INDIA AGRIVOLTAICS ALLIANCE

India Climate Collaborative

Accelerating Agrivoltaics in Uttar Pradesh

Potential Analysis and Policy Recommendations

State Task Force Uttar Pradesh

India Agrivoltaics Alliance

Accelerating Agrivoltaics in Uttar Pradesh

Potential Analysis and Policy Recommendations

State Task Force Uttar Pradesh

India Agrivoltaics Alliance

Suggested citation:
India Agrivoltaics Alliance. 2024. Accelerating Agrivoltaics in Uttar Pradesh Potential Analysis and Policy Recommendations New Delhi: IAA secretariat: NSEFI

Disclaimer
The views expressed in this issue brief are those of the authors and views collected from the consultations and do not necessarily reflect the views and policies of the National Solar Energy Federation of India, India Climate Collaborative, India Agrivoltaics Alliance, Center for Study of Science, Technology and Policy

State Task Force Chair
Council on Energy, Environment and Water (CEEW)

Co-Chair
2030 Water Resource Group, World Bank

Reviewer
Ms Shweta Srinivasan, ICC, Mr. Neeraj Kuldeep, CEEW, Ms Meghana Pahlajani, 2030 WRG, Mr Prashant Badal, CEEW

Author
Ms Mahima Malyan, IAA, Ms Shubhashree Chakraborty, IAA, Mr Prasoon Anand, NSEFI, Mr Subrahmanyam Pulipaka, NSEFI

Contributors
Mr Prashant Badal, CEEW, Mr Avinash Tiwari (Intellecap - TSU WRG), Ms Phoolvi Agarwal, Mr Raghav Agarwal (Veetaday Industries Pvt Ltd), Mr Vikas Sharma (India Hub), Mr Upkari Nath Tripathi (RMI), Ms Nimishee Singh (Ruvexa), Mr Arun Kumar Singh (Phytec), Ms Tripti Khanna (India Hub), Dr Sidhartha Singla (IIT Guwahati), Mr Shashank Misra (Ekak Innovation), Mr Mayur Sarode (BAIF), Mr Pushpendra Kumar Tripathi (BAIF), Mr Anuj Tiwari (Zodiac Energy), Dr Kalyan Ghadai (BHU)

Design by: Madre Designing

Organization
The India Agrivoltaics Alliance is a collaborative platform of 48 organisations anchored at the NSEFI secretariat in New Delhi. The IAA aims to build partnerships and platform voices from the agriculture and solar sectors to address issues at the nexus of food-energy-water, including carbon emissions, rising food insecurity, and a need to enhance agrarian livelihoods and land productivity.

Version: V1.0, 12 August 2024, New Delhi

Published: August 2024

Table of **Content**

List of **Figures**

List of **Tables**

1. Introduction

1.1. Overview of the State

Uttar Pradesh, commonly known as UP, renowned for vastness, it holds the status of being the country's most populous state and the fourth largest in terms of area. Nestled amidst a diverse landscape, it shares borders with Nepal and several Indian states including Bihar, Madhya Pradesh, and Haryana. The terrain varies from the expansive Gangetic Plains dominating the central and southern territories to the majestic Himalayas gracing its northern boundaries. Economically, Uttar Pradesh's backbone is its agricultural sector, with prominence in the production of wheat, rice, sugarcane, and potatoes, significantly contributing to India's food security. However, challenges such as low farm income due to fragmented landholdings and inadequate processing facilities persist. The state government has taken proactive measures to address these challenges, notably through initiatives like the PM-KUSUM scheme, promoting the adoption of solar irrigation pumps to enhance energy security and reduce costs for farmers. Additionally, a concerted effort towards bolstering Farmer Producer Organizations (FPOs) aims to empower farmers by augmenting their bargaining power and facilitating better market access for agricultural produce. Amidst the challenges and triumphs, Uttar Pradesh's vibrant amalgamation of history, culture, and agriculture offers a unique and enriching experience. As the state endeavours towards sustainable development, its inherent potential for growth and resilience paints a promising tableau for the future. (Pradesh, n.d.)

1.2. Agro-climatic Zones in the State

UP is divided in nine agro-climate zones- Terai, western plains (WP), midwestern plains (MWP), western semi-dry plains (SWDP), mid-western south plains (MWSP), south-western semi-dry plains (SWSDP), Bundelkhand (BUND), north eastern plains (NEP) and Vindhyachal (VIND). There are wide climatic variations across the zones-while Bundelkhand is drought-prone, eastern UP sees frequent floods and waterlogging. Agriculture is the base of the economy of Uttar Pradesh. About 59.3% population of the state is engaged in the agricultural sector. The state produces about 19.87% of the foodgrains in the country. Thus, it stands at the first position at all India level in terms of foodgrains production. The state of Uttar Pradesh is divided into 9 agro-climatic regions or zones on the basis of factors affecting the agriculture. These zones are discussed Here:

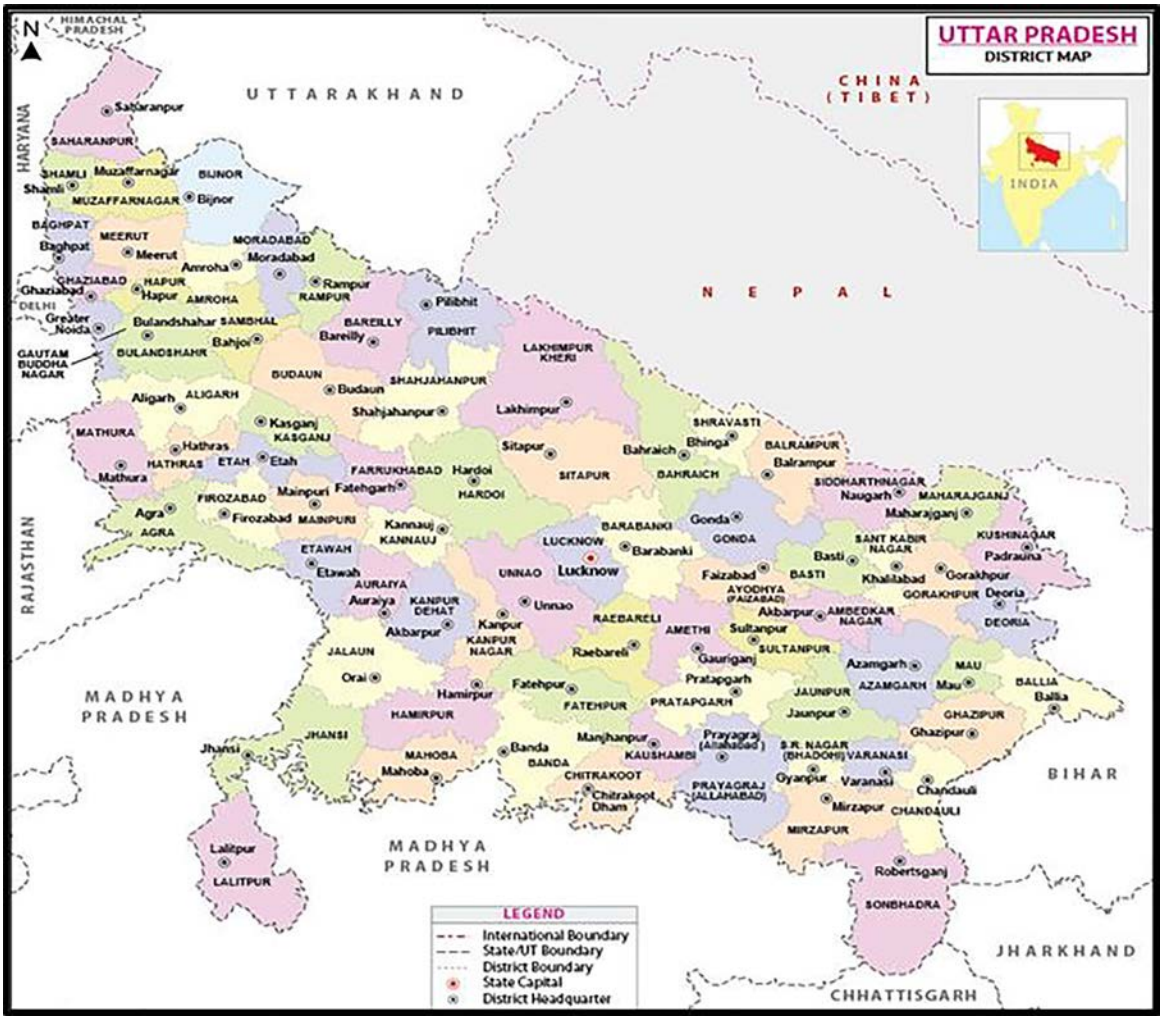


Figure 1: Map of Uttar Pradesh

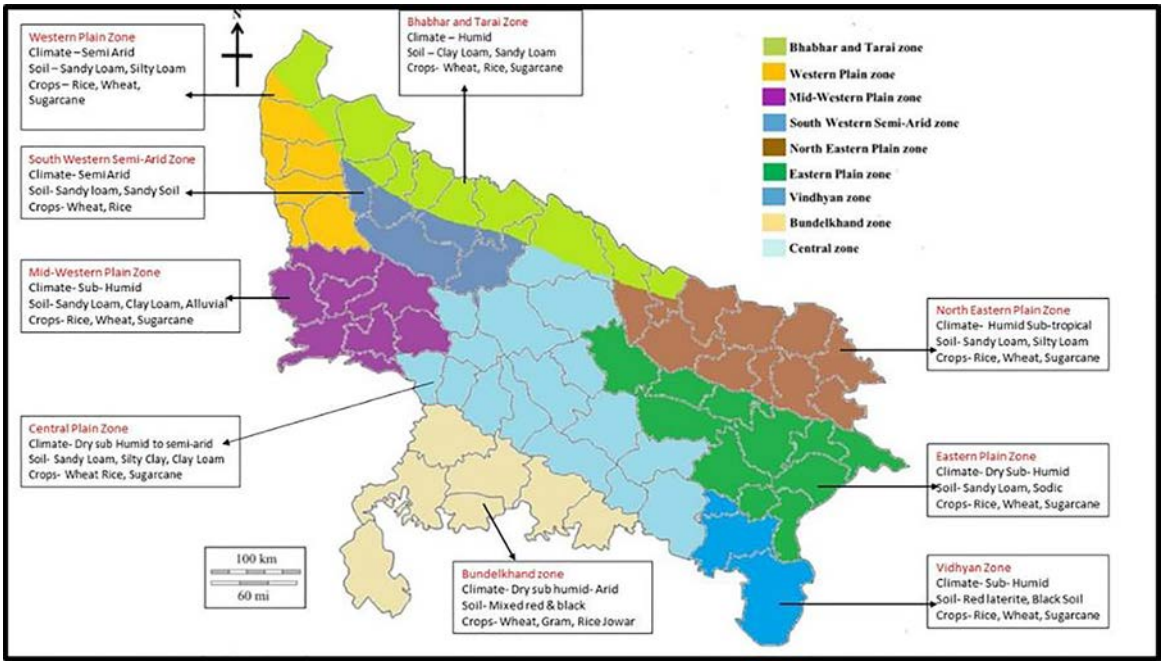


Figure 2: Agro-Climatic Zones of Uttar Pradesh

Table 1: Agro-Climatic Zones of Uttar Pradesh

SN	Agro Climatic Zone	Temperature (degree Celsius) Min & Max		Average Annual Rain Fall (mm)	Irrigated Area (%)	Soil	Total Cultivated area (Lac hectare)	District
1	Bhawar and plain, tarai plain	5.5	38.4	1400	73.29	Minimum to medium in Alluvial phosphorous Medium to high in potassium and organic matter in high quantity.	Area of different district under agro climatic zone A has been included in concerned agro climatic zone	Parts of different district under the zone have been included in concerned agro climatic zone.
2	Western Plain Zone	1.5	43.3	795	89.23	Alluvial, pH-normal to alkaline and organic matter minimum to medium quantity	19.36	Shaharanpur Muzzaffar nagar, Baghpat,
3	Mid western plain zone	4.5	45.4	1032	83.21	Mostly alluvial, PH Normal to slightly alkaline and organic matter in medium quantity.	30.36	Bijnore, Moradabad, Rampur, Bareilly, Badaun, Pilibhit and Shahjahanpur (7 district)
4	Western sub tropical zone	4	47	662	75.52	Alluvial and aravali	22.3	Aligarh, Mathura, Agra, Firozabad, Etah, Mainpuri (6 districts)
5	Mid plain zone	5.5	45	863	66.41	Alluvial, PH Normal to slightly alkaline and organic matter in medium quantity.	61.22	Farrukhabad, Kannauj, Etawah, KanpurNagar, KanpurDehat, Unnao, Hardoi, Khiri, Sitapur, Lucknow, Raebareilly, Fatehpur, Pratapgarh and Allahabad (14 districts)

SN	Agro Climatic Zone	Temperature (degree Celsius) Min & Max		Average Annual Rain Fall (mm)	Irrigated Area (%)	Soil	Total Cultivated area (Lac hectare)	District
6	Bundel-khand Zone	3	47.8	867	38.65	Rakar, Parwa, Kabar and Mar	29.61	Lalitpur, Jhansi, Jalaun, Hamirpur, Banda and Chitrakott (7 districts)
7	North Eastern Plain Zone	4.9	44.2	1240	48.24	Alluvial and calcarious soil	33.8	Behraich, Balrampur, Gonda, Siddharthnagar, Basti, Maharajganj, Kushinagar and Deoria (9 districts)
8	Eastern Plain Zone	5.7	41.4	803	69.43	Alluvial , sodic and diara soil	32.05	Barabanki, Faziabad, Sultanpur, Jaunpur, Azamgarh, Mau, Ballia, Ghazipur, Varanasi and Sant Ravidasnagar (10 districts)
9	Vindhya Zone	5	45.2	1134	52.85	Black heavy, Red granular and Alluvial soil in plains	11.34	Mirzapur and Sonbhadra (2 Districts)

Western UP had much lower 527.4 mm rainfall, with 27% deficit. Ghaziabad (146.1 mm, 73% below normal, the lowest rainfall of the state), Shamli (170 mm, 72% deficit) and Pilibhit (371.9 mm, 60% deficit) at Large Deficits. Only Hamirpur had Excess rain at 917 mm, 27% above normal, it had the highest rainfall in the region. 18 districts were in Deficit category and 11 in Normal rain category. (Pradesh, Government of Uttar Pradesh, n.d.)

1.3. Challenges for the agriculture sector in Uttar Pradesh

Agriculture is a cornerstone of Uttar Pradesh's economy, with the state being a major producer of a wide array of crops. Key crops include wheat, rice, sugarcane, pulses, and various fruits and vegetables. Wheat and sugarcane are particularly significant, with UP being the largest producer of sugarcane in India. The state also has substantial cultivation of fruits like mangoes and guavas, and vegetables such as potatoes and onions, contributing significantly to both the state and national agricultural output.

Despite its robust agricultural production, Uttar Pradesh faces several critical challenges. Water management is a major issue, especially in the eastern and Bundelkhand regions, where water

scarcity hampers agricultural productivity. In contrast, the western region benefits from better irrigation facilities. Soil health is another pressing concern; extensive use of chemical fertilizers and pesticides has led to soil degradation, prompting a shift towards organic farming and sustainable agricultural practices.

Climate change poses a significant threat to agriculture in UP, with erratic weather patterns, including unseasonal rains and prolonged droughts, impacting crop yields. Additionally, small and fragmented landholdings, which are prevalent across the state, reduce farming efficiency and hinder the adoption of modern agricultural techniques. This fragmentation also limits the scalability of farm operations and access to credit and inputs.

The government of Uttar Pradesh has implemented several initiatives to support farmers and address these challenges. These include subsidies on seeds, fertilizers, and machinery, as well as central sector crop insurance schemes like the Pradhan Mantri Fasal Bima Yojana (PMFBY) to protect farmers against crop failure due to natural calamities. Efforts to improve irrigation infrastructure, such as the Pradhan Mantri Krishi Sinchai Yojana (PMKSY), are also underway. Additionally, there is a push towards promoting technological integration in agriculture through the use of digital platforms for market access, weather forecasting, and precision farming techniques.

Despite being a major agricultural producer, Uttar Pradesh faces significant challenges that limit farm income and overall sector growth. Here's a breakdown of some key issues with data examples:

Land fragmentation and salt-affected soils are two significant challenges faced by the agricultural sector in Uttar Pradesh. The state's average land holding size is a mere 0.780 hectares, significantly lower than the national average, contributing to land fragmentation. This fragmentation poses a substantial hurdle for farmers in adopting modern farming practices, mechanization, and achieving economies of scale, ultimately impacting their productivity and profitability.

