



73RD INTERNATIONAL EXECUTIVE COUNCIL MEETING



24th ICID
INTERNATIONAL
CONGRESS
73rd IEC MEETING
3rd OCT - 10th OCT 2022
ADELAIDE | SOUTH AUSTRALIA



Theme: Innovation and research in agriculture water management to achieve sustainable development goals



INTERNATIONAL WORKSHOP ON “THE WATER ENERGY FOOD NEXUS: IMPLEMENTATION AND EXAMPLES OF APPLICATIONS”

**04 October 2022: 08:45-10:30 and 11:15 to 13:00 Hours
Adelaide, Australia**



Spatial-Scale Water-Energy-Food Nexus Analysis in India – Insight from Implemented Policies

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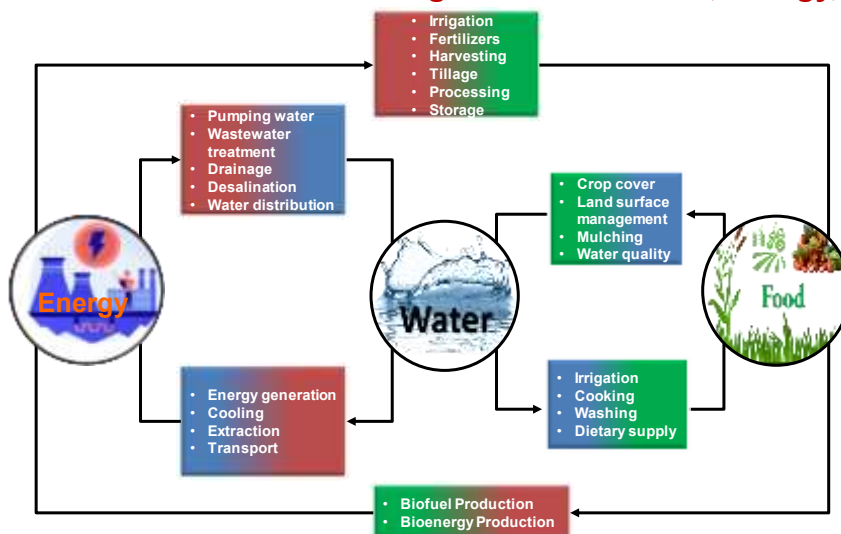
(Co-authors: Krishna Mondal, Ashok Mishra, Rajendra Singh)



Introduction

Multi-dimensional interlinkages between water, energy, food

Water-Energy-Food Nexus



Sustainable Development Goals



UNESCO



Objectives

Absence of **WEF Nexus analysis and impact of various implemented policies on WEF nexus** in different **states and union territories** of India

1. To quantitatively evaluate the **spatial-scale (state-level) WEF Nexus** for two different years (2015-16 and 2019-20) in India, and
2. To quantitatively analyse the **impact of implemented governmental policies on WEF nexus** at state levels in India

Objectives

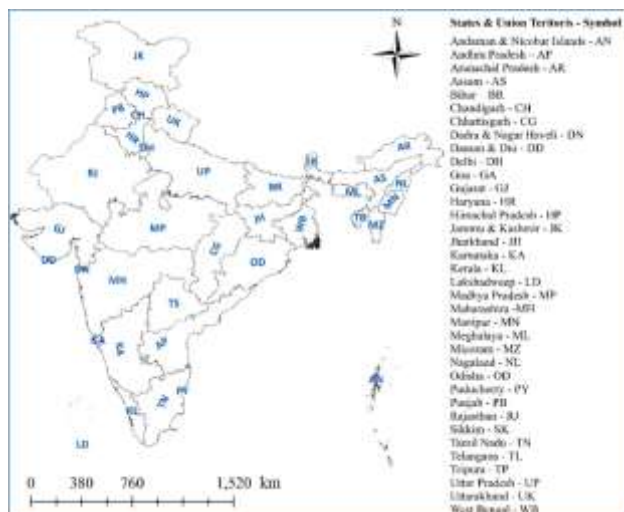


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Study Area

Study area



India (as on January 2019) (29 states and 7 Union Territories)

