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The Economics of Ecosystems and Biodiversity - TEEBAgriFood initiative in Uttar Pradesh, India

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List of Acronyms

AgF: Agroforestry

AI-NPOF: All India Network Programme on Organic Farming

APEDA: Agricultural and Processed Food Products Export Development Authority

BAU; Business as Usual

CAGR: Compound Annual Growth Rate

CAUs: Central Agricultural Universities

EEI: Economic Efficiency Index

EPA: Environment Protection Act

ESI: Ecological Security Index

FiBL: The Research Institute of Organic Agriculture

FPOs: Farmers Producers Organisations

FSSAI: Food Safety and Standards Authority of India

FYM: Farmyard Manure

GA: Geographical Area

GSDP: Gross State Domestic Product

ICAR: Indian Council of Agricultural Research

IFOAM: International Federation of Organic Agriculture Movements

IFS: Integrated Farming System

IGP: Indo-Gangetic Plain

IMD: India Meteorological Department

IWMP: Integrated Watershed Management Programme

KVKs: Krishi Vigyan Kendras

LGU: Local Government Units

LULC: Land Use Land Change

MGNREGS: Mahatma Gandhi National Rural Employment Guarantee Act

MLD: Megalitres per Day

MPT: Multi-Purpose Trees

NAP: The National Agroforestry Programme

NAPCC: National Action Plan on Climate Change

NCOF: National Centre for Organic Farming NMSA: National Mission for Sustainable Agriculture

NGRBA: National Ganga River Basin Authority

NMCG: National Mission for Clean Ganga

NPOP: National Programme for Organic Production

NRCAF: National Research Centre for Agroforestry

NSC: National Seed Corporation

NSOP: National Standards for Organic Production

NWDPRA: National Watershed Development Programme for Rain fed Areas

OF: Organic Farming

PGS: Participatory Guarantee Systems (PGS)

PKVY: Paramparagat Krishi Vikas Yojana

RAD: Rainfed Area Development

RCs: Regional Councils

RKVY: Rashtriya Krishi Vikas Yojana

RVP & FPR: River Valley Project and Flood Prone River

SAUs: State Agricultural Universities

SDG: Sustainable Development Goals

SEI: Social Equity Index

SFAC: Small Farmers Agribusiness Consortium

SHM: Soil Health Management

SLSI: Sustainable Livelihood Security Index

SMAF: Sub-Mission on Agroforestry

TEEB: The economics of Ecosystems and Biodiversity

UNFCCC: United Nations Framework Convention on Climate Change

UPSOCA: Uttar Pradesh State Organic Certification Agency

SCOPING AND SCENARIO SETTING REPORT

The Economics of Ecosystems and Biodiversity: Agriculture and Food initiative in Uttar Pradesh, India

"The Economics of Ecosystems and Biodiversity: Agriculture and Food initiative in Uttar Pradesh, India" is functional under the EU-funded project titled 'The Economics of Ecosystems and Biodiversity: Promoting a Sustainable Agriculture and Food Sector' (TEEB Agriculture and Food Implementation) with the aim to protect ecosystems and value the hidden services of nature in agriculture. The objective of the initiative is to protect biodiversity and contribute to more sustainable agriculture and food systems in the partner countries (Brazil, China, India, Indonesia, Malaysia, Mexico and Thailand). TEEB is a global initiative focused on "making nature's values visible", located under the United Nations Environment Programme (UNEP) working on assessing the costs of the loss of biodiversity and the associated decline in ecosystem services at all levels worldwide.

Further, the project involves analysing agricultural interventions, policies and schemes, which have already been applied or proposed by the government in the seven countries, that claim to stimulate positive livelihood and biodiversity benefits, and assess their hidden or unaccounted outcomes on natural, human, social and produced capitals.

The TEEBAgriFood project in India focuses on agricultural practices and ecosystem services and aims to assess agricultural schemes on organic farming (OF) and agroforestry (AgF) practices in the Ganga River basin region of India, including the two states Uttar Pradesh and Uttarakhand. The project will address the evaluation of food production systems (agricultural ecosystems) and their impact and complex linkages to the environment, society and human health.

Thus, the main aim of the TEEBAgriFood initiative is to help decision-makers recognize, demonstrate and capture the values of ecosystem services and biodiversity worldwide and develop sustainable solutions under the various scenario-based analyses. In short, the report on scope finalization of the assessment and scenario development options includes a qualitative description of agriculture systems (agri-food eco-systems) and policy priorities in Uttar Pradesh, identifying environmental variables and causal relations between these variables, as well as other drivers of change.

1. Selection criteria for the study area

In our eco-agri-food systems these externalities include the huge but hidden costs and benefits of agriculture and food systems, which need to be unravelled, understood, and evaluated if the world is ever to be able to work out how to feed and nourish billions of people in a manner that provides everyone with adequate nutrition, in an equitable manner, without seriously damaging ecological security or environmental sustainability.