Compounding these challenges is the issue of salt-affected soils, which is particularly acute in Uttar Pradesh. With a staggering 1,295,000 hectares of land affected by salinity, the state ranks highest among all states in India for this problem. Salt-affected soils can severely impair soil fertility, water uptake by plants, and overall crop yields, leading to reduced agricultural production and income for farmers.

The combination of land fragmentation and salt-affected soils creates a formidable obstacle for the state's agricultural sector. Small and scattered land holdings make it difficult for farmers to invest in modern technologies, implement efficient irrigation systems, or utilize advanced farming techniques that could potentially mitigate the effects of soil salinity. Additionally, the high prevalence of salt-affected soils exacerbate the challenges faced by farmers, further constraining their ability to achieve optimal crop yields and sustain their livelihoods.

Addressing these interconnected issues require a multifaceted approach, involving land consolidation initiatives, promotion of cooperative farming models, and the implementation of soil reclamation and management strategies. Concerted efforts from policymakers, agricultural extension services, and farmers themselves are crucial to overcome the challenges posed by land fragmentation

and salt-affected soils, ensuring the long-term sustainability and productivity of Uttar Pradesh's agricultural sector.

1.4. Renewable energy, climate change and ambitious targets

Climate change today poses a significant challenge, driven by the accumulation of greenhouse gas emissions in our atmosphere. While fossil fuels have long been the primary sources of our energy infrastructure, contributing to global warming and its associated impacts. Hence, there is a dire need of the hour to bring a sustainable approach in every sector of human activity. By shifting towards renewable energy resources, we can not only reduce our reliance on fossil fuels but also embrace cleaner, more sustainable energy sources. This transition not only mitigates the impacts of climate change but also paves the way for a brighter, more sustainable future for generations to come.

1.5. Integration of renewable energy and agriculture as a solution

Under the PM-KUSUM scheme, replacing diesel pumps with solar-powered irrigation systems can significantly lower farmers' electricity bills while also providing a clean and reliable energy source for irrigation and other agricultural operations, particularly in off-grid areas. Additionally, leasing fallow land for solar power plants (Component A of PM-KUSUM) offer farmers an opportunity for supplementary income. Solar pumps support precision irrigation techniques, enhancing water efficiency. Given that agriculture constitutes a substantial share of Uttar Pradesh's power consumption, transitioning to solar irrigation pumps can substantially alleviate this energy burden.

Overall Benefits:

- Improved Farm Income: Lower electricity bills and additional income from land leasing can improve the financial situation of farmers.
- Sustainable Agriculture: Reduced reliance on fossil fuels and efficient water management contribute to a more sustainable agricultural sector.
- Climate Change Mitigation: Integration of renewable energy reduces greenhouse gas emissions from agriculture.

Integrating renewable energy with agriculture presents a promising solution for Uttar Pradesh. By addressing farm income limitations, resource constraints, and climate concerns, this approach can contribute to a more sustainable and prosperous agricultural sector in the state.

1.6. What is Agrivoltaics?

Agrivoltaics is an innovative approach of strategically co-locating the agricultural activities with the generation of electricity from solar energy. Both the solar PV and crops require solar resources for producing their outputs. Agrivoltaics aims to achieve an optimal sharing of the incident solar energy to accrue maximal land utilization. Agrivoltaics can significantly help in addressing the climate change problem without compromising on the crop cultivation, simultaneously powering the energy crisis-ridden agriculture sector and improving the farmers' income. Hence agrivoltaics promises to be an effective solution for addressing the challenges discussed in the previous sections and converting them into opportunities.

The effect of the shade imparted by the solar panels onto the crop yield is different in all crops. Some crops tend to be negatively impacted by the shade while other benefit from them. Leafy vegetables and some of the horticultural crops are known to either be benefited from the shade or unaffected by it. Almost all the cereals such as paddy, wheat, maize, and some of the vegetables and fruits, etc. are usually impacted negatively by the shade for yield. The decrease in the yield, however can be compensated by taking several measures. Agrivoltaics projects across the world and in India have demonstrated several additional benefits apart from improved land utilization. These include a cooler microclimate, protection from scorching sunlight during the brightest hours of summer, reduced evapotranspiration due to the shade imparted by the solar panels allowing saving of water and resulting in deduction in irrigation water requirement, improvement in the efficiency of the solar panels, increased bifacial generation of electricity with enhanced albedo, protection of crops from damage due to extreme weather events like squall, hailstorm, heat and cold waves, etc. Hence agrivoltaics encourages climate resilience in agriculture. The energy generated in agrivoltaics farms is cleaner, greener and promotes decarbonization of agriculture sector, thus bringing a sense of sustainability to the agriculture. The electricity generated from agrivoltaics can be utilized not only for fulfilling the energy requirements for agricultural purposes but also for supporting side-businesses and allied activities, protected climate-controlled cultivation, value addition through processing of agricultural produce and buttressing employment opportunities for rural communities through cottage industry.

Table 2: Agrivoltaics Pilots in Uttar Pradesh

Sl. No.	Project Name	Developer	Installed Capacity (kW)	Type of Agrivoltaics	Type of Crops	Commission-ing Year	Additional Remarks
1	Amity University plant Noida, Uttar Pradesh	Amity University	10	Overhead (Optimum tilt angle - Approximately 15 ft (4.6m) height of the mounting pole)	Maize, potato brinjal, mustard	2017	Automated sprinkler system for panel cleaning
2	Dayalbagh project Agra, Uttar Pradesh	Dayalbagh Educational Institute	200	Overhead (A height of 18 feet)	Grams, brinjal, tomato, wheat, spinach, cauliflower, carrot	2020	Panel mounted on towers at 18' feet height provide enough space for machinery use

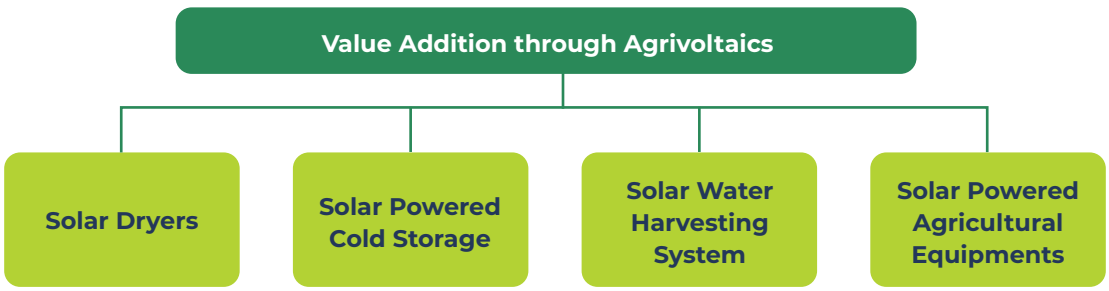
1.7. Research in agriculture and related fields

Uttar Pradesh, a state with a strong agricultural base, has established a robust research ecosystem to drive innovation and address the challenges faced by its farming community. Several premier institutions and state research stations conduct location-specific research, demonstrations, and training programs to disseminate new technologies and best practices to farmers. The research initiatives in Uttar Pradesh aim to enhance productivity, improve resource utilization efficiency, and ensure food security while promoting environmentally friendly agricultural practices tailored to the diverse agro-climatic conditions of the state.

Table 3: Agricultural Universities in the State

Sl. No.	University	Location
1.	Sardar Vallabh Bhai Patel University of Agriculture & Technology (SVPUAT)	Meerut
2.	Chaudhary Charan Singh University	Kanpur
3.	Narendra Deva University of Agriculture and Technology (NDUAT)	Faizabad
4.	C.S. Azad University of Agriculture and Technology (CSAUAT)	Kanpur
5.	Banaras Hindu University (Department of Agronomy)	Varanasi
6.	Banda University of Agricultural and Technology	Banda
7.	ICAR-Indian Institute of Sugarcane Research	Lucknow
8.	Indian Institute of Pulses Research	Kanpur
9.	Indian Institute of Vegetable Research	Varanasi
10.	National Botanical Research Institute	Lucknow

1.8. Value Addition through Agrivoltaics



Sl. No.	Value Addition through Agrivoltaics
Solar Dryers	The adoption of solar dryers for drying agricultural produce, especially fruits, vegetables, and grains help farmers reduce post-harvest losses, improve product quality, and add value to their produce. Subsidies and training programs are provided to promote the installation and use of solar dryers in Uttar Pradesh.
Solar-powered Cold Storage	In order to address post-harvest losses and improve market access for farmers, the Uttar Pradesh government supports the establishment of solar-powered cold storage facilities. These facilities utilize solar energy to maintain the required temperature for storing perishable agricultural produce, thereby extending their shelf life and reducing wastage.
Solar Water Harvesting	The state government promotes the adoption of solar-powered water harvesting systems in rural areas to recharge groundwater and improve water availability for agricultural purposes. Solar-powered water harvesting structures, such as rooftop rainwater harvesting systems and solar pumps for groundwater recharge, are encouraged through subsidies and awareness campaigns.
Solar-powered Agricultural Equipment	In line with the central government's initiatives, Uttar Pradesh promotes the adoption of solar-powered agricultural equipment such as solar-powered sprayers, tillers, and grain dryers. These technologies help farmers reduce operating costs, improve efficiency, and reduce carbon emissions associated with conventional fossil fuel-powered equipment.

1.9. Business Models of Agrivoltaics

Business Models for Agrivoltaics		
BM 1	**Individual Farmer Owned**	• Land and project Ownership – Farmer • Project ownership – Farmer • Revenue from sale of electricity and agricultural produce - Farmer
BM 2	**Developer Owned**	• Land and project Ownership – Farmer • Project ownership – Developer • Revenue from sale of electricity – Developer • Revenue from Lease of Land – Farmer • Revenue from sale of agricultural produce - Farmer
BM 3	**Community Owned by FPOs / NGOs / Panchayats**	• Land and project Ownership – Farmer groups, FPOs, NGOs, and Panchayat • Project ownership – FPOs, NGOs, and Panchayat or Developer • Revenue from sale of electricity – FPOs, NGOs, and Panchayat or Developer (based on ownership) • Revenue from Lease of Land – Farmer groups, FPOs, NGOs, and Panchayat (in the case of developer ownership) • Revenue from sale of agricultural produce - Farmer groups, FPOs, NGOs, and Panchayat
BM 4	**DISCOM owned model**	• Land and project Ownership – Farmer • Project ownership – DISCOM • Evacuation of power – DISCOM • Revenue from Lease of Land – Farmer • Revenue from sale of agricultural produce - Farmer

 # For the in-depth study on various agrivoltaics business models, India Agrivoltaics Alliance has prepared a report "Business Models for Agrivoltaics".

1.10. Overview of the agriculture sector in the state

Uttar Pradesh, often referred to as the heartland of agriculture in India, has a significant contribution to the country's agricultural output. The state accounts for approximately 19% of the total cultivated area in India and plays a pivotal role in the production of various crops (Uttar Pradesh Economic Survey 2021-22). Wheat and rice are the major cereal crops, with Uttar Pradesh being the largest producer of wheat, contributing around 37% of the country's total wheat production (Agricultural Statistics at a Glance 2021, Ministry of Agriculture and Farmers Welfare). The state is also a leading producer of sugarcane, accounting for nearly 27% of the national sugarcane production (Uttar Pradesh Sugar Mills Association). Other significant crops include pulses, oilseeds (mustard and groundnut), and vegetables like potatoes and peas.

Uttar Pradesh has an extensive network of irrigation facilities, with a combined irrigation potential of 27.5 million hectares (Uttar Pradesh Irrigation and Water Resources Department). The state's major rivers, such as the Ganga, Yamuna, and Gomti, play a crucial role in irrigation and water management. However, issues like soil salinity, water scarcity, and declining groundwater levels pose significant challenges for sustainable agriculture in the state (CSSRI, 2022).

The state has established several regulated markets (mandis) and agricultural produce market committees (APMCs) to facilitate the sale and marketing of agricultural produce. As of 2021, there were 235 principal market yards and 842 sub-market yards in Uttar Pradesh (Uttar Pradesh State Agricultural Produce Marketing Board). However, there is a need for further improvement in storage facilities, cold chains, and transportation infrastructure to reduce post-harvest losses and enhance market access for farmers (Aayog, 2017)

One of the major challenges faced by the agriculture sector in Uttar Pradesh is land fragmentation, with the average landholding size being relatively small at 0.78 hectares (Agriculture Census 2015-16). This fragmentation makes it difficult for farmers to adopt modern farming practices and achieve economies of scale. Additionally, there is a need to promote crop diversification, high-value agriculture, and value addition to increase farmer incomes and enhance the competitiveness of the agricultural sector (Pradesh, Uttar Pradesh Agricultural Policy, 2013).

Continued investment in agricultural research, technology transfer, and extension services is crucial for promoting sustainable and productive farming practices in Uttar Pradesh. Institutions like the Indian Institute of Pulses Research (IIPR), Central Institute for Subtropical Horticulture (CISH), and renowned agricultural universities like Govind Ballabh Pant University of Agriculture and Technology (GBPUAT) and Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUAT) play a vital role in driving innovation and addressing the challenges faced by the state's farming community.

1.11. Major Crops in the State

Uttar Pradesh is a major agricultural state in India, with a diverse range of crops cultivated across its different regions. The state is the largest producer of wheat in the country, contributing around 37% of the total wheat production. Rice is another significant cereal crop, with Uttar Pradesh accounting for approximately

13% of the national rice production. In the cash crop segment, sugarcane takes the lead, with the state being the second-largest producer, contributing nearly 27% of India's total sugarcane output. Pulses, such as pigeon pea (arhar/tur), chickpea (gram/bengal gram), and lentils (masur), are widely grown, catering to the protein requirements of vegetarian diets. Oilseeds like mustard and groundnut are also major crops, with mustard being the primary source of edible oil in the state.

Uttar Pradesh is a leading producer of potatoes and peas, along with other vegetables like cauliflower, cabbage, tomatoes, and onions. The state is known for its high-quality mangoes, particularly from the Malihabad region near Lucknow, and also contributes significantly to the production of banana and guava. Spices and condiments, including chili and turmeric, are cultivated in various districts of Uttar Pradesh, adding to the diversity of crops grown in the state.

Table 4: Cost of Production in Uttar Pradesh

Crop	Cost of Production for Uttar Pradesh (₹ per quintal)	Cost of Production for all India (₹ per quintal)
Paddy	1,820	1,360
Wheat	1,710	1,065
Jowar	1,542	1,977
Bajra	1,425	1,268
Maize	1,250	1,380
Arhar/Tur (Pigeon pea)	3,890	4,131
Moong	5,270	5,167
Udad	4,860	6,732
Gram	3,120	3,205
Cotton	4,230	4,053
Soybean	2,950	2,805
Sugarcane	150	162

Table 5: Major Crops in the State

Season	Crops
Rabi	Wheat, Gram, Mustard, Barley
Kharif	Rice, Jute, Sugarcane, Cotton, Arhar, Bajra, Groundnut, Maize
Zaid	Watermelon, Muskmelon, Bittergourd, Pumpkin, Cucumber

Following are the main horticulture crops grown in different parts of the state: [9]

Table 6: Main horticulture crops in UP

Fruits	Mango, Guava, Litchi, Amla, Banana, Bael, Ber, Citrus
Vegetables	Potato, Peas, Onion, Brinjal, Cucumber, Parwal, Tomato, Okra, Cauliflower, Cabbage, Lobia & other cucurbits.
Spices	Garlic, Chillies, Ginger, Turmeric, Coriander.
Floriculture	Rose, Tuberose, Gladiolus, Marigold, Jasmine
Aromatic/ Medicinal Plants	Mentha, Aloe vera, Ashwagandha, Tulsi, Sarpa Gandha & Damask rose, etc
Others	Betel vine, Mushroom, Honey production

Uttar Pradesh boasts a diverse array of crops cultivated across different seasons, reflecting the state's rich agricultural heritage. During the rabi season, wheat emerges as the dominant crop, with Uttar Pradesh being the largest producer of wheat in the country. Other rabi crops, such as gram (chickpea), mustard, and barley, also hold significant importance. In the kharif season, rice takes center stage, with the state contributing substantially to the national rice production. Cash crops like sugarcane, cotton, and arhar (pigeon pea) are also widely cultivated during this period, along with coarse cereals like bajra (pearl millet) and groundnut. The zaid season, which falls between the rabi and kharif seasons, is characterized by the cultivation of various cucurbitaceous crops, including watermelon, muskmelon, bitter gourd, pumpkin, and cucumber. These crops not only contribute to the state's agricultural diversity but also play a crucial role in meeting the nutritional needs of the population.