Lat.: 6°N to 37° 6'N

Long.: 68° 7'E to 97° 25'E

Area: 3.28 million km²

Population: 1.35 billion

Rainfall: 119 cm

Water availability: 1458 m³/capita

(Water stress - 1667 m³/capita)

Water Withdrawal: 91% (agriculture) 7% (municipal) 2% (industry)

Water stressed: 600 million people

Energy availability: 3rd largest producer (1714.82 TWh capacity)

Energy consumed: 1695.4 TWh

Energy stressed: 13% of households

Food availability: 2581 Kcal/capita (min. req. 1800 KCal)

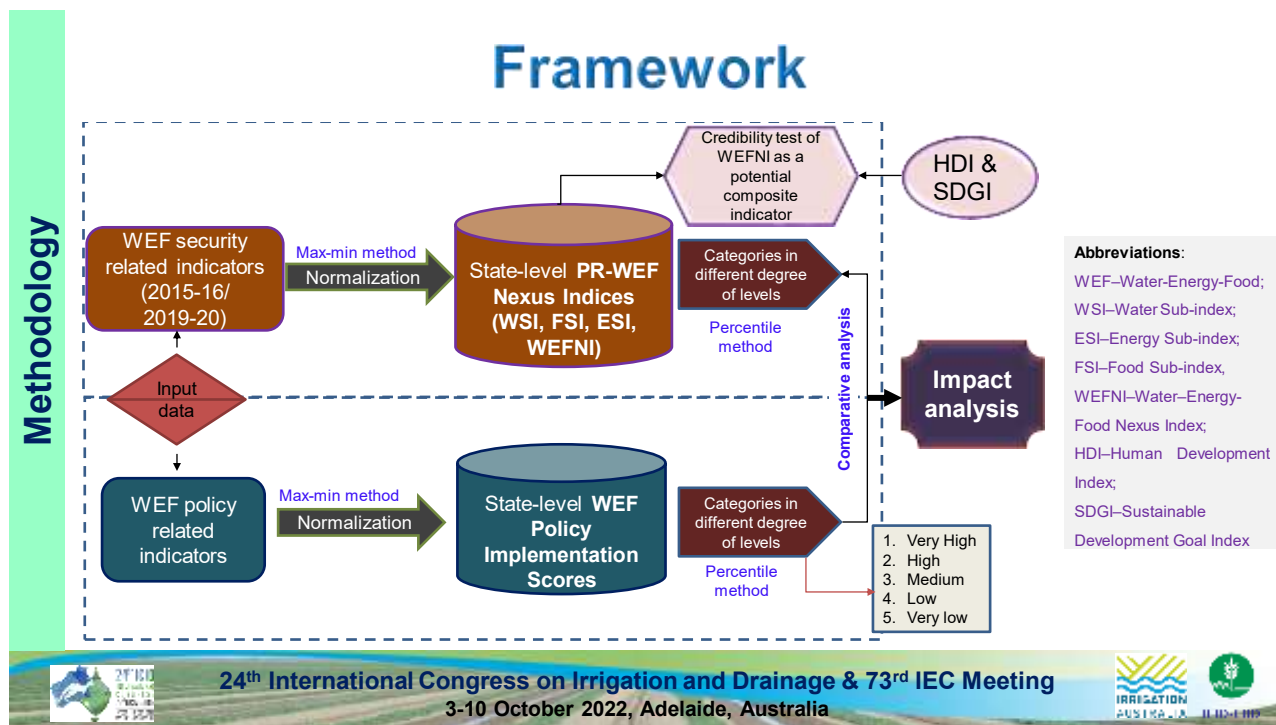
Undernourished: 189.2 million



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Framework



Schemes implemented during 2015–2020

Methodology

SL. No	Scheme (Ministry)	Duration	Status	Objective of the scheme	Fund release
1	JJM (Ministry of Jal Shakti)	2019-2024	Ongoing	Drinking water supply by having a functional tap connection to every rural household (min. 55 lit/capita/day)	\$ 464.6 billion
2	NWQSM (Ministry of Drinking Water and Sanitation)	2017-2020	Completed	Provide safe drinking water to arsenic and fluoride-affected habitations	\$ 2.34 billion
3	JSA (Ministry of Labour and Employment Archives)	2019 (July–November)	Completed	Water conservation and rainwater harvesting reuse and recharge structures	No separate funds allocated
4	PMKSnY (Ministry of Water Resources)	2015 - 2019	Completed (1 st phase)	Har Khet ko Pani, watershed development, per drop more crop	\$ 6.84 billion
5	NNM (Ministry of Women and Child Development)	2018-2021	Completed	Improve nutritional outcomes for children, pregnant women and lactating mothers	\$ 6.86 billion
6	PMKSmY (Ministry of Food Processing Industries)	2016-2020	Completed	Supplement agriculture, create processing and preservation capacities, modernise and expand existing food processing units	\$ 7.74 billion
7	PMUY (Ministry of Petroleum and Natural Gas)	2016-2019	Completed	Providing clean energy	\$ 16.52 billion
8	PMSBHGY (Ministry of Power)	2017-2021	Completed	Provide energy access to all to achieve universal household electrification in the country	\$ 210.62 billion
