised the importance of providing access to WEF nexus through their priority method allocation of resources. For instance, the first National Water Policy (NWP 1987) took the priority route in the allocation of water resources namely- Drinking water, irrigation, hydropower, navigation, and industrial and other uses. In its Second NWP (2002) the order was Drinking water, irrigation, hydropower, ecological needs, Industry, and navigation. In its

[10] Cr. MMO No. 403 of 2018 https://indiankanoon.org/doc/192600945/ Accessed on 11 June 2020

third NWP (2012) it stated that Safe Water for drinking and sanitation should be considered as pre-emptive needs, followed by high priority allocation for other basic domestic needs (including needs of animals), achieving food security, supporting sustenance agriculture, and minimum eco-system needs. Available water, after meeting the above needs, should be allocated in a manner to promotes its conservation and efficient use (Pandit & Biswas, 2019). Despite these efforts, the lacking figures show a daunting picture. On top of this, the second priority i.e. irrigation consumes 80 percent of available water resources. The political clout retained by farmers refrains the state from taking sustainable measures towards it (Hanumankar, 2015). We advocate for human rights, since as a process contributes to the better devolution of powers into the hands of common people and places greater obligations and accountability on the state. Moreover, as a process, it can able to tackle the inequalities between Urban and Rural; Wealthy and Poorer; and the social inequalities based on caste and gender concerning the provision of access to WEF nexus better. Though this paper suggests a right-based approach to ensure access to WEF nexus, the clear prescription would be that WEF nexus rights are to be provided as a ‘triplet’ of rights. The interconnections between these resources are emphasised so far from the production point of view. But from the consumption point of view, we cannot conclude that having access to one of the resources translates into having access to the WEF nexus. It is the contention that distinguishes the access literature on interconnected resources. This drawing is based upon the integrative nature of the WEF nexus. Hence, the three rights are to be provided as a bundle as they are basic needs with positive protection.

# CHAPTER 9

## Conclusion and Policy Implications

This short chapter draws heavily from the analysis of the previous chapters. For policy design and implementation to be effective, decision-makers need to consider all three sectors. In other words, effective engagement of the stakeholders from three sectors and at all levels is necessary. Following the principles of good governance serves as an enabler to bringing forward all the stakeholders. Social dimensions need to be effectively incorporated. Technological solutions intended to reduce trade-offs and reap the synergies has to be integrated with the other important elements of the WEF nexus such as the markets, prices, property rights, and equity. Climate change appears to be a critical factor in driving the WEF nexus as a response strategy to the many problems that humanity faces today. In a nutshell, the above description is given in the form of the following sections.

### 9.1 Conclusion

- The issues of access to and allocation of natural resources are becoming central development discourses in a world with growing inequalities within and across national borders. Multiple tradeoffs and synergies are the results of governing resources for socio-economic development along with the conservation of the environment. The synergies of conservation policies has to weigh against the trade-offs with ownership and livelihoods. Consideration of all stakeholders dependent on these resources is a promising approach for making decisions without affecting any section of society. Legitimate and transparent democratic processes can promote effective public participation in decision and policy making for ensuring justice in the allocation of resources. However, the quality of participation and inclusiveness in policy and decision-making in environmental governance require interrogation of the role of agency, the modes of power in which agency acts; and understanding how agency acquires the power. The agency plays an important role in every phase of the policy cycle (decision-making, agenda-setting, problem definition, policy design, policy implementation, policy enforcement, and policy evaluation), which has a direct impact on the allocation of and access to resources. The resources are conceived either in silos or integrated.

- The integrated governance of the WEF system allows allocating the scarce resource among multiple uses and users i.e. intra and inter-sectoral demands (Weitz et al., 2017).

However, in developing countries (and many developed countries), there is a lack of coordination in policy aspects related to the WEF nexus perspective. The establishment of legitimacy (participation, accountability, transparency) in the governance of the WEF system is crucial for equitable allocation and access. The inclusion of all stakeholders with the representation of rights in the decision-making regarding WEF at all scales of governance in general and local governance, in particular, can solve the potential tradeoffs and manage the synergies. Since water, energy, and food are interconnected and interdependent, it is desired that policy coordination is in place rather than governing them in silos i.e. ministries, bureaucracies and all the actors acting upon the policy planning, regulation, consumption, and production of individual resource would share a common platform in governing these three resources in an integrated manner.

- The synergies highlighted in the WEF nexus so far by the literature are more technocratic in nature. This study analyses the synergies arising out of WUAs from an institutional perspective and hints at one of the opportunities for the sustainable management of the WEF nexus at a decentralised level. Although reforms were implemented in Andhra Pradesh, the increase in GIA from the wells (i.e. with a concomitant increase in electricity consumption) is worth mentioning to address the coordination and the other is financial returns did improve). To tackle the groundwater over-abstraction in Andhra Pradesh APWALTA act has been designed. Even if technology is to be deployed, institutions matter. The applied Multi-level perspective framework to the analysis of the WUAs in Andhra Pradesh suggests the importance of policy coordination for the effective governance of the WEF nexus and the sustainable management of the WEF resources. The policy coherence among the fragmented sources of a single resource along with the policy coordination among all the resources in the WEF system namely- water, energy, and food are essential for decision-making to mitigate the trade-offs and tapping the synergies. For a sustainable transition to be successful, integration would emerge from all three levels in MLP. Succinctly put, niche level coordination, regime-sub regime, regime-regime, and landscape integration are key for a sustainable transition process to be effective as well. Unfortunately, Andhra Pradesh state does not have electricity prices for farmers. Thus this paper suggests that integrated governance and institutions play an equivalent role as the technocratic management does in the WEF nexus. A wide range of actors across many levels in the three resources adds complexity to the integration. The tradeoffs emphasised and the solutions suggested demand a framework that sought to better embrace the actors, aspects, and levels of governance. In this vein, it is suggested that the integration of the existing Institutional Analysis and Development (IAD) Framework along with the Multi-Level Perspective (MLP) enhances the mapping of actors, understanding the nodes and edges in a network, and subsequently making decisions regarding sustainability transitions.