Uttar Pradesh is also a significant producer of various horticulture crops. The state's fertile land and favorable climatic conditions support the cultivation of a wide range of fruits, including mangoes, guavas, litchis, amla, bananas, bael, ber, and citrus fruits. In the vegetable segment, potatoes, peas, onions, brinjals (eggplants), cucumbers, parwal (pointed gourd), tomatoes, okra, cauliflowers, cabbages, and various cucurbits are grown extensively across different regions. Additionally, Uttar Pradesh plays a vital role in the production of spices, with garlic, chilies, ginger, turmeric, and coriander being among the main spice crops cultivated. The state is also known for its floriculture industry, with rose, tuberose, gladiolus, marigold, and jasmine being the prominent flower crops. Furthermore, aromatic and medicinal plants, such as mentha, aloe vera, ashwagandha, tulsi, sarpa gandha, and damask rose, are grown, contributing to the state's diverse agricultural portfolio. Complementing these crops are other agricultural products like betel vine, mushrooms, and honey production, which add to the state's agricultural wealth and provide livelihood opportunities for farmers across various regions of Uttar Pradesh.

Share and Rank (Area and Production)

- Uttar Pradesh is estimated to account for roughly 11% of India's net sown area. [Source: Agricultural Production Trends and Cropping Pattern in Uttar Pradesh: An Overview, IJAIR]

In terms of production, Uttar Pradesh is a major contributor, especially for these crops

- **Wheat:** The state produces around 38% of India's total wheat. [Source: Agricultural Production Trends and Cropping Pattern in Uttar Pradesh: An Overview, IJAIR]
- **Potato:** Uttar Pradesh is the undisputed leader, contributing an estimated 31.26%% of India's total potato production.
- **Sugarcane:** Uttar Pradesh ranks the highest, contributing around 21% of India's sugarcane production. [Source: Agricultural Production Trends and Cropping Pattern in Uttar Pradesh: An Overview, IJAIR]

1.12. Position of state in the livestock, poultry, milk, honey, wool, meat, etc. animal products

Table 7: Position of UP in various components

Sl No.	Components	Rank	Other information
1	**Livestock**	1	Uttar Pradesh has 67.8 million livestock (released by department of Animal Husbandry and Dairying in year 2012)
2	**Poultry**	3	3.59 lakh tons Poultry meat production during 2018-19
3	**Milk**	1	36 million metric tons in year 2023
4	**Honey**	1	Accounting for over 30% of the country's honey production.
5	**Wool**	3	In the year 2019-2020, Uttar Pradesh produced 11,672 tons of wool, which accounts for about 14.32% of the total wool production in the country.
6	**Meat**	3	Production rate 12.14%

Uttar Pradesh holds a prominent position in the horticulture sector, contributing significantly to the production of various fruits, vegetables, spices, and other crops. According to the data, the state accounts for an average productivity of 21 quintals per hectare in the horticulture sector. Vegetables occupy the largest area under cultivation, with an area of 1326.92 thousand hectares and a production of 29940.09 thousand metric tons. Fruits follow closely, with an area of 505.13 thousand hectares and a production of 11113.86 thousand metric tons. Spices and aromatics & medicinal plants also play a crucial role, with an area of 565.59 thousand hectares dedicated to their cultivation.

Uttar Pradesh's agricultural dominance extends beyond horticulture crops. The state accounts for roughly 11% of India's net sown area and is a major contributor to the production of several essential crops. Notably, Uttar Pradesh produces around 38% of India's total wheat and contributes an impressive 31.26% to the country's potato production. Additionally, the state ranks highest in sugarcane production, contributing approximately 21% of India's total sugarcane output.

Furthermore, Uttar Pradesh holds a significant position in the livestock and animal products sector. With 67.8 million livestock, the state ranks first

in the country. It is also the leading producer of milk, accounting for 36 million metric tons in 2023, and honey, contributing over 30% of the country's honey production. In terms of poultry, Uttar Pradesh ranks third, with a poultry meat production of 3.59 lakh tons during 2018-19. The state also holds a notable position in wool production, ranking third with an output of 11,672 tons in the year 2019-2020, accounting for about 14.32% of the total wool production in India. Additionally, Uttar Pradesh ranks third in meat production, contributing 12.14% to the country's total meat output.

These statistics highlight Uttar Pradesh's diverse and robust agricultural sector, encompassing a wide range of crops, livestock, and animal products. The state's favorable climatic conditions, fertile lands, and dedicated efforts in agriculture have contributed to its remarkable position as a leading producer of various agricultural commodities, playing a crucial role in ensuring food security and economic prosperity for the nation.

1.13. Income of the Agriculture Sector in the State

The Economic Survey for 2022-23 highlights that as of 2021, 65% of India's population resides in rural areas, with 47% of the populace depending on agriculture for their livelihoods. Total population of Uttar Pradesh is approximately 24.14 Crores and rural Population of is 16,67,91,591. It means 65 per cent (2021 data) of the country's population lives in the rural areas and 47 per cent of the population is dependent on agriculture for livelihood. In the fiscal year 2022-23, Uttar Pradesh's Gross State Domestic Product (GSDP), when adjusted for inflation, expanded by 8.3%, down from the 10.2% growth observed in 2021-22. Comparatively, the national Gross Domestic Product (GDP) is expected to increase by 7.2% in 2022-23. Additionally, the agriculture sector in Uttar Pradesh experienced a growth of 10% during the same period, as opposed to a 14% growth in 2021-22, as measured by current prices. (India, 2023)

- **Crop Production:** Uttar Pradesh plays a crucial role in India's agriculture, especially in cultivating crops such as rice, wheat, sugarcane, and pulses. Ministry of Agriculture & Farmers' Welfare data consistently places Uttar Pradesh among the leading states in producing rice, wheat, and sugarcane. For instance, in the crop year of 2020-2021, Uttar Pradesh harvested around 37 million metric tons of rice and 33 million metric tons of wheat, making a substantial contribution to the country's overall food grain output.

- **Sugarcane Industry:** Uttar Pradesh stands out as India's primary producer of sugarcane, exerting a significant influence on the nation's sugar sector. The state's sugarcane cultivation is pivotal in fulfilling India's sugar requirements and holds considerable importance in the overall national sugar economy. Uttar Pradesh's sugar mills generate considerable income through various avenues, including sugar manufacturing, ethanol production, and the utilization of by-products such as molasses.

- **Livestock Sector:** Uttar Pradesh holds a significant position in India's livestock industry, especially concerning milk production. In the fiscal year 2019-2020, the state produced more than 30 million metric tons of milk, establishing itself as one of the top contributors to India's dairy sector. The income generated from milk sales, dairy goods, and other

activities related to livestock further enhances the agricultural sector's overall revenue in Uttar Pradesh.

Uttar Pradesh is largely dominated by small and marginal farmers with 93 % of agricultural households operating 65% of the land. The average landholding size declined marginally from 0.76 ha in 2010-11 to 0.73 ha in 2015-16. Agriculture is the main occupation in the state. According to the situation assessment of agriculture households Uttar Pradesh had 18 million Agri-households which announced for 20% of the total agricultural households in rural area.

Table 8: Income in farm and non farm sources

Sources of farm Income (%)				Source of Non- Farm income (%)						
Farmers Category	Agri-culture Income	Agri-culture Wage Income	Total	Casual Wages Income	Salary	Business	Subsidy	Remi-ttances	Other	Total
Marginal	0.43	0.07	0.50	0.23	0.09	0.10	0.05	0.01	0.02	0.50
Small	0.59	0.05	0.64	0.14	0.08	0.08	0.05	0.00	0.01	0.36
Medium	0.69	0.03	0.71	0.11	0.05	0.07	0.04	0.00	0.02	0.29
Large	0.65	0.00	0.65	0.10	0.13	0.08	0.04	0.00	0.00	0.35

The table provided presents a breakdown of income sources for different categories of farmers in Uttar Pradesh, categorized into farm income and non-farm income sources.

Farm Income Sources

The table shows that for all farmer categories (marginal, small, medium, and large), agriculture income and agriculture wage income constitute the primary sources of farm income. However, the contribution of agriculture income is higher for medium (0.69) and large (0.65) farmers compared to marginal (0.43) and small (0.59) farmers. On the other hand, agriculture wage income plays a more significant role for marginal (0.07) and small (0.05) farmers, indicating their reliance on agricultural labor as an additional income source.

Non-Farm Income Sources

The table highlights several non-farm income sources, including casual wages income, salary, business, subsidy, remittances, and other sources. For marginal farmers, casual wages income (0.23) is the most significant non-farm income source, followed by business (0.10) and salary (0.09). As the farm size increases, the contribution of casual wages income decreases, with large farmers relying more on salary (0.13) and business (0.08) as non-farm income sources.

Subsidy and remittances play a relatively minor role in non-farm income across all farmer categories, with marginal farmers receiving a slightly higher share of subsidy (0.05) and remittances (0.01) compared to other categories.

Overall, the data suggests that while agriculture income remains the primary source of income for all farmer categories, non-farm income sources become increasingly important, particularly for marginal and small

farmers. Diversification of income sources through non-farm activities, such as casual labor, salaried employment, and business ventures, is a common strategy adopted by farmers to supplement their agricultural income and mitigate risks associated with agricultural production.

Table 9: State-wise/UT-wise Average monthly income per agricultural household (Considering paid out expenses only) during the agricultural year July 2018-June 2019

State/ Group of UTs	Average monthly income per agricultural household (₹)
Andhra Pradesh	10,480
Arunachal Pradesh	19,225
Assam	10,675
Bihar	7,542
Chhattisgarh	9,677
Gujarat	12,631
Haryana	22,841
Himachal Pradesh	12,153
Jammu & Kashmir	18,918
Jharkhand	4,895
Karnataka	13,441
Kerala	17,915
Madhya Pradesh	8,339
Maharashtra	11,492
Manipur	11,227
Meghalaya	29,348
Mizoram	17,964
Nagaland	9,877
Odisha	5,112
Punjab	26,701
Rajasthan	12,520
Sikkim	12,447
Tamil Nadu	11,924
Telangana	9,403
Tripura	9,918
Uttarakhand	13,552
Uttar Pradesh	**8,061**
West Bengal	6,762
Group of N E States	16,863
Group of UTs	18,511
All India	**10,218**

(Source: NSS Report No. 587: Situation Assessment of Agricultural Households and Land and Livestock Holding of Households in Rural India, 2019, https://pib.gov.in/PressReleasePage.aspx?PRID=1884228)

The table presents the state-wise/union territory-wise average monthly income per agricultural household in India during the agricultural year July 2018 to June 2019, considering only the paid-out expenses. According to the National Sample Survey (NSS) Report No. 587, the average monthly income per agricultural household in India during the agricultural year July 2018 to June 2019, considering paid-out expenses, was ₹10,218. However, there were significant variations across different states and union territories. Meghalaya recorded the highest average monthly income per agricultural household at ₹29,348, followed by Punjab at ₹26,701, and Haryana at ₹22,841. These states are known for their relatively advanced agricultural practices and higher productivity levels.

On the other hand, Jharkhand had the lowest average monthly income per agricultural household at ₹4,895, followed by Odisha at ₹5,112, and Bihar at ₹7,542. These states have a higher concentration of marginal and small-scale farmers, often facing challenges related to resource constraints, infrastructure, and access to modern agricultural technologies.

Several other states, including Uttar Pradesh (₹8,061), Madhya Pradesh (₹8,339), and Chhattisgarh (₹9,677), also reported relatively lower average monthly incomes per agricultural household compared to the national average. States like Kerala (₹17,915), Jammu & Kashmir (₹18,918), and Arunachal Pradesh (₹19,225) had higher average monthly incomes, possibly due to factors such as cash crop cultivation, horticulture, or other region-specific agricultural activities.

1.14. Mechanization of agriculture

Uttar Pradesh, a major agricultural state in India, is undergoing a gradual process of mechanization. While traditional methods are still prevalent, the government and private initiatives are pushing for increased adoption of farm machinery.

Level of Mechanization

As of 2018, Uttar Pradesh had an average farm power availability of 2.836 kW/ha, reflecting a moderate level of mechanization compared to the national average. This moderate level can be attributed to a blend of traditional farming practices and a gradual shift towards mechanization, hampered by financial constraints and limited access to modern equipment. Tractor ownership, a key indicator of mechanization, shows moderate density in the state, influenced by factors such as financial barriers, small landholdings that don't justify heavy machinery investments, and reliance on traditional methods, with tractor rental services potentially reducing the need for individual ownership.

1.15. Agricultural Markets

Uttar Pradesh boasts a diverse array of crops, ranging from essentials like wheat, rice, and pulses to lucrative cash crops such as sugarcane and potatoes. Additionally, vegetables, fruits, notably mangoes, thrive in the state's fertile soil. The market system in UP is a blend of various types, comprising 381 regulated markets spread throughout the region, ensuring stability and guaranteed prices. These regulated markets are complemented by rural markets, wholesale hubs, and collection centers. To modernize and expand market access, Uttar Pradesh is actively adopting initiatives like e-NAM (National Agriculture Market), facilitating connections between farmers and distant markets, potentially leading to improved prices. Moreover, UP is rapidly emerging as a key player in agricultural exports, witnessing substantial growth in

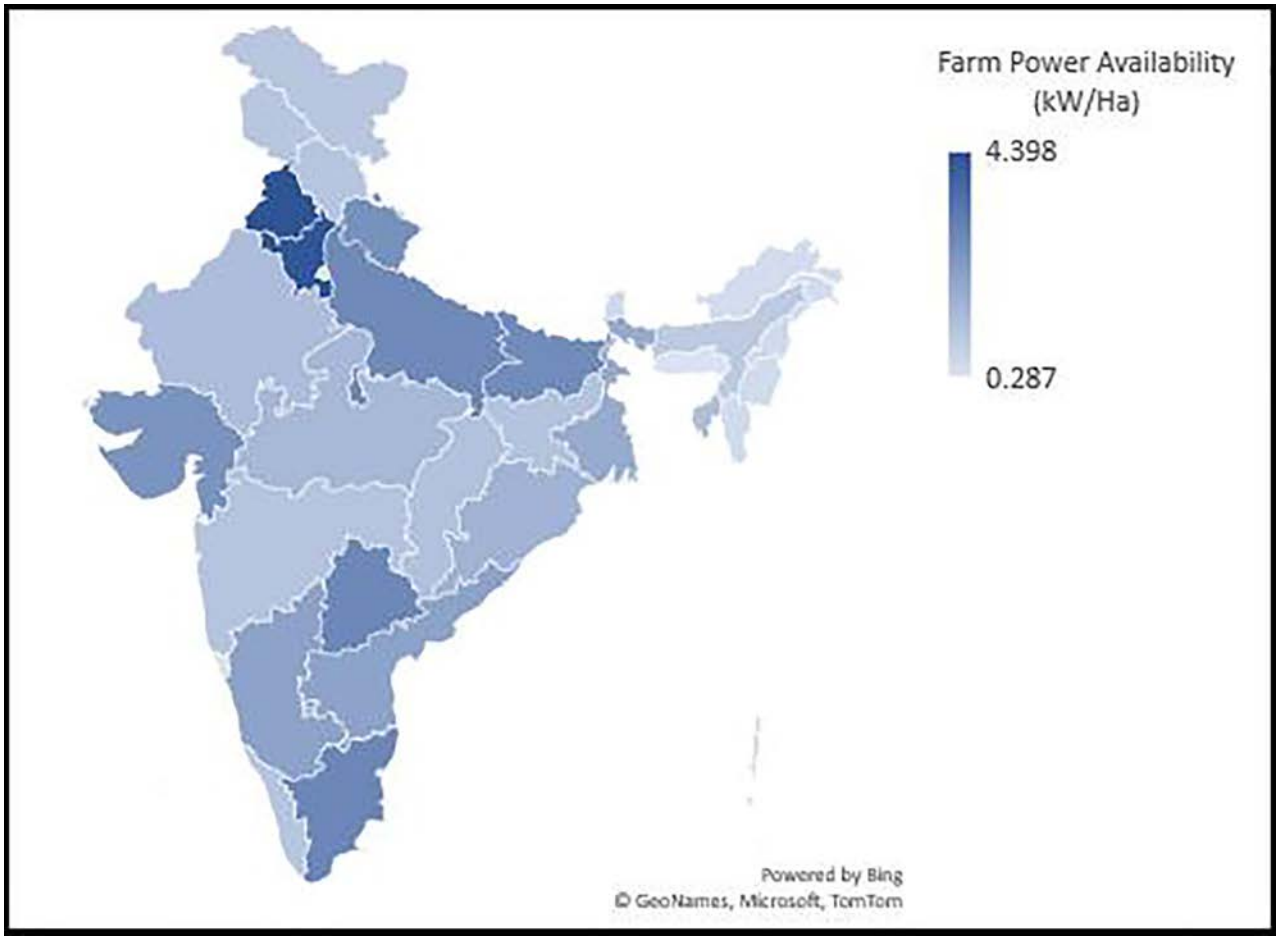


Figure 3: Farm Power availability in India

the export value of products like onions, processed vegetables, wheat, and maize. The state boasts a robust market network, encompassing government-regulated markets (APMC Mandis), subordinate markets serving rural areas, and private markets, including direct purchase arrangements with companies, all contributing to the dynamic agricultural market landscape in Uttar Pradesh.