9	PM-KUSUM (Ministry of New and Renewable Energy)	2019-2022	Ongoing	Providing energy and water security to farmers, enhancing their income, de-dieselise the farm sector and reducing the environmental pollution	\$ 438.79 billion

Abbreviations:
 JJM - Jal Jeevan Mission;
 NWQSM - National Water Quality Sub-mission;
 JSA - Jal Shakti Abhiyan;
 PMKSnY - Pradhan Mantri Krishi Sinchayee Yojana;
 NNM - National Nutrition Mission;
 PMKSmY - Pradhan Mantri Kisan Sampada Yojana;
 PMUY - Pradhan Mantri Ujjwala Yojana-1.0;
 PMSBHGY - Pradhan Mantri Sahaj Bijli Har Ghar Yojana;
 PM-KUSUM - Pradhan Mantri Kisan Urja Suraksha Uthhan Mahabhiyan

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PR-WEFNI & WEFNIS

Pardee RAND Water-Energy-Food Nexus Index (PR-WEFNI)

$$\text{WEFNI Index} = \sqrt[3]{\text{WSI} \times \text{ESI} \times \text{FSI}}$$

$$\text{Water sub-index (WSI)} = \sqrt{\text{Water Accessibility} \times \text{Water Availability}} = \sqrt{\text{Indicator 1} \times \text{Indicator 2} \times \frac{\text{Indicator 3}}{\text{Indicator 4}}}$$

$$\text{Energy sub-index (ESI)} = \sqrt{\text{Energy Accessibility} \times \text{Energy Availability}} = \sqrt{\text{Indicator 5} \times \text{Indicator 6} \times \frac{\log(\text{Indicator 7})}{\log(\text{Indicator 8})}}$$

$$\text{Food sub-index (FSI)} = \sqrt{\text{Food Accessibility} \times \text{Food Availability}} = \sqrt{\left(\frac{1}{\text{Indicator 9}}\right) \times \text{Indicator 10} \times \frac{\text{Indicator 11}}{\text{Indicator 12}}}$$

Water-Energy-Food-Policy Implementation score (WEFPIS)

$$\text{WEFPIS} = \sqrt[3]{\text{WPIS} \times \text{EPIS} \times \text{FPIS}}$$

$$\text{Water policy implementation score (WPIS)} = \sqrt[3]{\text{Indicator 13} \times \text{Indicator 14} \times \text{Indicator 15}}$$

$$\text{Energy policy implementation score (EPIS)} = \sqrt[3]{\text{Indicator 16} \times \text{Indicator 17} \times \text{Indicator 18}}$$

$$\text{Food policy implementation score (FPIS)} = \sqrt[3]{\text{Indicator 19} \times \text{Indicator 20} \times \text{Indicator 21}}$$

Methodology



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Data

Indicators used for WEF nexus analysis (2015-16 & 2019-20)