- Water, Energy, and Food form the essentials for the survival of the human race. Often the nexus implementation is thought of from a top-down approach. Such a centralised view may lead to the under-representation of local scales – household or individual scales. However, it is at these scales most resource insecurity is experienced. Governance seen as an outcome tends to require fairness in distribution, broader stakeholder participation, and inclusive, alleviating of poverty. Yet procedural justice also plays a key role in determining the outcome. Access to the WEF nexus, from an integrated perspective, enables us to state that access in the nexus is achieved if all three resources are provided as a 'Triplet'. In the light of North-South dialogue and global inequities, Rights as a process enables the paradigm to percolate to the lower levels of governance and place greater obligation and accountability on the state. Upon integration, this would be equivalent to saying that the three rights namely- Right to water, Right to Energy, and Right to water are to be enshrined with positive protection. The interconnections between these resources are emphasised so far from the production point of view. But from the consumption point of view, we cannot conclude that having access to one of the resources translates into having access to the WEF nexus. The Indian Judicial system has already recognised the three rights in its verdicts. Moreover, the executive policy in India has also recognised the importance of providing access to WEF nexus through their priority method allocation of resources. The applied RPF framework emphasises the positive protection of these rights.

## 9.2 Policy Implications

1. Climate Change remains a central element in the WEF nexus and other natural resources as well such as forestry, and biodiversity. Climate Change is the prominent link that establishes the bidirectional links among the resources that span across the WEF nexus and assesses the tradeoffs and synergies in the WEF nexus. Hence,

Climate Change has to be incorporated into the WEF nexus thinking, action, and policy cycle.

2. The involvement of all the relevant stakeholders in the WEF nexus decision-making is the key to effective and sustainable management of the nexus. Embracing participatory, collaborative, and polycentric governance structures and processes coupled with the principles of good governance enhances the size and width of the list of stakeholders to be involved. Along with this, decentralised management of the WEF nexus would promote equitable allocation and access.
3. Renewable energy adoption would lead to cross-cutting solutions across three sectors and help mitigate tradeoffs and raise synergies in the WEF nexus. Thus, the integration of renewable energy concomitant with the institutions, and property rights existing across the three sectors contribute to the effective management of the WEF nexus. It would also require multi-level coordination and policy coherence to become a sustainability transition.
4. In comparision with IWRM, this work put forward a case that intends to synergise the WEF nexus from an institutional perspective. WUAs have the potential to be a synergy in the WEF nexus. This is possible due to the water-centric nature of the nexus. The analysis tends to prescribe that greater integration and promotion of WUAs to the sustainable management of the WEF nexus is necessary although seemingly heuristic.
5. Coming to the rights sphere, nations shall strive for the positive protection of these ‘triplet’ rights although negative protection is present in some nations. Robust legal instruments accompanied with respecting, protecting, and fulfilling these rights would contribute to equitable access to the WEF nexus.

## 9.3 Limitations of the study

1. Most parts of the thesis can better be couched in terms of the process-outcome dichotomy of governance. In this vein, the movement from process to outcome is achieved from chapter 4 through chapter 6. Within chapter 6, this work adhered to the notion of institutions in the WEF nexus very narrowly i.e. relied solely on the analysis of water users associations (WUAs) as a sustainability transition. However, institutions in the broader sense within the WEF nexus would encompass myriad other institutions rather than WUAs. Due to the integrated nature of the WEF nexus, it is important to understand the implications drawn from the analysis of these institutions. However, this study focused only on WUAs leaving the rest of the institutions.

2. This study did not conduct any quantitative study. One good reason for it is the lack of data availability.
3. Though this study focused on the themes such as justice and equity, these broad themes are not utilised for the in-depth analysis of other themes such as gender, core-periphery inequalities of various kinds, and marginalisation of various stakeholders or sectors involved.

### 9.4 Expected work in the future

1. Toward fulfilling our drawback of not conducting the quantitative study, in the future, we expect to construct a composite indicator from and among sustainable development goals. For this to happen, a detailed analysis of various indicators and establishing their validity using multivariate techniques is the key. In a step toward this objective, we have reviewed the literature on composite indicator methodology from Organisation for Economic Cooperation and Development (OECD) and Joint Research Centre, Ispra, Italy.
2. We wish to conduct a primary study on the efficacy of solar irrigation pumps on the fronts of economic, environmental, and social dimensions. In this vein, we would also like to analyse the drivers and barriers to making it a societal transition.
3. Using Rawl's notion of distributive justice i.e. Equity dimension of justice, we anticipate providing a measure for energy access because unlike water access (55 LPCD), and Food Access (2400 calories in rural India and 2100 calories in urban India) it does not have a precise measure. However, we did not start any activity related to this objective.

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