1.16. Minimum Support Price

The Minimum Support Price of selected crops is announced by the Government of India in advance of the growing seasons. The objective of providing MSP is to guarantee the price and assured market to the farmers against the fluctuations in the price. The crops that the government of India announces MSP for are Paddy, Jowar, Bajra, Maize, Ragi, Tur (Arhar), Moong, Udad, Groundnut, Sunflower seed, Soybean, Sesamum, Nigerseed, Cotton during Kharif season and Wheat, Barley, Gram, Lentil (Masur), Rapeseed/ Mustard, Safflower, etc. during the Rabi season and Jute, Sugarcane, Copra, etc. commercial crops.

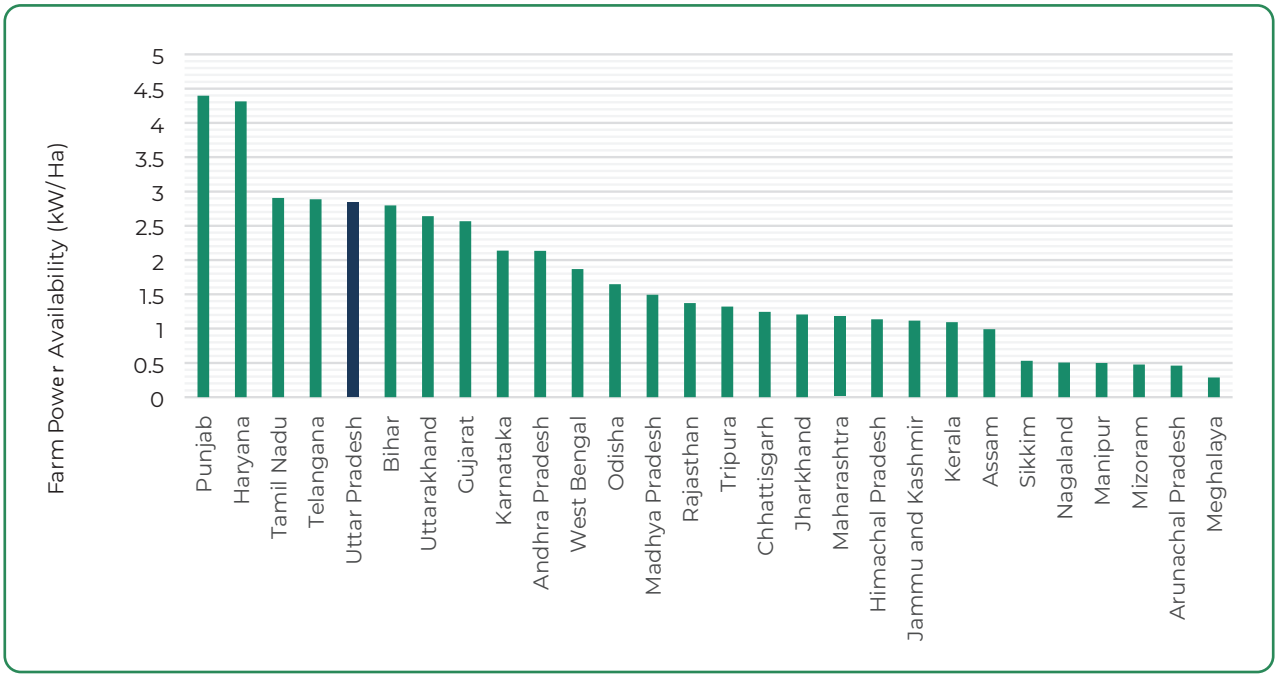


Figure 4: Average monthly income per agricultural household

2. Status of Resources in Uttar Pradesh

2.1. Land

Land is the most important natural resource for both solar and agriculture sectors. The availability of land for new solar PV projects in GW scale is a key issue and must be addressed through approaches such as agrivoltaics. Land utilization is an important statistics that needs to be studied prior to the implementation of agrivoltaics. As the implementation of agrivoltaics on agricultural land is subject to availability of continuous patches of lands, the level of fragmentation of the operational holdings becomes crucial in understanding the suitability of agrivoltaics in the state and district levels. This section presents an overview of the relevant statistics of the operational agricultural holdings and land utilization statistics. The total geographical area of Uttar Pradesh is 29.44 million hectare and the area under forest 1657023 hectare. The cultivable area is 24170403 hectare (82.1% of total geographical area) and the net area sown is 16573478 hectare (68.5% of cultivable area). The gross cropped area is 25.415 million hectare and the area sown more than once is 8.841 million hectare with the cropping intensity of 153.54 %. The net irrigated area is 13.313 million hectare (By canals- 25.18 %, by tubewells- 66.94% and by others – 7.88%). The gross irrigated area is 19.218 million hectare and the percentage of net irrigated sown area is 80.3%. The total number of land holdings are 224.57 lakhs out of which 175.07 lakh (78.0%) are marginal farmers, 31.03 lakh (13.8%) small farmers and 18.47 lakh (8.22%) farmers hold land above 2 hectare.

Table 10: 4 Number and area of operational holdings in U.P. by size Call of Holdings

Size Class (in hectares)	Total Holdings ('000)	Percentage	Total Area	Total Area
1	2	3	4	5
<1.0	19100	80.2	7298	41.8
1.0-2.0	3008	12.6	4175	23.9
2.0-4.0	1314	5.5	3560	20.4
4.0-10.0	377	1.6	2075	11.9
10.0 and above	23	0.1	343	2.0
Total	**23822**	**100.0**	**17450**	**100.0**

Source: Board of revenue, U.P. Figure 6 Land Utilization in UP

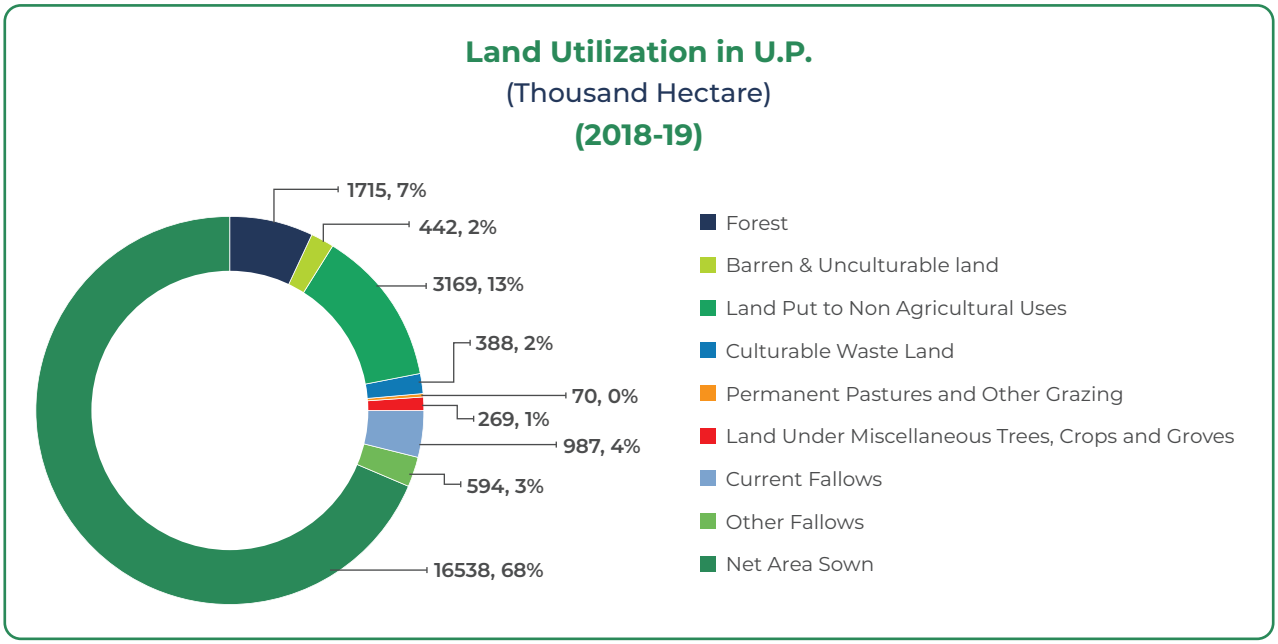


Figure 5: Land Utilization in UP

Table 11: 5 District-wise No. of Total, Marginal and Small holdings, and Agricultural Labourers Census

District	Total (All holding group)	Marginal (Below 1.0 hect.)	Small (1.0 to 2.0 hect.)	Agricultural Labourers
1	2	3	4	5
1 Saharanpur	259	169	51	211
2 Muzaffarnagar	339	236	59	251
3 Shamli	-	-	-	-
4 Bijnor	353	244	69	211
5 Moradabad	431	336	60	223
6 Sambhal	-	-	-	-
7 Rampur	207	148	36	151
8 Amroha	194	144	30	82
9 Meerut	209	148	35	112
10 Baghpat	116	81	20	49
11 Ghaziabad	172	128	28	83
12 Hapur	NA	NA	NA	NA
13 Gautam Buddha Nagar	87	68	12	28
14 Bulandshahar	349	262	55	137
15 Aligarh	289	194	54	149

District	Total (All holding group)	Marginal (Below 1.0 hect.)	Small (1.0 to 2.0 hect.)	Agricultural Labourers
1	2	3	4	5
16 Hathras	164	114	30	77
17 Mathura	177	93	39	90
18 Agra	260	169	51	136
19 Firozabad	179	123	33	88
20 Etah	251	193	39	80
21 Kasganj	185	142	30	64
22 Mainpuri	303	249	40	80
23 Budaun	581	452	87	158
24 Bareilly	460	365	64	211
25 Pilibhit	222	152	41	138
26 Shahjahanpur	409	306	65	175
27 Kheri	612	461	88	258
28 Sitapur	660	530	90	262
29 Hardoi	609	486	81	229
30 Unnao	487	403	59	157
31 Lucknow	246	207	27	103
32 Rae Bareli	332	274	39	174
33 Amethi	434	382	36	NA
34 Farrukhabad	250	185	29	97
35 Kannauj	257	216	31	83
36 Etawah	210	165	30	84
37 Auraiya	202	159	29	90
38 Kanpur Dehat	299	233	43	134
39 Kanpur Nagar	254	205	31	160
40 Jalaun	253	137	57	125
41 Jhansi	255	157	50	127
42 Lalitpur	207	101	65	59
43 Hamirpur	201	114	38	90
44 Mahoba	149	77	35	67
45 Banda	264	157	55	155
46 Chitrakoot	158	104	30	90
47 Fatehpur	402	305	67	205
48 Pratapgarh	488	433	39	128
49 Kaushambi	215	178	25	187

District	Total (All holding group)	Marginal (Below 1.0 hect.)	Small (1.0 to 2.0 hect.)	Agricultural Labourers
1	2	3	4	5
50 Prayagraj	552	453	60	235
51 Barabanki	466	401	47	226
52 Faizabad	341	305	27	106
53 Ambedkar Nagar	340	304	26	110
54 Sultanpur	382	343	29	190
55 Bahraich	506	425	56	223
56 Shrawasti	193	153	29	68
57 Balrampur	295	234	41	143
58 Gonda	500	430	50	200
59 Siddharth Nagar	406	339	50	133
60 Basti	332	285	33	94
61 Sant Kabir Nagar	226	196	21	73
62 Mahrajganj	386	338	34	154
63 Gorakhpur	473	411	44	164
64 Kushinagar	463	418	32	177
65 Deoria	390	340	35	86
66 Azamgarh	607	532	51	154
67 Mau	262	236	18	67
68 Ballia	380	322	37	161
69 Jaunpur	656	585	52	203
70 Ghazipur	416	352	42	220
71 Chandauli	191	161	18	82
72 Varanasi	268	251	14	98
73 Sant Ravidas Nagar	187	170	12	36
74 Mirzapur	273	211	38	151
75 Sonbhadra	196	132	34	147
76 Uttar Pradesh	23325	18532	3035	9750

Data Source: *https://updes.up.nic.in/esd/reports/diary%20eng%202021_merged.pdf*

2.2. Groundwater

Uttar Pradesh has four distinct geographical regions namely the Western, Eastern, Central and Bundelkhand Regions having distinct hydro-geological, climatic, agronomic, and socio-economic conditions. Water availability and its management completely differ across these regions underlining the need for region specific strategies and institutional strengthening at the State, regional and local level.

Major river basins are Yamuna, Ganga, Ramganga, Rapti, Ghaghra, Gandak, Gomti and Sone. It falls within the climatic zones Sub-humid to tropical climate with three distinct seasons- summer, monsoon, and winter. With the groundwater presence the state can be grouped in two regions:

a) The largest groundwater repository in the country is the Central Ganga Plain with 85% region under it, unconsolidated alluvium sediment of quarter age overlying the Precambrian basement. This alluvium is a rich reservoir of groundwater, with four aquifer zones and extremely varying. The shallow one is highly exploited

b) Remaining 15% area under Bundelkhand plateau with Bijawar and Vindhyan group. The present physiography and landforms are greatly determined by geological formations and structures and is the product of the past fluvial cycle of deposition from the Himalayan rivers. The State forms a part of Ganga basin. The master drainage of the state is river Ganga and its tributaries. The Ramganga, Ghaghra and Gomti are the main left bank tributaries, while the Yamuna is the main right bank tributary. All these rivers except Gomti originate from Himalayan ranges and are snow fed. Initially the rivers flow southward in the north-western part of the State, then turn south eastward and finally leave the State in an easterly direction.

2.3. Ground water availability and utilization

The ground water monitoring is being carried out through a network of observation wells- the National Hydrograph Network Stations (NHS). The National Hydrograph Network set-up is a system of spatially distributed observation points at which periodic monitoring of ground water and regime behaviour. The major portion of Uttar Pradesh is covered by Ganga-Basin. The state is known for having the richest repository of ground water resource as it comprises the largest aquifer systems in the world. The significance of the ground water resource can be judged by the fact that 75% of the irrigated agriculture is mainly dependent on ground water resources. The ground water availability in UP is estimated at 56.93 MAF. Allowing for other uses ground water useable for irrigation is about 48.42 MAF, of which 36.82 MAF is already being utilized.

- **Annual Replenishable Ground Water Resource:** 76.35 BCM (**BCM-Billion Cubic Meter**)
- **Net Available Ground Water Availability:** 70.18 BCM
- **Annual Ground Water Draft:** 48.78 BCM
- **Stage of Groundwater Development:** 70 %
- **Reserved for Drinking:** 8.52 BCM

Further, 80-90% of the drinking water and about 85% of all the industrial needs are fulfilled by ground water. In agriculture, industrial and urban areas after the decade of 70's, unprecedented development/ withdrawal of groundwater has been witnessed. While agricultural productivity has increased because of groundwater based irrigation, the contribution of this resource is also the maximum in fulfilling the water demand for drinking water and industrial sectors.

But due to its unplanned and unlimited exploitation, adverse effects are also being noticed which mainly include problems like water-level decline, reduced availability of groundwater, failure of tube-wells, ground-water pollution, etc. As a (2) result, and as a matter of concern, marked shortage is observed in ground-water resource availability in many parts of the state both in urban and rural areas.

2.4. Groundwater policies and governance in the State

Groundwater policies and governance in the State	
Uttar Pradesh State Water Policy, 2010	• There shall be constituted a Gram Panchayat Ground Water Sub Committee in every Gram Panchayat, which shall be the lowest public unit in rural areas within a block to protect and manage ground water resources under this Act. • There shall be constituted a Block Panchayat Ground Water Management Committee, which shall be a public unit at block level for overall management of ground water. • There shall be constituted a Municipal Water Management Committee, which shall be the lowest public unit for managing water in urban areas in an integrated manner. • There shall be constituted a District Ground Water Management Council, which shall be an overall unit for management of ground water resources at district level. Formation of state ground water management and regulatory authority.
Ground Water (Management and Regulation) Act, 2019 and Rules, 2020	• Constitution of Uttar Pradesh Ground Water Management and Regulatory Authority in the chairmanship of chief secretary • Constitution of ground water subcommittee at panchayat level Constitution of ground water management committee at block panchayat level and at the level of municipal body. • Constitution of ground water management council at district level. • The authority has power notify areas for management and regulation of ground water resources. • Registration of existing commercial, industrial, infrastructural and bulk users of Ground Water. • Preparation and implementation of Ground Water Security Plans in notified areas • Grant of Authorisation for Ground Water abstraction in Non-notified Areas
The Uttar Pradesh Participatory Irrigation Management Act, 2009 And Rules 2010	• Empowers water users' association (WUA) to manage and maintain the irrigation system given in its charge, and to do all things necessary, proper or expedient for the safety and security of the Government property under its control and management provided that no water users. • For the purpose of supply of bulk water to the water users' associations and related issues, the distributary level water users' association shall enter into an agreement with the Irrigation Department • Every water users' association shall prepare its crop plan according to its Water budgeting water budget taking into account conjunctive use of surface and ground water well before the crop season and accordingly plan a preliminary irrigation programme, in consultation with the competent canal officer

2.5. Irrigation

Regional Disparity in Terms of Irrigation Facilities

Uttar Pradesh has large regional variations in terms of irrigation facilities. The western region has the highest percentage of net irrigated area to the net sown area. Central and eastern regions are ranked second and third respectively. Bundelkhand region has the lowest percentage.