Sl. No.	Indicator	Data Source	Area
1	% of population having access to sufficient water for sanitation	National Family Health Survey-5, 6	Water
2	% of population having access to sufficient water for improved drinking	National Family Health Survey- 5, 6	Water
3	Amount of water withdrawal for domestic purposes	India groundwater yearbook	Water
4	Per capita minimum daily water required for domestic purposes		Water
5	% of population having access to sufficient energy for cooking and heating	Indiastat (https://www.indiastat.com/)	Energy
6	% of population having access to sufficient electricity for domestic purposes	National Family Health Survey-5, 6	Energy
7	Electricity available/year	National Family Health Survey-5, 6	Energy
8	Electricity requirement/year	Indiastat	Energy
9	Consumer Food Price Index (CFPI)	National Statistical Office Reports of India	Food
10	% of Calories/capita/day intake from non-starchy food	National Sample Survey Organization (66 th & 68 th) Report	Food
11	Annual per capita food grain supply	Indiastat	Food
12	Annual per capita food grain minimum required	ICMR, 2010	Food

Methodology



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Data

Indicators used for Policy Analysis (2015-2020)

Methodology

Sl. No.	Indicator	Data Source	Area
13	% of rural households provided tap water connection under JJM	Indiastat	Water
14	% of District implementing JSA	Indiastat	Water
15	% of habitation achieved under NWQSM	Indiastat	Water
16	% of households getting LPG connection under PMUY	Indiastat	Energy
17	% of households electrified by PMSBHGY to the un-electrified family till 2020	Indiastat	Energy
18	Normalised value of installed capacity of solar power under PM-KUSUM	Indiastat	Energy
19	% of area brought under agriculture; Number of ponds/unit agriculture area constructed under PMKSnY	Indiastat	Food
20	% of stunted children benefited by NNM	Indiastat	Food
21	Normalised value of installed Cold storage capacity to the total number of projects completed under PMKSmY	Indiastat	Food

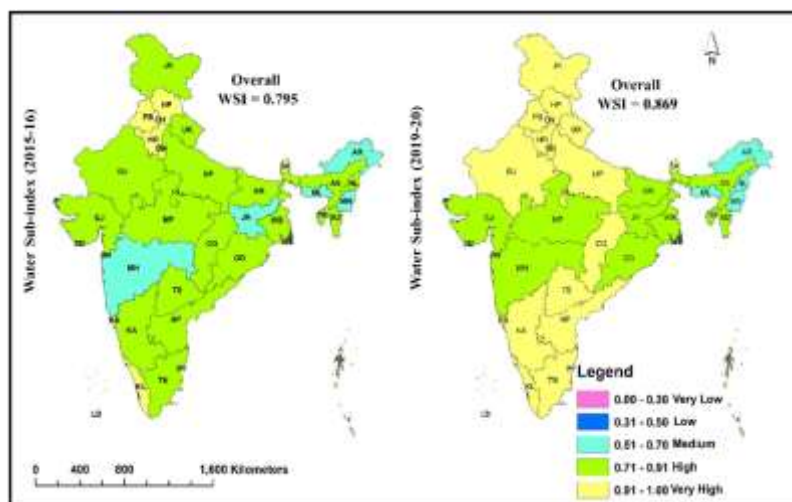


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Spatial variation of WSI in India

Results



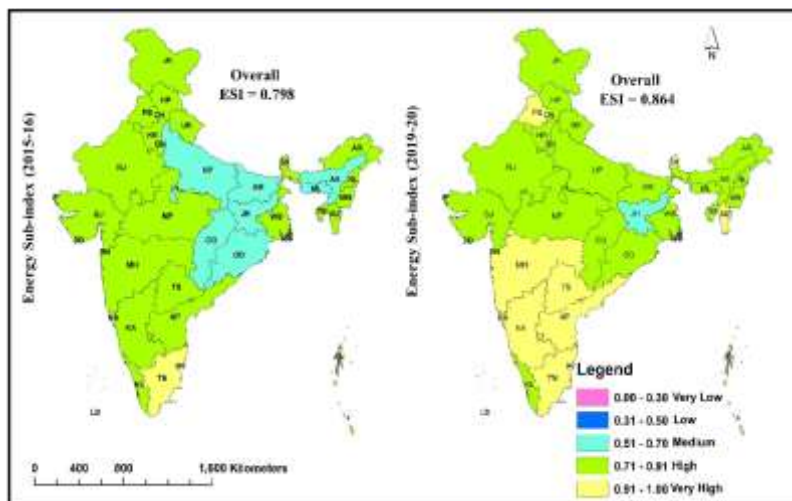
- In 2015-16, 22, 53, 25% of states have very high, high and medium range WSI
- In 2019-20, 50, 33, 17% of states have very high, high and medium range WSI
- Overall water security of India increased by 7.4%



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Results

Spatial variation of **ESI** in India

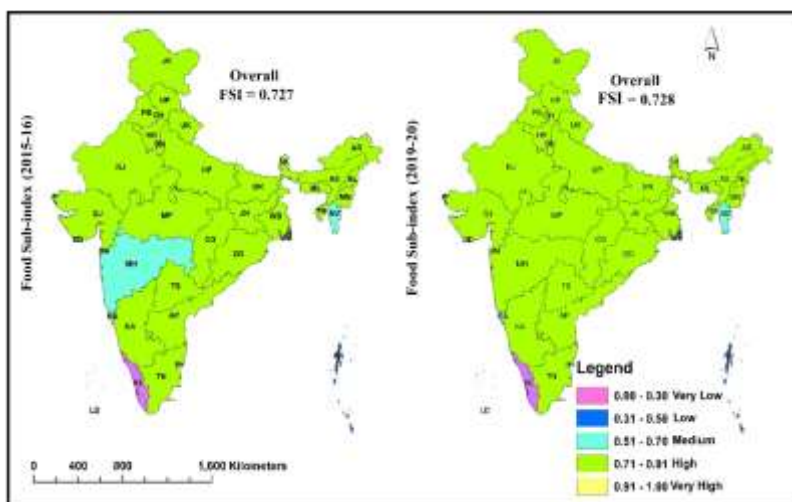
- In 2015-16, 11, 69, 20% of states have very high, high and medium range ESI
- In 2019-20, 31, 67, 2% of states have very high, high and medium range ESI
- Overall energy security of India increased by 6.6%



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Results

Spatial variation of **FSI** in India

- In 2015-16, 11, 8, 79% of states have very low, medium and high range FSI
- In 2019-20, 11, 6, 81% of states have very low, medium and high range FSI
- Overall food security of India increased by 0.1%

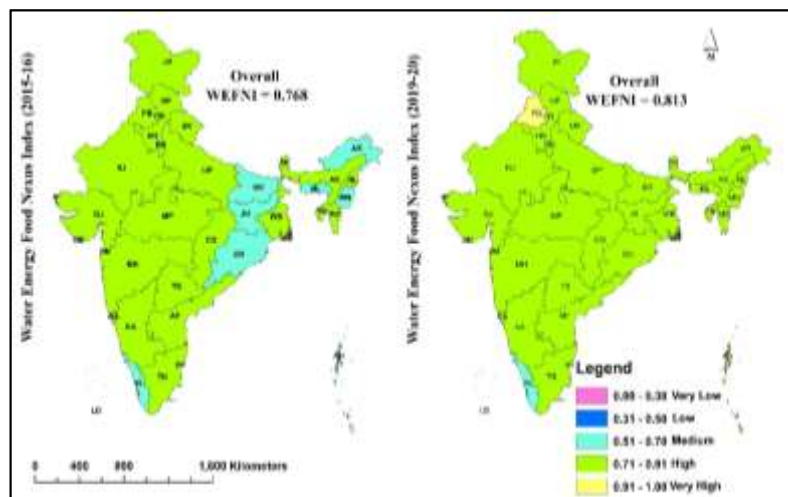


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Results

Spatial variation of WEFNI in India



- WEFNI implies the overall WEF security
- Most of the states (72% in 2015-16 and 89% in 2019-20) have high WEFNI
- The overall WEFNI of India improved by 4.5 %