The western region has the highest net irrigated area followed by the eastern region. Bundelkhand has the least net irrigated area. Eastern region is the first in terms of area under canal irrigation and Bundelkhand is least.

In terms of area under well and tubewell irrigation, the western region ranks first and Bundelkhand is least. Bundelkhand is highest in terms of tank irrigation followed by the eastern region.

Meerut,Bagpat,Ghaziabad,Bulandshahar, Bagpat, Hapur (Meerut division) and Shamli have 100% net irrigated area to the net sown area.

On the other hand, Mahoba and Sonbhadra have 25%and 32.2% of the net sown area under irrigation.

Meerut division has the highest 100% net sown area under irrigation whereas Chitrakoot Dham division has the lowest amounting to 51%.

Important Terms Related to Irrigation

- **Net Irrigated Area** – It is the total of all the area irrigated in a year by any means of irrigation.
- **Gross Irrigated Area** – It is similar to the gross sown area. It is the total of the irrigated area under various crops during the same year. Area irrigated under each different crop is counted as a separate area for the calculation of gross irrigated area.
- **Irrigation Intensity** – It is the percentage of net irrigated area to the net sown area.

Table 12: 5 Net Irrigated Area by All Sources

Region	Net Irrigated Area by All Sources	Percentage of Net Irrigated Area to Net Sown Area
Western	5,841,063	96.8
Central	2,615,294	87.6
Eastern	4,607,951	82.5
Bundelkhand	1,167,138	62.4

Net Irrigated Area by Different Sources of Irrigation in the State

Table 13: Sources of Irrigation

S. No.	Source	Percentage Area
1	Tubewells	74.9
2	Canals	15.2
3	Wells	8.8
4	Ponds, Lakes etc.	0.5
5	Others	0.6

Means of Irrigation in the State

- Groundwater and surface water both are extensively used for irrigation in Uttar Pradesh. Tubewells and wells are used for groundwater irrigation whereas canals and ponds are used for surface-water irrigation.
- As per the statistics of 2015-16, tubewells are the largest source of irrigation in the state.
- Out of the total irrigated area, approximately 84% comes under well and tubewell irrigation.
- Out of the rest 15.2% under canal irrigation, 0.5% under tank irrigation and 0.6% are under other sources of irrigation.
- Net irrigated area in Uttar Pradesh in 2015-16 was 14,232 thousand hectares.

Sources of irrigation

Wells and Tubewells

- Wells and tubewells use underground water for irrigation. Tubewells and wells are one of the most widely popular means of irrigation. Traditionally Persian wheel Rabat, Charas were the methods of utilising groundwater.
- It is more prevalent in Ganga-Satluj Plains due to higher ground water table. Construction of Tubewell is easy and takes less time.
- Tubewell irrigation is the largest source of irrigation in the state and national level. Uttar Pradesh has the largest area under tubewell irrigation in the country.
- Most of the tubewells are privately owned. Persian wells, pump set on earth, pump set on boring, electric tubewells, diesel tubewells, deep tubewells, artizancoop, etc. are the different methods of well irrigation. Among these pump sets on boring and diesel tubewells are the most popular.
- Depletion of groundwater and high cost of electricity and diesel are the problems associated with tubewell irrigation.

Tanks, Lakes and Ponds

- Tanks, lakes and ponds are the main sources of irrigation in the areas which are out of canal network and the groundwater level is low.
- Bundelkhand region of Uttar Pradesh is traditionally dependent on tanks for irrigation and drinking water. A large number of ponds and lakes were constructed in Bundelkhand since ancient times. These lakesand ponds are used for collecting rainwater and later utilising it.
- In 2015-16, about 64,000 ha land in the state was tank irrigated. It is a significant decline from 2014-14 when 134,000-ha land was tank irrigated.
- Construction of tanks is a time consuming and expensive process. It is also dependent on rain and tanks may dry up during summer seasons.
- Other Means of Irrigation
- As per the statistics of 2015-16, approximately 83,000-ha land is under other sources of irrigation.
- Springs, kuhls, swing basket, dhenkti, dongs and bokka are the other sources of irrigation.

Canal Irrigation

- Canal irrigation is an effective method of irrigation in the northern plains where the perennial source of water in the form of the Himalayan rivers are available.
- Uttar Pradesh is ranked first in the country in terms of canal irrigation. Uttar Pradesh has a total of 2,166 thousand hectare area under canal irrigation. The state has a high concentration of canals in the western part.
- Problems of overirrigation, waterlogging and environmental impacts are associated with the canals. Interstate canal projects also become a cause of inter-state disputes sometimes.

Minor Irrigation Resources

- Minor irrigation resources may be government-owned or private owned. It includes both surface water and groundwater irrigation projects.
- More than 80% of the total irrigation in the state is done by minor irrigation resources. Private minor irrigation resources are more than 70 % of the total irrigation resources.
- Tubewell, check dam, minor canals, etc. are included in minor irrigation resources.
- The minor irrigation department of the state provides technical and financial assistance to make farmers self-sufficient in termsof irrigation facilities.
- **Minor Dal (Lift) Irrigation Projects:** Following minor dal (lift) irrigation projects are being operated by the State Government.
  - Dr Ram Manohar Lohia Govt. Tubewell Modernisation Project
  - Modernisation of existing Minor Dal irrigation canal
  - Deum Pump Canal Project, Pratapgarh
  - Adsad New Pump Canal Project
  - Dohrighat Pump Canal Project, Mirzapur
  - Chari New Pump Canal Project

Schemes/ Projects for Micro Irrigation

- Pradhan Mantri Krishi Sichai Yojna (Per Crop More Drop) – This scheme is applicable in all the districts of the State. Farmers are being provided subsidies up to 90% for setting up micro-irrigation systems.
- Kulpahar Sprinkler Irrigation Project – This project is aimed to create a sprinkler irrigation facility by pumping water from Arjun dam. The project will benefit Kulpahar of Mahoba district.
- Masagaon and Chilli Sprinkler System– This project is financed under the Bundelkhand package. It aims tocreate sprinkler irrigation facilities in Masagaon and Chilli villages of Hamirpur.
- Shahzad Sprinkler Irrigation Project – Under this project, sprinkler irrigation facilities for Paraun, Rajpura, Baroda Dang, Baswaha, etc. villages of Lalitpur district have been constructed.

Table 14: 6 Percentage of gross irrigated area to total cropped area for Indian states.

Sr. No.	State/Territory	Percentage of Gross Irrigated Area to Total Cropped Area
1	Ladakh	100
2	Haryana	99.1
3	Punjab	97.5
4	Puducherry	85.7
5	**Uttar Pradesh**	**80.5**
6	Bihar	76.4
7	Telangana	69.6
8	Gujarat	68.9
9	West Bengal	65.9
10	Delhi	62.7
11	Tamil Nadu	61.3
12	Uttarakhand	56.5
13	Madhya Pradesh	56.1
	All India	**54.9**
14	Andhra Pradesh	53.4
15	Rajasthan	43.2
16	Jammu and Kashmir	42.6
17	Karnataka	41.3
18	Chhattisgarh	37.6
19	Meghalaya	34.8
20	Odisha	29.9
21	Maharashtra	24.3
22	Himachal Pradesh	23.7
23	Tripura	23.6
24	Kerala	22.2
25	Goa	20.2
26	Arunachal Pradesh	18.7
27	Nagaland	15.9
28	Chandigarh	15.8
29	Manipur	15.7
30	Assam	14.4
31	Mizoram	14
32	Sikkim	10
33	Dadra, Nagar Haveli and Daman and Diu	7.4
34	Andaman and Nicobar Islands	0.8
35	Lakshadweep	

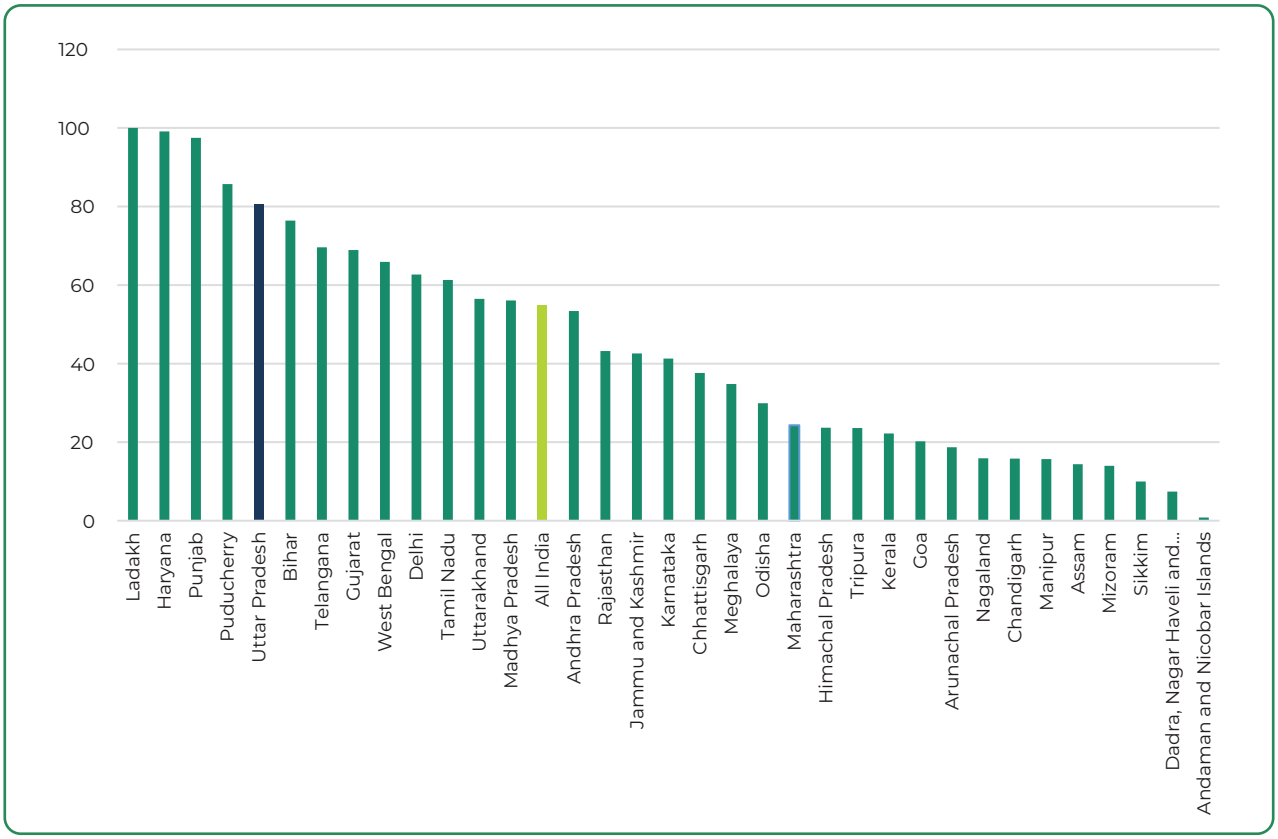


Figure 6: Percentage of gross irrigated area to total cropped area for Indian state

2.6. Electricity

Generation of Electricity

As of 2021, Uttar Pradesh has a total installed power capacity of around 27,000 MW, and it produced around 142 billion units of electricity in 2020-21. The state has set a target to achieve a 10% share of renewable energy in its energy mix by 2022. As of 2021, the percentage of renewable energy in the state's energy mix is around 4%. Uttar Pradesh has a huge potential for solar power generation, and the state government has taken various initiatives to promote solar energy, such as the installation of solar rooftop panels, solar power parks, and solar irrigation pumps. As of 2021, the installed solar power capacity in the state is around 1,600 MW.

Table 15: 8 Central Sector generating stations

Sl. No.	Name of Power Station	Owner	Prime Mover	Total installed Capacity (MW)
1	DADRI(NCTPP)	NTPC	Steam	(210*4) + (490*2) = 1820
2	RIHAND STPS	NTPC	Steam	500*6 = 3000
3	SINGRAULI STPS	NTPC	Steam	(200*5) + (500*2) = 2000
4	TANDA TPS	NTPC	Steam	(110*4) + (660*2) = 1760
5	UNCHAHAR TPS	NTPC	Steam	210*5 + 500 = 1550
6	MEJA STPP	MUNPL	Steam	660*2 = 1320
7	DADRI CCPP	NTPC	GT/ST-Gas	(130*4) + (154*2) = 828
8	AURAIYA CCPP	NTPC	GT/ST-Gas	(111*4) + (109*2) = 662

Source: https://cea.nic.in/wp-content/uploads/pdm/2023/05/List_of_Power_Stations_31.03.2023.pdf

The UP* Government has claimed that state owned power plants managed to generate 39,691 million units of power in 2022-23 which was a record till date. The maximum electricity produced by power plants of UP Rajya Vidyut Utpadan Nigam was in 2018-19 when 37,657 MU were generated. This way the state produced 5.40% more power in comparison to 2018-19. In 2022-23 fiscal, UPRVUNL owned power plants like Anpara Obra, Paricha and Harduaganj thermal projects generated a total of 39,691 million units of power which is 13.33% more than the total gross power generation of 35,022 million units in 2021-22., a state government spokesperson said.

Table 16: 20 State Sector generating stations

Sl. No.	Name of Power Station	Installed Capacity	Derated Capacity	Total Capacity
1	ANPARA, ONEBHADRA	3×210 MW, 2×500 MW, 2×500MW	3×210 MW = 630 MW, 2×500 MW = 1000 MW, 2×500MW = 1000 MW	2630 MW
2	OBRA, SONEBHADRA	1×100 MW, 5×200 MW	1×94 MW = 94 MW, 5×200 MW = 1000 MW	1094 MW
3	PARICHHA, JHANSI	2×110 MW, 2×210 MW, 2×250 MW	2×110 MW = 220 MW, 2×210 MW = 420 MW, 2×250 MW = 500 MW	1140 MW
4	HARDUAGANJ, ALIGARH	1X110 MW, 1X660 MW , 2X250 MW	1×110 MW = 110 MW,1×660 MW = 660 MW, 2×250 MW = 500 MW	1270 MW
5	Total UPRVUNL Generation Capacity			6134 MW

Source: https://www.uprvunl.org/introduction

The state Power plants functioned at 76.44% Plant Load Factor(PLF). This was more than 68.80%, 69.71% and 71.82% in 2019-20, 2020-21 and 2021-22 respectively.

The 2*500 units of Anpara Thermal Power station Produced electricity at a record 95.75% annual plant load Factor(PLF). The unit generated the highest ever gross power generation of 8388 million units.

Table 17: Private Sector generating stations

Sl. No.	Name of Power Station	Owner	Prime Mover	Total installed Capacity (MW)
1	KHAMBARKHERA TPS	BEPL	Steam	45*2 = 90
2	MAQSOODPUR TPS	BEPL	Steam	45*2 = 90
3	BARKHERA TPS	BEPL	Steam	45*2 = 90
4	UTRAULA TPS	BEPL	Steam	45*2 = 90
5	KUNDARKI TPS	BEPL	Steam	45*2 = 90

Source: https://cea.nic.in/wp-content/uploads/pdm/2021/06/list_power_stations_2021.pdf

2.7. Solar Power Generation

With roughly 1 GW of commissioned capacity as of May 2019, Uttar Pradesh's solar power uptake has been limited till now. This can be attributed to the state's low utilisable solar potential, policy irregularities, poor power supply infrastructure and unavailability of adequate land near major load centres. For making solar power development in Uttar Pradesh attractive for both developers and investors, the state authorities have introduced a slew of measures and revamped their existing policies. The state has revised its land allocation laws and stepped up its efforts to expand transmission infrastructure in the solar-rich Bundelkhand and Purvanchal regions. The state authorities are planning to add about 7,250 MW of solar power by 2023-24.