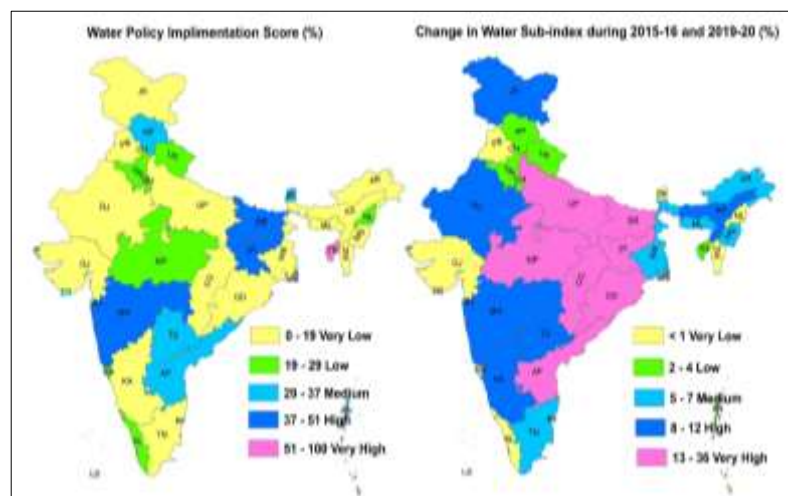


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Results

Spatial variation of WPIS and change in WSI



- Most of the states have substantial WSI changes due to higher WPIS
- Low improvement in WSI despite having higher or medium WPIS due to having higher water security in both years
- High improvement in WSI despite having low WPIS due to the effective and efficient use of resources

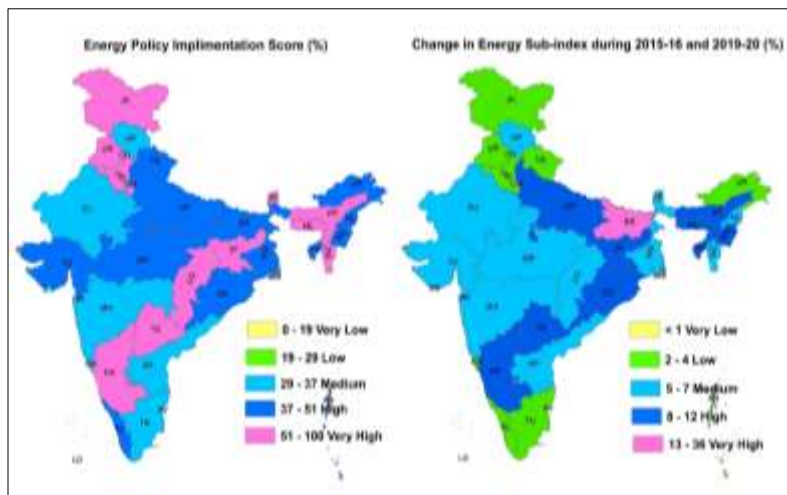


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Spatial variation of EPIS and change in ESI

Results



- Most states have a high and very high value of ESI improvement due to the higher value of EPIS

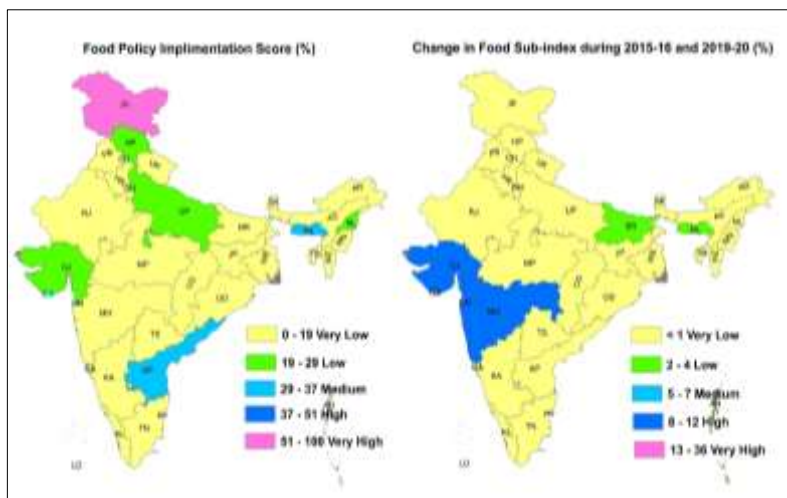


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Spatial variation of FPIS and change in FSI

Results



- Most states have very low improvement in FSI due to the lower value of FPIS.