Table 18: 1 Installed capacity (in MW) of power utilities in Uttar Pradesh including allocated shares in joint & central sector utilities

State	Owner-ship/ Sector	Mode wise breakup									Grand Total
		Thermal					Nuclear	Renewable			
		Coal	Lignite	Gas	Diesel	Total		Hydro	RES* (MNRE)	Total	
Uttar Pradesh	State	7135.00	0.00	0.00	0.00	7135.00	0.00	724.10	49.10	773.20	7908.20
	Private	8814.33	0.00	0.00	0.00	8814.33	0.00	842.40	5116.47	5958.87	14773.20
	Central	5538.42	0.00	1029.51	0.00	6567.93	289.48	1857.52	30.00	1887.52	8744.93
	Sub-Total	**21487.75**	**0.00**	**1029.51**	**0.00**	**22517.26**	**289.48**	**3424.02**	**5195.57**	**8619.59**	**31426.33**

Source: *https://cea.nic.in/wp-content/uploads/installed/2024/03/IC_Mar_2024_allocation_wise.pdf*

2.8. Focus on rooftop solar

To make up for the limited available solar potential, Uttar Pradesh authorities have been encouraging large-scale rooftop solar deployment through innovative regulatory interventions. For instance, the Gautam Buddha University in Greater Noida, which has a sanctioned load of 4,000 kVA, wanted to expand its rooftop solar project from 0.5 MW to 3.34 MW for captive consumption. In a landmark order in November 2018, UPERC allowed net metering for a 3.34 MW rooftop solar project, thus relaxing the provisions of the UPERC (Rooftop Solar Grid-Interactive System Gross/Net Metering) Regulations, 2015.

Noida Power Company Limited (NPCL) also confirmed that it had no technical issues in providing grid-connectivity for the proposed capacity. In January 2019, UPERC released the Rooftop Solar Power Plant Regulations, 2019, which raised the cap for net-metered rooftop solar plants from 1 MW to 2 MW. The move is aimed at meeting the energy deficit of the state and reducing discoms' technical and financial losses. These regulations have fixed a tariff of Rs 2 per kWh for net-metered projects. However, the net metering facility is limited to residential and agricultural categories. Other consumer categories such as industries and commercial and public establishments can opt for gross metering. In doing so, UPERC aims to rationalise benefits for both consumers and discoms. For gross metering, the tariff is determined as the weighted average tariff for grid-connected solar projects of 5 MW and above capacity for the previous financial year plus a 25 per cent incentive.

2.9. Bioenergy uptake

Uttar Pradesh has about 1.9 GW of installed bagasse-based cogeneration capacity owing to the abundance of sugar industries in the state. These industries use the power generated from bagasse for captive consumption. However, the growth of these projects has slowed in recent years due to power offtake issues and unviable tariffs. To promote this segment and encourage developers to set up biomass projects, UPERC has adopted a transparent approach for project allocation. To this end, the commission disapproved three power purchase agreements (PPAs) for the procurement of 32.5 MW of bagasse-based power in December 2018. These PPAs had been signed as bilateral agreements after mutual consent despite the fact that UPPCL had initiated competitive bidding for the projects. This decision of UPERC prompted UPPCL to propose amendments to the bidding documents for the procurement of bagasse-based power from generators, which were approved by UPERC in January 2019. As per the amendments, an upper ceiling tariff of Rs 4.81 per kWh has been set for bagasse-based power and a separate charge of Rs 0.18 per kWh has been fixed for utilizing the existing transmission infrastructure. Further, in May 2019, UPERC directed UPPCL to conduct a transparent competitive bidding process for the procurement of power from congenators producing power from bagasse and spent wash.

2.10. Consumption of Electricity

Classification of consumers and connected load Uttar Pradesh utilities:

Table 19: 2 Classification of consumers and connected load Uttar Pradesh utilities

Category		Consumption
Domestic	Connected Load (KW)	38576858 KW
	Consumers	26467750
Commercial	Connected Load (KW)	4744360 KW
	Consumers	1623408
Industrial	Connected Load (KW)	2563711 KW
	Consumers	176251
Public Lighting	Connected Load (KW)	214526 KW
	Consumers	4680
Traction	Connected Load (KW)	108600 KW
	Consumers	10
Agriculture	Connected Load (KW)	8571784 KW
	Consumers	1330329
Public Water Works	Connected Load (KW)	503198 KW
	Consumers	23168
Miscellaneous	Connected Load (KW)	4101849 KW
	Consumers	215792
Total	Connected Load (KW)	63976311 KW
	Consumers	29854591

Source: https://cea.nic.in/wp-content/uploads/general/2022/GR_2022_FINAL.pdf

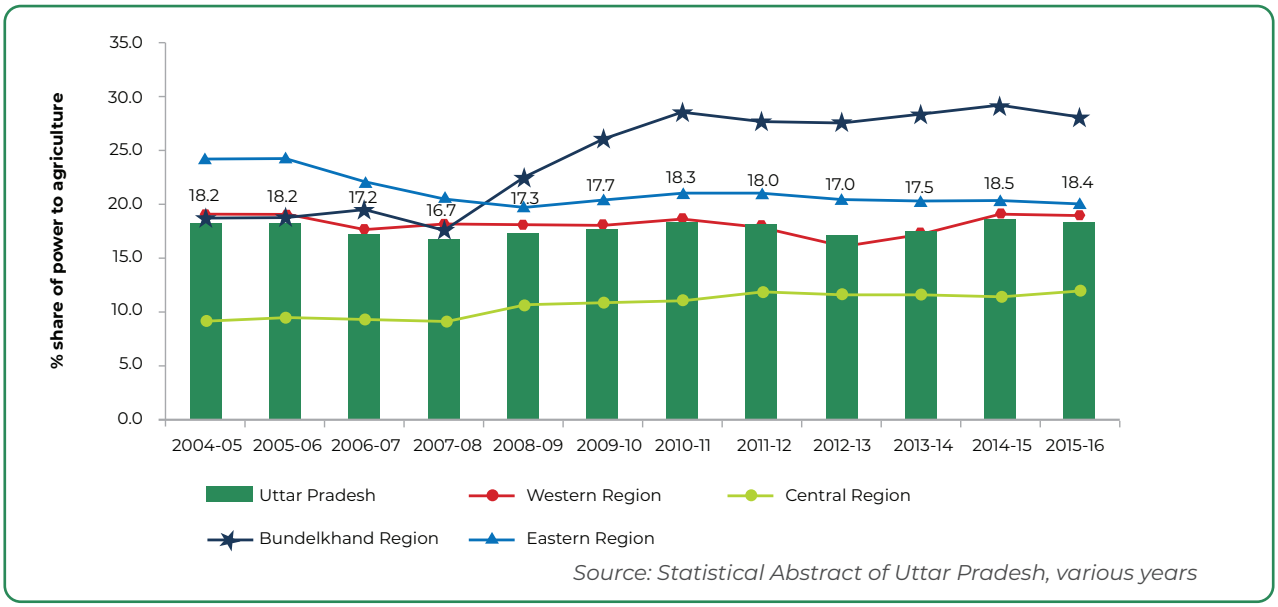
The state requires a healthy and sustainable power sector to accelerate agricultural growth and productivity. UP has the largest number of people without electricity, accounting for 49 per cent of the state's 38.2 million households (GSI, 2018). The per capita power consumption in the state was 524 kWh in 2016-17, much lower than the national average of 1075 kWh (GoUP, 2017a). The share of agriculture in total power consumption in the state has remained stagnant between 2004-05 and 2015-16. However, there are wide variations in power supply to the agricultural sector across the regions (Figure 13).

Table 20: 3 Irrigation pumpsets / tubewells energised in Uttar Pradesh

Number. of Pumpsets Energised up to 31.03.2020	Steam	997444
New Pumpsets Energised during the year 2020-21	Steam	66
No. of Existing Pumpsets Enersiged upto 31.03.2021	Steam	997510
Agricultural Consumption	Energy (GWh)	18931.27
	% of total Consumption in the state	17.92
Agriculture Connected Load (kW)		8571784
Average Capacity Pumpsets (kW)		8.59
Average consumption pe Pumpset (kWh)		18979

Source: https://cea.nic.in/wp-content/uploads/pdm/2021/06/list_power_stations_2021.pdf

The share of agriculture in power consumption in the eastern region was the highest among the regions in the early 2000s, but its share has come down from 24.2 per cent in 2004-05 to 20.2 per cent in 2015-16. There was no significant change in power consumption in the western region in the period from 2004-05 to 2015-16 while in the central region, which has the lowest power consumption among all the regions, power consumption in the agricultural sector increased from 9.3 per cent in 2004-05 to 15.5 per cent in 2015-16. The Bundelkhand region.



Source: https://icrier.org/pdf/Performance_of_Agriculture_in_UP_Report.pdf

Figure 7: Region Wise Power Consumption in agriculture sector

3. Evaluation of Agrivoltaics Potential in the state

3.1. Solar resources of the state

Uttar Pradesh experiences more than 300 days of sunshine. This abundant sunlight can easily be transformed into electricity. In fact, studies have shown that the solar potential of the state of around 22.83 GWp.

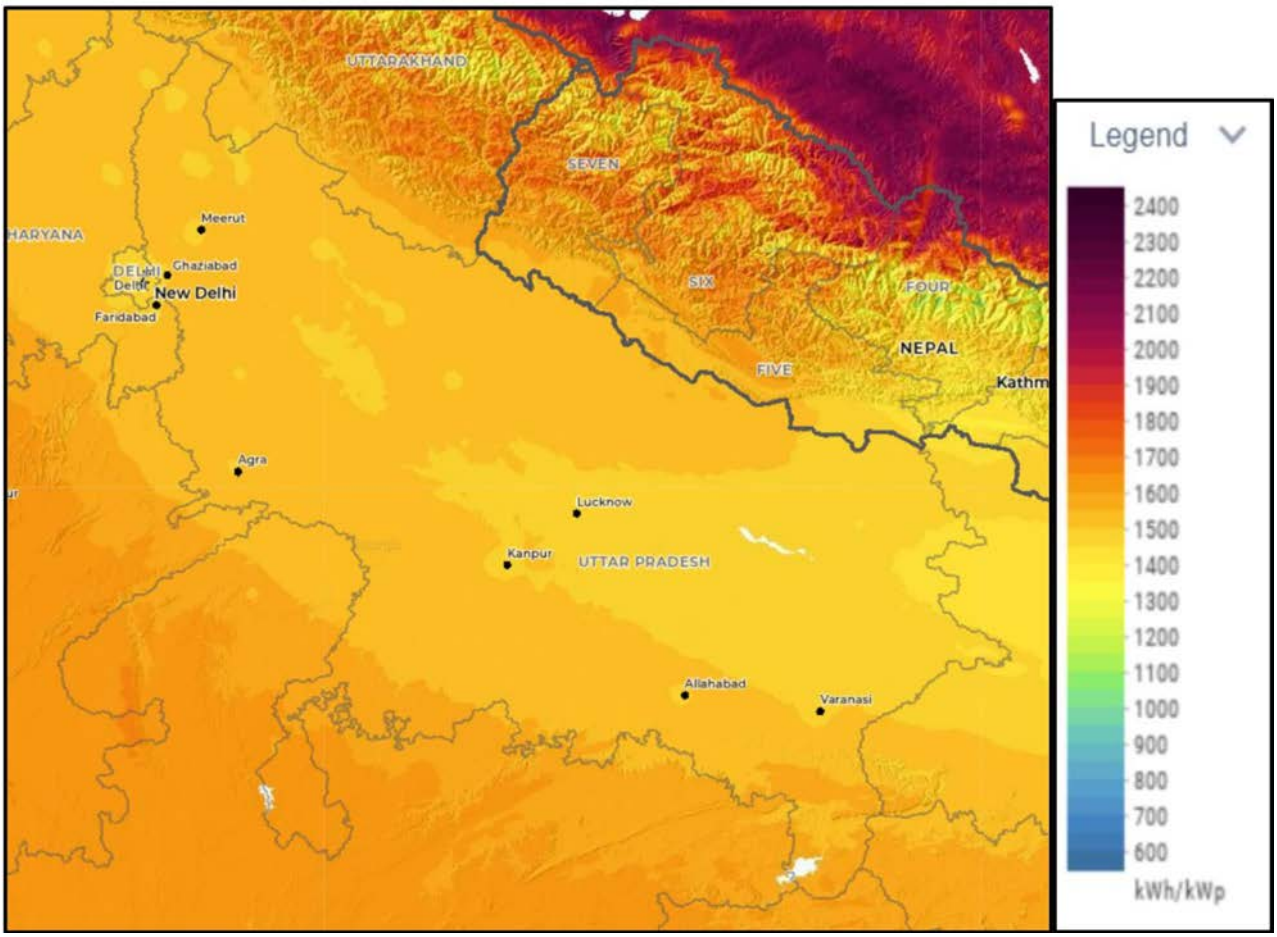


Figure 8: Solar Potential of the state

The abundance of solar resources in this area opens new doors for use of solar PV systems in order to fulfil the electricity demands. Such large-scale solar farms require a huge amount of land. This however challenges the paralleled increasing food demands by the booming population. This conflict between agriculture and solar PV questions the fundamental motivation

of sustainability behind the expansion of share of renewable resources. Agrivoltaics can be a very effective step to bring a sense of sustainability to the agricultural sector. Agrivoltaics is now being seen as a promising solution to cater ever-rising demands of both food and energy.

3.2. Solar Policy 2022

Toward the end of 2022, the UP government approved a new solar policy that will be in effect till 2026-27. The Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) will act as a nodal agency for implementing it.

Some of the key highlights of the document are as follows:

- The state government plans to establish solar cities, aiming for a minimum 10% reduction in traditional electricity consumption by transitioning to renewable energy sources.
- UPNEDA will create a land bank, with areas that are not suitable for agriculture for the development of solar projects.
- Government buildings, including schools and Anganwadi centres, will be solarized.
- The net metering facility will also be given to residential consumers, government-owned public sector buildings, and all educational institutions.
- The government will promote the development of solar parks
- Solar equipment manufacturing units will receive a ten-year electricity duty exemption, promoting local product growth.

The state also recently announced Solar Policy 2022, with the target to generate 22 GW of solar power by 2026-27. Under this policy, UP is developing Ayodhya as a solar city and has approved a 40 MW project in the city.

In a bid to reduce air pollution and offset emissions, the state has also begun integrating solar with the transportation sector. The state has launched solar-powered ferry rides and has unveiled plans to install solar panels on the entire 296km stretch of Bundelkhand Expressway.

The government has also stated that it has received investment commitments of ₹2 lakh crore after the launch of its new solar policy.

Source: https://ornatesolar.com/blog/potential-of-solar-power-in-uttar-pradesh#:~:text=Uttar%20Pradesh%20experiences%20more%20than,solar%20capacity%20is%202.5%20GW.

3.3. Harvesting precious rainwater with agrivoltaics

Several agrivoltaics projects also demonstrate rainwater harvesting from the modules using gutters or channels that collect the rainwater tripping over the PV module. The collected rainwater can be stored separately for irrigation or cleaning purposes or used to recharge the groundwater level using a percolation pit. The PV panels are also cleaned from time to time to remove the soil and dust layer built-up on the active area. If water is used for cleaning, this water can also be harvested and used for irrigation ensuring minimal wastage. Let us consider a moderate figure of 700 mm for average annual rainfall in a location where the agrivoltaics plant is located. Assuming 330 W panels with the dimensions of 2m x 1m, 3030 panels will be required for 1 MW agrivoltaics plant. The total area of the panels will be 6060 m2. Assuming a 24^0 average tilt for Uttar Pradesh, the total area of panels projected onto the ground would be 5536 m2. 1 mm of rainfall corresponds to 1 litre of water received on 1 m2 area of ground. Hence 700 mm rainfall incident on 5536 m2. Of area will amount to 38,75,260 litres of rainwater harvested from solar panels which would have flown down the slope over the ground, sweeping away invaluable topsoil.

4. Key Recommendations to adopt Agrivoltaics in Uttar Pradesh

Agrivoltaics is a fairly new technology and needs to be explored systematically before finally scaling up to a state-wide implementation. Based on the study of the existing situation of the agriculture and energy sector of the state, and the points that emerged during the discussions of the State Task Force, following recommendations may be considered while formulating the policy around agrivoltaics in the state. The recommendations have been divided into short-term, mid-term and long-term periods for smooth and effective inception of agrivoltaics into the agricultural ecosystem of the state.

4.1. Recognition of agrivoltaics as an innovative farming practice

As of today, agrivoltaics is not formally recognized by any of the government entities neither at the central level nor at the state level. Agrivoltaics today is mostly implemented under the schemes available for solarization of agriculture either at the central level such as PM KUSUM. There is an absence of a clear requirement on whether or not the agriculture should continue in co-location with the solar PV modules. The fact that these schemes don't stop the farmers from performing agricultural activities underneath or around the panels, has enabled the project developer/ owner to implement the solar power plant as an agrivoltaics project. Formal recognition would incentivize farmers and landowners to adopt agrivoltaics by providing them with regulatory clarity and legal protection. This recognition would assure stakeholders that agrivoltaics is a sanctioned land-use practice, reducing uncertainty and risks associated with investment in such projects. This could lead to increased funding and investment in agrivoltaics infrastructure, accelerating its deployment in Uttar Pradesh. Hence agrivoltaics needs to be recognized in the short term to begin with for a smooth induction of agrivoltaics in the agricultural ecosystem of the state.

Without formal recognition, agrivoltaics projects may face regulatory ambiguity, hindering their development and prohibiting potential investors and stakeholders. Lack of clear guidelines and legal status could lead to delays, disputes, and uncertainty surrounding agrivoltaics initiatives. Failure to recognize agrivoltaics as a viable land-use option could result in missed opportunities for sustainable development in UP. Multiple benefits offered by agrivoltaics may not be fully realized without government support and recognition. In the absence of formal recognition, agrivoltaics projects may be

implemented scarcely and inconsistently across UP. This fragmented approach could lead to suboptimal outcomes, with missed synergies between agriculture and renewable energy sectors, as well as uneven distribution of benefits among different regions and communities.

Taking agrivoltaics further to a wider scale of implementation puts it in the ambit of all the intricacies of the agriculture side and the existing ecosystem for the solarization of agriculture will not be enough. The agriculture is not only limited to growing certain kinds of crops, with fixed cropping patterns and methods. This existent diversity in the agriculture sector may lead to ambiguity when coupled with energy generation on the same piece of land pushing agrivoltaics into a grey area. It is thus of utmost importance that agrivoltaics is recognized by the government properly defining and categorizing it according to combinations of structures, arrangements and other design aspects, crops, farming practices, complementary and allied activities like animal husbandry, sericulture, aquaculture, apiculture etc.

4.2. Defining of agrivoltaics

Agrivoltaics isn't just about rows of crops basking in dappled sunlight. This innovative concept can be a boon for nearly all agricultural sectors, offering a chance to double your land's duty by co-locating solar panels with your existing operations. Imagine lush pastures shaded by strategically placed solar panels, providing a cool retreat for your cattle, sheep, or goats during scorching summer days. This can significantly reduce heat stress in livestock, leading to improved health and potentially higher yields. Even poultry farmers can benefit – strategically placed panels can create much-needed pockets of shade for your birds while still allowing ample room for them to roam. In the world of horticulture and apiculture, the story is similar. Partial shade can act like a natural sunscreen for certain fruits, vegetables, and even beehives. For instance, some berries thrive in cooler environments, and strategically placed panels can mimic this ideal growing condition. By carefully designing a system, you can cultivate a diverse range of crops, raise healthy livestock, nurture buzzing hives brimming with honey, all while generating clean energy that can power your farm or feed back into the grid. This creates a true win-win for your farm – increased productivity, potentially lower energy bills, and a reduced environmental footprint – a strategy that benefits both your bottom line and the planet. So, if you're a farmer looking to embrace sustainable practices and boost your operations, agrivoltaics might just be the key to unlocking a new era of agricultural productivity.

4.3. Technical standards and best practices

There should also be technical standards and best practices for sustainable implementation of the technology and safety of life and equipment. This may be viewed as a long-term activity as it will demand a greater depth of our knowledge as well as a significant database of results and their analyses obtained from the pilots implemented in all the agro-climatic zones of the state. The technical standards would encourage innovation and experimentation in the field. Stakeholders, including farmers, researchers, and technology providers, could explore different approaches and techniques to optimize agrivoltaics systems, leading to the identification of best practices and performance benchmarks. Limits for several factors will be set to eliminate the risks associated

with them such as the Ground Coverage Ratio of the panels must be capped to ensure that the crops underneath the PV modules receive an adequate amount of sunlight securing a promising crop yield from the agrivoltaics system. The standards and qualifying requirements will ensure that the primary focus of implementing agrivoltaics is centered on sustaining continued cultivation on the lands utilized for solar energy generation.

It must be ensured that the co-location of agriculture and solar energy generation is not implemented for the sake of robbing the economic benefits sanctioned through the schemes formulated for agrivoltaics, overexploiting the invaluable agricultural lands for solar energy generation. This will safeguard the agricultural productivity and prevent potential losses resulting from inadequate light penetration, shading caused by solar panels or other effects inflicted due to the footprint of the solar subsystem on the crops. Failure to establish limits and caps on key parameters may result in reduced agricultural productivity and compromised crop yields underneath solar panels leading to diminished harvests and stressed food value-chains. This may cause apprehension regarding the technology, prohibiting the policy-makers from prioritizing it over conventional systems. Constantly adhering to the prescribed limits and continuous reporting of the crops in the agrivoltaics farm for vigilance and monitoring would ensure that agrivoltaics projects contribute towards socio-economic development without compromising agricultural productivity. By preventing misuse or overexploitation of agrivoltaics for purely economic benefits, the integrity of agricultural systems can be upheld, promoting equitable distribution of resources and opportunities among stakeholders.

If technical standards and best practices are not made, this could hinder effective planning, policy-making, regulation, and potential investment in agrivoltaics projects, as stakeholders may lack clarity on applicable guidelines and standard practices. In the absence of clear guidance, certain stakeholders may prioritize short-term gains over long-term sustainability, leading to sub-optimal outcomes and missed opportunities from integration of agriculture and energy sectors. Farmers, project developers, investors, policymakers, and researchers will hesitate to participate in agrivoltaics projects if the scope and expectations are not properly defined, leading to limited uptake and slow progress in realizing the potential benefits of agrivoltaics in UP.

4.4. Subsidies and Financial Incentives

Financial Assistance: Uttar Pradesh could establish a grant program similar to the one in Gujarat, which offers up to 30% subsidy on the capital cost of installing agrivoltaic systems for farmers. This can make the initial investment more manageable, especially for smaller farms.

Pilot Projects: The state government could be partner with agricultural universities like Dayalbagh Educational Institute (Agra) or Sam Higginbottom Institute of Agriculture & Technology (Allahabad) to set up pilot agrivoltaic projects. These projects can focus the crops like shade-tolerant crops (mushrooms, spinach) or fruits (berries) commonly grown in Uttar Pradesh. The data and experience gained can guide future large-scale projects.

4.5. Research and Development

Research Collaboration: Making Partner with institutions like the Indian Institute of Sugarcane Research (Lucknow) to analyse the impact of agrivoltaics on sugarcane, a major crop in Uttar Pradesh. Research can explore optimal panel spacing and height to ensure sufficient sunlight for sugarcane growth while maximizing energy generation.

Data Sharing: Developing an online platform where research findings, best practices, and success stories from pilot projects are documented and easily accessible to farmers across the state. This platform could be integrated with existing agricultural information resources managed by the Department of Agriculture, Uttar Pradesh.

4.6. Farmer Education and Training

Workshops and Trainings: Organizing workshops and training programs in collaboration with Krishi Vigyan Kendras (KVKs) or Farmer Producer Organizations (FPOs). These programs help educate farmers on agrivoltaic system design, maintenance, and potential benefits for specific crops and livestock in the region.

Extension Services: By trainning agricultural extension officers on agrivoltaics so they can provide on-site guidance and support to farmers interested in adopting this technology. This can help address specific concerns and ensure efficient system implementation.

4.7. Policy and Regulatory Framework

Streamlined Permitting: By establishing a single nodal agency to handle all permissions related to agrivoltaic installations. This can reduce bureaucratic hurdles and expedite the approval process for farmers.

Net Metering: Implementation of net metering policies that allow farmers to sell excess electricity generated by their agrivoltaic systems back to the power grid. This can create an additional income stream and incentivize wider adoption. The Uttar Pradesh Electricity Regulatory Commission can play a key role in establishing clear guidelines for net metering in the state.

4.8. Public Awareness

Promotional Campaigns: Launching public awareness campaigns through local media channels and agricultural publications. These campaigns may highlight the benefits of agrivoltaics to farmers – increased productivity, potential for higher income, and environmental sustainability.

Success Stories: Featuring success stories of farmers who have successfully implemented agrivoltaics in their operations. This can showcase real-world examples and inspire others to consider this approach.

4.9. Leading to more sustainable practices

By implementing these targeted recommendations with clear and accessible examples, Uttar Pradesh can pave the way for widespread adoption of agrivoltaics, leading to a more sustainable and productive agricultural future for the state. As the production of daytime electricity can power multiple units such as cold storage and other storage facilities, bulk milk chilling and other dairy operations, dryers and other food processing and packaging units, climate-controlled cultivation of special crops such as mushroom, saffron, exotic vegetables, charging stations for electric vehicles, strengthening cottage

industry simultaneously empowering rural women through initiatives such as SHGs and Mahila Bachat Gat, village/ eco-tourism, generation of other forms of clean energy such as energy storage, green hydrogen, biofuels, biogas and bio-fertilizers, biomass energy, waste to energy, etc. The coupling of such units with the agrivoltaics will not only improve the utilization of electricity generated through agrivoltaics but also result in value addition contributing towards self-sufficiency and income diversification of rural communities. Supporting value addition through agrivoltaics has a potential to transform rural areas of the state into centers of economic activity relieving the migration stress on urban areas of the state. By supporting village industries, promoting employment opportunities, and enhancing agricultural productivity and value addition, agrivoltaics projects stimulate economic growth, reduce dependency on agrarian income, and improve livelihoods for rural communities, fostering inclusive and sustainable development across the state.

Without a support for adopting collective approach through FPOs, smallholder farmers inUttar Pradesh will face significant financial barriers in implementing agrivoltaics projects due to the high capital costs and limited financial resources. Individual adoption of agrivoltaics projects may result in fragmented efforts and limited scalability of the technology due to lower overall economic viability.

4.10. Selection of crops to be cultivated in agrivoltaics

4.10.1 Background

The overall agricultural output can be improved by securing the availability and reliability of required resources. Uttar Pradesh is a large state and has diverse climatic conditions, soils and thus crops and cropping patterns. This is utmost important to be considered while introducing a new technology.

4.10.2 Selection of crops for cultivation in agrivoltaics

There are multiple combinations and possibilities of structures, configurations and designs of agrivoltaics systems with the crops. Selection of crops is a crucial step in cultivation under agrivoltaics installation considering the interactions between the solar PV and cropping subsystems. It has been observed in various pilots across the state, country and the world, that crops such as green leafy vegetables, root crops, tomato, etc. are most suitable for cultivation in an agrivoltaics plant. Various key parameters to be considered for selection of crops include: shade tolerance of the crop, physical dimensions of the shoot of the plant (size of the leaf, height of the stem, spread, etc.), depth of roots, requirement for structural support (e. g. in Tomato, Betel leaves, Pea, Melons, Cucumber, gourds, etc.), part of the plant harvested, water requirements, tolerance against humidity, etc. Most of the crops are suitable for cultivation in the inter-row spacing in an agrivoltaics plant, however, some crops may also be grown directly underneath the solar panels. Following are some of the crops that may be considered in the initial phase of agrivoltaics implementation in the state.

4.10.3 Crops to be considered for cultivation in agrivoltaics systems (Refer to the Famers Handbook on Agrivoltaics - Holistic Perspective of Co-Locating Agriculture and Solar for more details)

Studies shows that Uttar Pradesh's shade-tolerant vegetables like Methi (fenugreek), Palak (spinach), Chaulai

(amaranth), and Chenopodium album (Chiwal) can thrive in agrivoltaic systems with lower panel clearance. Similarly, stem vegetables like Gobhi (cauliflower), Patta Gobhi (cabbage), and Kaddu (pumpkin) might experience minimal yield impact. Root vegetables like Adrak (ginger), Haldi (turmeric), Aloo (potato), and Gajar (carrot) could also be suitable options. High-demanding vegetables like Lettuce, Kale, and Broccoli can be cultivated under the protective shade of agrivoltaics, promoting diversification and potentially opening doors to contract farming with restaurants and urban markets. Fruits like Strawberry, which benefit from cooler environments, and shade-tolerant options like Pineapple and Papaya could also be explored in specific regions. Additionally, incorporating spices like Methi (fenugreek), Dhaniya (coriander), Ajwain (carom seeds), and medicinal plants like Aloe vera might be promising avenues for diversification within Uttar Pradesh's agricultural landscape. (Reference: https://www.lkouniv.ac.in/)

Other crops that are less tolerant to shade such as oilseeds (e. g. Groundnut, Soybean, Niger, Safflower, sesamum, etc.), pulses (e. g. Pigeon-pea, gram, Mung, Urad, Masur, etc.), millets (Jowar, Bajra, Ragi, Vari, etc.), cotton, jute, etc. may also be cultivated in interspace configuration of agrivoltaics considering higher inter-row separations. Agrivoltaics systems are elevated and stilt mounted, providing a readily available structure for support crops such as tomato, etc. also climbers and creepers. These crops include betel leaves, bottle gourd, cucumber, muskmelon, watermelon, ivy gourd, pointed gourd, pumpkin, sponge gourd, ridge gourd, pea, jasmine, etc. Other non-food crops such as fodder crops, green manure crops and energy crops such as Napiar grass may also be considered for growing underneath the solar modules in agrivoltaics plants. The microclimate and shade in agrivoltaics installations is very suitable for nursery practices such as propagation of plants through cuttings, budding, grafting, seedling nursing, etc. which also promise higher returns. Initially, we may assume that the effect of shade is more or less negative on the crop yield for most of the crops. It is well understood that the availability of irrigation mechanisms provides opportunities for enhancement in the crop yield. In the areas with currently rainfed agriculture, irrigation powered through electricity generated can compensate for the yield loss due to the shade imparted by the solar panels. Furthermore, optimization of density of panels and inter-row separation will minimize the impact on the crop yield.

4.10.4 Agrivoltaics with protected cultivation

With agrivoltaics integrated protected cultivation of many of the above crops have great potential to offer higher yields and greater reliability. Mushroom farming, Floriculture, aquaculture, animal husbandry and apiculture are other complementary agricultural activities that may be implemented with agrivoltaics for multiplexed benefits. Crops such as sugarcane, Paddy, Wheat, Maize, cotton which need higher amounts of solar intensities should be avoided for a wide-scale implementation of agrivoltaics. Adverse effects on the yields of these crops may result in disruption of value chains of markets of these crops and in turn, income of the farmers. Taller crops that may cast shadow on the solar panels or cause damage to the equipment such as coconut, Arecanut, Mango, Cashewnut, Sapota, other taller crops, etc.

5. References

[1] State Portal : Govt. of Uttar pradesh https://up.gov.in/en

[2] Agriculture Department Uttar Pradesh : https://upagripardarshi.gov.in/Staticpages/JayadAgroclaimetikZone.aspx

[3] https://invest.up.gov.in/wp-content/uploads/2023/09/uttar-pradesh-leading_190923.pdf

[4] Indian Meterological Society - https://imetsociety.org/wp-content/pdf/vayumandal/2016421/2016421_4.pdf

[5] Indian Council of Agriculture Research (ICAR)

[6] Crop Production in Uttar pradesh, Chaudhury Charan Sing University- https://www.ccsuniversity.ac.in/ccsu/Departmentnews/2020-08-24_168.pdf

[7] Ministry of Agriculture & Farmers welfare https://agriwelfare.gov.in/Documents/CWWGDATA/crops_(27)_0.pdf

[8] Agriculture Statistics at a Glance - https://desagri.gov.in/wp-content/uploads/2023/05/Agricultural-Statistics-at-a-Glance-2022.pdf

[9] Horticulture Statistice at a Glance, Department of Agriculture & Farmers Welfare -https://agriwelfare.gov.in/Documents/Horticultural_Statistics_at__Glance_2021.pdf

[10] Changing Crop Production Cost in India: Input Prices, Substitution and Technological Effects S.K. Srivastava*, Ramesh Chand and Jaspal Singh NITI Aayog, New Delhi-110 001- https://www.niti.gov.in/sites/default/files/2023-02/2_Changing_cost_of_crop_production_Srivastava_et_al.pdf

[11] Uttar Pradesh State Agricultural Marketing Board -http://www.cosamb.org/UploadedFiles/UP.pdf

[12] Groundwater Management in India- Uttar Pradesh State Report, Rajiv Gandhi Institute of contemporary Studies - https://www.rgics.org/wp-content/uploads/Groundwater-Management-in-India-Uttar-Pradesh-State-Report.pdf

[13] Irrigation in Uttar Pradesh – Sources and Projects, https://cag.gov.in/uploads/download_audit_report/2023/5-Chapter-I-064d387abb756c0.14208676.pdf https://lotusarise.com/psc/irrigation-in-uttar-pradesh-sources-and-projects/

[14] List of power stations as on 31.03.2021 , Central Electricity Authority- https://cea.nic.in/wp-content/uploads/pdm/2021/06/list_power_stations_2021.pdf

[15] Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited - https://www.uprvunl.org/introduction

[15] Central Electricity Authority, Ministry of New and Renewable Energy

[17] All India Electricity Statistics , General Review 2022 - https://cea.nic.in/wp-content/uploads/general/2022/GR_2022_FINAL.pdf

[18] All india Electricity Statistics, General review 2022, Government of India Ministry of Power Central Electricity Authority New Delhi

[19] Performance of Agriculture in Uttar Pradesh, Region waise Analysis :Indian Council for Research on International Economic Relations - Performance of Agriculture in UP_Report.cdr (icrier.org)

[20] Solar in Uttar Pradesh: Potential, Policy and Solar Subsidy (2024)- https://ornatesolar.com/blog/potential-of-solar-power-in-uttar-pradesh#:~:text=Uttar%20Pradesh%20experiences%20more%20than,solar%20capacity%20is%202.5%20GW.