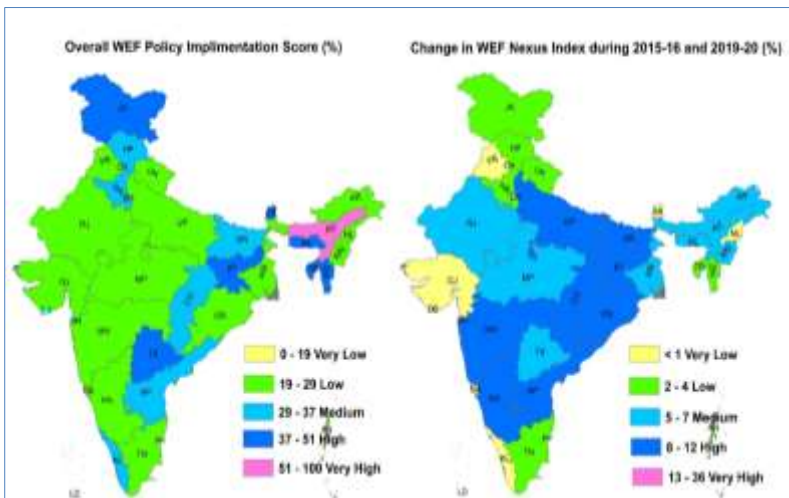


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Spatial variation of WEFPIIS and change in WEFNI

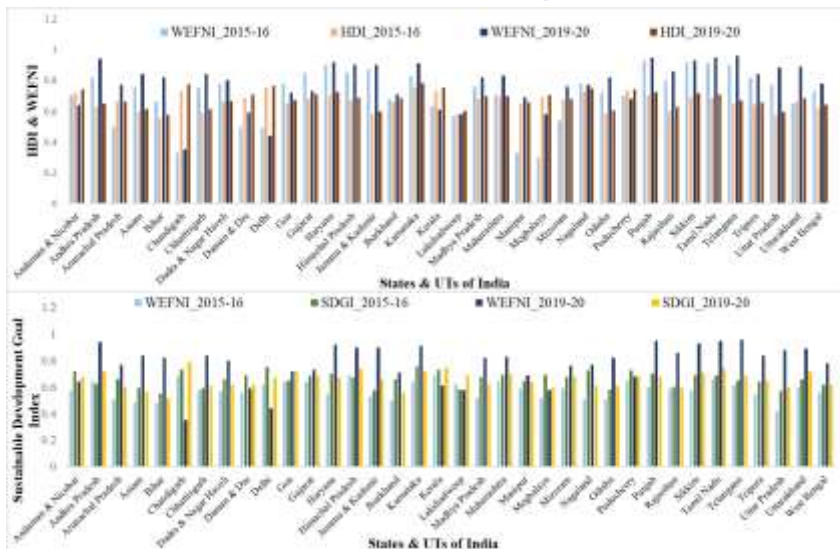
Results



- Significantly high values of policy implementation score (PIS) are responsible for improving WEF sub-indices

Variation of HDI, SDGI & WEFNI

Results



- In most states, WEFNI is highly connected with HDI and SDGI
- WEFNI may be used as a crucial indicator of achieving SDGs 2, 6, and 7

Conclusions

- Most states have increased water sub-index (WSI) and energy sub-index (ESI) but a decrease in food sub-index (FSI) during 2015-16 and 2019-20
- The changes in WSI and ESI are more significant than in FSI
- India's overall WSI, ESI, FSI, and WEFNI increased by 7.4%, 6.6%, 0.1%, and 4.5%, respectively, during 2015-16 and 2019-20 due to policy implementations
- WEFNI may be used as the country's resource management and sustainable development indicator



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