[21] Rural 21, The International Journal for Rural Development -https://www.rural21.com/english/archive/2023/01/detail/article/unlocking-the-potential-of-agrivoltaics.html

[22] C. E. Authority, "All India Electricity Statistics, General Review 2023," Ministry of Power, Government of India, New Delhi, 2023.

[23] Central Electricity Authority, "All India Installed Capacity (in MW) of Power Stations (As on 29.02.2024)," Ministry of Power, Government of India, New Delhi, 2024.

[24] P&C Division, "State-wise Installed Capacity of Renewable Power Including Off-grid as on 29.02.2024," Ministry of New and Renewable Energy, Government of India, New Delhi, 2024.

[25] Global Solar Atlas, "Global Solar Atlas Map," [Online]. Available: https://globalsolaratlas.info/map?c=18.90109,75.635376,7&r=IND:IND.20_1. [Accessed 23 March 2024].

[26] Aayog, N. (2017). Doubling Farmers' Income Volume VIII.

[27] CSSRI. (2022). Salinity in Uttar Pradesh: Causes, Status, and Management Strategies.

[28] India, G. o. (2023). ECONOMIC SURVEY HIGHLIGHTS THRUST ON RURAL DEVELOPMENT. Retrieved from PIB: https://pib.gov.in/PressReleasePage.aspx?PRID=1894901

[29] Pradesh, G. o. (2013). Uttar Pradesh Agricultural Policy.

[30] Pradesh, G. o. (n.d.). Government of Uttar Pradesh. Retrieved from Overview of the State: https://up.gov.in/en

[31] Pradesh, G. o. (n.d.). Government of Uttar Pradesh. Retrieved from Agricultural overview of the State: https://upagripardarshi.gov.in/Staticpages/JayadAgroclaimetikZone.aspx

Annexures

- **Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM)**

  The scheme was launched in 2019 by the Government of India to solarize the agriculture sector. The scheme has three components as follows:

  Component A: Solar power plants of capacity from 500 kW to 2 MW can be setup by individual farmers / group of farmers / cooperatives / panchayats / Farmer Producer Organisations (FPO) / Water User associations (WUA). However, there is no financial assistance provided by the government in this component. Component A has been seen as potential base for introducing agrivoltaics into the agricultural ecosystem. However, due to lack of finance assistance in component A and high upfront investment costs in agrivoltaics, the implementation of agrivoltaics through component A is apparently far-fetched. According to MNRE, Total sanctioned capacity is 155 MW but 0 MW of solar capacity has been installed in Uttar Pradesh as of April 2024.

  Component B: In this component, individual farmers from remote, tribal areas or the areas without grid connectivity can install standalone solar pumps for de-dieselization of the agriculture sector. Two lakh standalone solar pumps have been approved for the state between 2019-20 and 2025-26. Farmers can install standalone solar pumps with a capacity of up to 7.5 HP. A Central Financial Assistance of 30% is provided by the central government, 60% financial assistance is provided by the state while the remaining 10% of the capital cost is to be managed by the general category beneficiary farmer. For a beneficiary farmer from SC/ST categories, the state provides 65% of the capital cost while the farmer has to manage 5% on their own. A total of 84,020 standalone solar pumps have been installed in the state under PM KUSUM as of 31.03.2024.

  Component C-I: Individual farmers with existing grid-connected solar pumps are supported for solarizing their electric agricultural pump. A Central Financial Assistance of 30% is provided by the central government, 60% financial assistance is provided by the state while the remaining 10% of the capital cost is to be managed by the general category beneficiary farmer. For a beneficiary farmer from SC/ST categories, the state provides 65% of the capital cost while the farmer has to manage 5% on their own.

  Component C-II: The states can solarize agricultural feeders supplying to the pumps instead of solarizing individual pumps. There is also a provision for separation of

agricultural feeders if not completed already through various schemes. The project may be implemented in either CAPEX or RESCO models for a period of 25 years. A Central Financial Assistance of 30% on the cost of installation of the solar power plant (up to Rs. 1.05 Cr/MW) will be provided. This financial assistance makes component C-II a better scheme for implementation of agrivoltaics projects currently.

- **Pradhan Mantri Fasal Bima Yojana (PMFBY)**

  The Pradhan Mantri Fasal Bima Yojana (PMFBY) is a comprehensive crop insurance scheme launched by the Government of India in 2016. Its primary objective is to provide financial support to farmers in the event of crop losses due to natural calamities such as drought, floods, pests, and diseases. The scheme aims to stabilize the income of farmers and encourage them to adopt modern agricultural practices.

Table 21: PMFBY Objectives, Coverage and Compensation

Objective	Coverage	Compensation
To provide financial support to farmers in the event of crop loss or damage due to natural calamities, pests, and diseases.	Over 10 million farmers in Uttar Pradesh have been insured under this scheme since its inception in 2016	The scheme offers compensation for various stages of the crop cycle, including prevented sowing, post-harvest losses, and localized calamities.

Under the PMFBY, farmers pay a nominal premium, and the remaining premium is shared equally by the state and central governments. The scheme covers all food crops, oilseeds, and annual commercial/horticultural crops. It offers comprehensive risk coverage from pre-sowing to post-harvest, including prevented sowing, standing crop, and post-harvest losses. The PMFBY has been widely adopted across the country, providing a safety net for millions of farmers and contributing to the overall development of the agriculture sector.

- **Pradhan Mantri Krishi Sinchai Yojana (PMKSY)**

  The Pradhan Mantri Krishi Sinchai Yojana (PMKSY) is a flagship scheme launched by the Government of India in 2015 with the aim of ensuring access to irrigation facilities for every farmer in the country. The scheme aims to improve water use efficiency, expand cultivable area under assured irrigation, and enhance the adoption of precision irrigation techniques.

  PMKSY is an umbrella scheme that integrates several ongoing irrigation schemes and programs, such as the Accelerated Irrigation Benefit Programme (AIBP), Har Khet Ko Pani (HKKP), and the Integrated Watershed Management Programme (IWMP). It focuses on the creation of new irrigation sources, rejuvenation of existing water bodies, and promotion of water conservation techniques like micro-irrigation.

Table 22: PMKSY Objectives, Projects and Impact

Objectives	Projects	Impact
To improve irrigation facilities and ensure water availability for farming.	Includes micro-irrigation, rainwater harvesting, and the creation of farm ponds.	Approximately 1.2 million hectares have been brought under micro-irrigation in Uttar Pradesh, increasing water-use efficiency.

Under PMKSY, emphasis is placed on the 'Har Khet Ko Pani' component, which aims to extend the coverage of irrigation facilities to every cultivable field in the country. The scheme also encourages the adoption of efficient water conveyance and field application methods, such as sprinklers, drip irrigation, and drainage systems.

PMKSY plays a crucial role in improving water use efficiency in agriculture, enhancing crop productivity, and contributing to the overall food security of the nation.

- **Kisan Samman Nidhi (PM-KISAN)**

The Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) is a central sector scheme launched by the Government of India in 2019 to provide income support to small and marginal farmers. The scheme aims to supplement the financial needs of the farmers in procuring various inputs for ensuring proper crop health and appropriate yields.

Under the PM-KISAN scheme, eligible landholding farmer families are provided with an annual financial benefit of Rs. 6,000 in three equal installments of Rs. 2,000 each. The funds are directly transferred to the bank accounts of the beneficiary farmers through the Direct Benefit Transfer (DBT) mode.

Table 23: PM-KISAN Objectives, Benefits and reach

Objective	Benefits	Reach
To provide direct income support to farmers.	₹6,000 per year in three equal installments.	Over 24 million farmers in Uttar Pradesh have benefited from this scheme as of 2023.

The scheme initially covered farmers with cultivable landholdings of up to 2 hectares. However, in 2019, the eligibility criteria were revised to include all landholding farmer families, irrespective of the size of their landholdings.

The PM-KISAN scheme is intended to provide a supplementary income to the farmers to meet their basic needs and enhance their sources of livelihood. It is expected to help farmers in mitigating the risks associated with agriculture and encourage them to adopt modern agricultural practices.

The scheme has played a significant role in providing financial assistance to a large number of farmers across the country, contributing to their overall financial well-being and the development of the agricultural sector.

- **Rashtriya Krishi Vikas Yojana (RKVY)**

  The Rashtriya Krishi Vikas Yojana (RKVY) is a flagship centrally sponsored scheme launched in 2007 to incentivize states to increase their investment in agriculture and allied sectors. It provides flexibility and autonomy to states in planning and executing projects based on their specific needs and agro-climatic conditions. Under RKVY, funds are allocated to states for various initiatives, such as developing infrastructure like irrigation and storage facilities, promoting sustainable agricultural practices, soil health management, organic farming, and strengthening extension services.

Table 24: RKVY Objectives and Funding

Objective	Funding
Holistic development of agriculture and allied sectors	Uttar Pradesh received approximately ₹1,000 crore annually under RKVY for various projects including infrastructure development, agro-processing, and market linkage.

The scheme emphasizes the involvement of Panchayati Raj Institutions in planning and implementation at the grassroots level. RKVY has played a crucial role in boosting public investment, promoting diversification, and supporting the overall development of the agricultural sector in the country.

- **National Mission for Sustainable Agriculture (NMSA)**

  The National Mission for Sustainable Agriculture (NMSA) is one of the eight missions under the National Action Plan on Climate Change. Launched in 2014, it aims to make Indian agriculture more productive, remunerative, and resilient to climate change. The mission promotes sustainable practices like soil health management, optimum use of water resources, integrated pest management, and adoption of climate-resilient varieties.

Table 25: NMSA objectives, components and initiatives

Objectives	Components	Initiatives
To promote sustainable agricultural practices	Soil health management, efficient water use, climate-resilient farming	Distribution of over 5 million soil health cards, installation of micro-irrigation systems on 0.5 million hectares.

It emphasizes soil conservation, water harvesting, and efficient use of resources. NMSA provides financial assistance and technical support to farmers for activities like fertigation, aerial and drone-based seeding, mechanization, and promotion of traditional nutri-cereals. The scheme also focuses on capacity building, research, and extension to enable adaptation and mitigation of climate change impacts on agriculture.

- **Soil Health Card Scheme**

  The Soil Health Card Scheme is a flagship program launched by the Government of India in 2015 to promote soil testing and provide crop-specific nutrient management recommendations to farmers. Under this scheme, soil samples are collected and tested at authorized soil testing laboratories. Based on the test results, a Soil Health Card is issued to each farmer, containing crop-wise recommendations on nutrient and fertilizer requirements for their farm holdings.

Table 26: SHCS Objectives and Distribution

Objective	Distribution
To provide farmers with information on soil nutrient status	Over 22 million soil health cards have been distributed to farmers in Uttar Pradesh since the scheme's launch

The scheme aims to promote balanced and judicious use of fertilizers, improve soil health and fertility, and enhance crop productivity. It also provides a database for future soil management strategies. The Soil Health Card scheme has played a crucial role in creating awareness among farmers about soil health and promoting sustainable agricultural practices across the country.

- **Kisan Credit Card (KCC) Scheme**

  The Kisan Credit Card (KCC) Scheme is a credit facility launched by the Government of India in 1998 to provide affordable credit to farmers. Under this scheme, eligible farmers are issued a KCC, which acts as a legitimate borrowing instrument for meeting their short-term credit requirements related to agriculture and allied activities.

Table 27: KCCS Objectives and beneficiaries

Objective	Credit Limit	Beneficiaries
To provide farmers with timely access to credit	Credit limits up to ₹3 lakh with interest subvention	Over 15 million Kisan Credit Cards issued in Uttar Pradesh

The KCC enables farmers to access credit from financial institutions in a hassle-free manner for purchasing inputs such as seeds, fertilizers, pesticides, and meeting labor costs. The interest rates on KCC loans are kept at reasonable levels, and the credit limit is determined based on factors like the farmer's landholding size and crops cultivated. The scheme promotes financial inclusion and timely availability of credit to farmers, thereby supporting agricultural production and improving their overall economic well-being.

- **Sub-Mission on Agricultural Mechanization (SMAM)**

  The Sub-Mission on Agricultural Mechanization (SMAM) is a component of the National Mission on Agricultural Extension and Technology. Launched in 2014, it aims to increase the adoption of farm mechanization by providing financial assistance and promoting mechanized operations in agricultural activities. Under SMAM, subsidies are provided to farmers for the purchase of various farm machinery and equipment, such as tractors, power tillers, harvesters, and other implements.

Table 28: SNAM Objects, Impacts and Benefits

Objective	Subsidy	Impact
To promote farm mechanization	Up to 50% subsidy on agricultural equipment.	More than 200,000 units of agricultural machinery distributed, increasing mechanization coverage by 25%.

The scheme also supports the establishment of Custom Hiring Centers to provide farm machinery on a rental basis, making it accessible to small and marginal farmers. SMAM promotes mechanization in various farm operations, including land preparation, sowing, harvesting, and post-harvest management. It has played a significant role in reducing drudgery, improving productivity, and encouraging efficient use of resources in Indian agriculture.

- **National Food Security Mission (NFSM)**

  The National Food Security Mission (NFSM) is a centrally sponsored scheme launched in 2007 to increase the production and productivity of rice, wheat, pulses, coarse cereals, and commercial crops. It aims to augment the availability of food grains and enhance the income of farmers. Under NFSM, financial assistance is provided to states for distributing quality seeds, promoting integrated nutrient and pest management practices, developing infrastructure for storage and marketing, and implementing cropping system-based demonstrations.

Table 29: Key elements of the scheme

Objective	Achievements	Investment
To increase the production of rice, wheat, pulses, and coarse cereals	Additional production of 3 million tonnes of cereals and pulses	₹500 crore annually towards inputs and technology dissemination

The scheme emphasizes the transfer of advanced technologies to farmers through district-level staff and farmer field schools. NFSM has played a crucial role in enhancing food grain production, improving farm productivity, and promoting the adoption of improved agricultural practices across the country, thereby contributing to the nation's food security.

- **Kisan Rin Mochan Yojana**

  The Kisan Rin Mochan Yojana was a one-time scheme launched by the Government of India in 2023 to provide debt relief to small and marginal farmers. It aimed to alleviate the financial distress faced by these farmers due to outstanding debt and enable them to access fresh credit for agricultural activities. Under this scheme, the government announced a package to waive off outstanding loans up to a certain limit for eligible small and marginal farmers.

  Table 30: Key elements of the scheme

Objective	Waiver Amount	Beneficiaries
To provide debt relief to small and marginal farmers	Up to ₹1 lakh per farmer	Approximately 8 million farmers have benefited, with a total waiver amount of ₹36,000 crores

  The beneficiaries were identified based on their landholding size and outstanding loan amounts. The scheme was implemented through financial institutions and aimed to provide a fresh start for farmers by clearing their existing debt burden. It was expected to improve the financial condition of small and marginal farmers and facilitate their continued engagement in agricultural activities.

  These schemes collectively aim to improve agricultural productivity, ensure financial stability, promote sustainable practices, and enhance the overall agricultural infrastructure in Uttar Pradesh.

- **Various Schemes in Solarizing Agriculture in the State**

  The Uttar Pradesh government has introduced several initiatives to encourage farmers to adopt solar-powered water pumps. These initiatives offer subsidies and financial incentives to help farmers transition from diesel or electric pumps to solar-powered ones. Solar pumps provide reliable irrigation water, especially in areas with unstable or insufficient grid electricity. The state government supports solar energy for irrigation through various programs and subsidies. Solar-powered drip and sprinkler systems are promoted to enhance water use efficiency and reduce reliance on traditional energy sources. Additionally, Uttar Pradesh is promoting solar greenhouse technology to farmers with the help of PM-KUSUM Scheme. These solar greenhouses extend the growing season, protect crops from adverse weather, and boost productivity by creating controlled cultivation environments. The government provides subsidies and technical assistance for building and operating these solar greenhouses.

NOTES

NOTES

INDIA AGRIVOLTAICS ALLIANCE

India Climate Collaborative