India constitutes 28 states and 8 union territories and produced 315.7 million tonnes of food grain in 2021-2022, thereby feeding 18.2% of the world population (~1.38 billion population). The TEEBAgriFood project in India focuses on Uttar Pradesh as it contributes ~20% of the food grain production in the country. The main water sources in Uttar Pradesh are the Ganga, Yamuna and their tributaries rivers which have very good fertile alluvium soils. Gangetic basin states were selected by the Steering Committee in line with key national policy priorities and areas of action such as the National Mission for Clean Ganga, Paramparagat Krishi Vikas Yojana (PKVY) and the National Agroforestry Policy.

Additionally, OF and AgF are in growing demand under the pressure of the climate crisis, as well as social issues and inequalities, additional environmental and agricultural concerns all together. Conventional farming and high-input modern agriculture involves the use of synthetic chemical fertilizers, fungicides, insecticides, and herbicides etc. which all include highly toxic/carcinogenic chemicals and pose serious threats to our complex ecosystems relations at all levels. As such, it is imperative to measure the agricultural role/services not only in terms of productivity but also in terms of ecosystem services associated with farming practices and damage caused to the present day. For these reasons, the TEEBAgriFood projects came into existence and the India study was proposed.

2. Importance of the study in the context of Indian agriculture

The Indian agriculture sector and its food industries have a crucial role to play in the economy, and presently the sector is facing a lot of challenges due to the excessive use of harmful toxic chemical inputs in the fields, which is an issue that can only be tackled by changes in policy making, providing capacity building and training opportunities to enable a sustainable agriculture system, and to support various natural ecosystem services and regulatory processes. Therefore, evaluating the ecosystem services related to OF, AgF and conventional farming practices in monetary terms, is important to be able to achieve a sustainable environment. Additionally, OF and AgF practices rely on basic principles, i.e., 1) the principle of health: sustaining and enhancing the health of soils, plants, animals, humans and planet as one and indivisible; 2) the principle of ecology: based on living ecological systems and cycles, working with them, emulating them and helping to sustain them; 3) the principle of fairness: building relationships that ensure fairness with regard to the common environment and livelihood opportunities; and 4) The principle of care: managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. These practices rely on natural principles such as biodiversity and composting to produce healthy and abundant food, whereas, chemical-based farming is focused only on meeting the food demand-supply and maintaining food security.

Further, AgF offers many ecological, environmental, economic, and social benefits which give reason to incentivize and empower landowners to adopt such practices. It is also important to consider the evidence of the trade-offs associated with AgF. Agroecosystem practices and management are central to biodiversity conservation, food and nutrition security, as well as sustainable livelihoods. The adoption of planet-friendly agricultural practices is imperative for realizing the UN-SDGs and also for halting future degradation. In this context, the study area, Uttar Pradesh, in the Indo-Gangetic Plain (IGP) has been selected because this region is diverse in agricultural practices and crop-cultivation (rice-wheat production system is the main cropping system in the region). Therefore, a comparative study is essentially required to assess the OF, AgF and synthetic fertilizer-based farming systems to draw the attention of policy makers for implementation of climate resilient and sustainable farming practices in these areas.

3. Aims and purpose of the TEEBAgriFood-Uttar Pradesh study

The TEEBAgriFood project in Uttar Pradesh in collaboration with ICAR-IIFSR Modipuram will focus on economics and ecosystem services related to chemical-based farming, OF and AgF practices, and will also evaluate the government schemes ongoing in the area, to pinpoint the sustainable livelihood security indicators and ecosystem services of the ongoing schemes. This will included differentiated analysis of those participating and not participating in such schemes in order to assess the impact of the

schemes on indicators of natural, social, human and produced capital. The IGP region (Uttar Pradesh) has been selected for the study as the region is highly fertile but is losing its vitality, resources and productivity under the extensive/intensive chemical fertilizer based agricultural practices that are being implemented, in addition to the impacts of climate change as well. The proposed study aims to evaluate the natural, human, social, and produced capitals under OF- and AgF-based supporting ecosystem services and ecosystem service flows. The aims of the TEEBAgriFood analysis therefore, are to provide evidence to:

- ✓ Inform policy about the long-term impacts of OF on ecosystem services, produced capital as well as livelihoods and health.
- ✓ Inform policy, institutional and governance solutions that take a food systems approach, promoting coherence across different policy areas (e.g. agriculture, trade and food).
- ✓ Support spatial planning of agricultural production to maximize ecosystem services.
- ✓ Evaluate the economic case for scaling up OF and AgF.
- ✓ Inform sustainable food production policy interventions, such as policies related to pollution, pesticide and fertiliser use, sustainable value chains, market linkages and certifications.

4. Expected outcome of the study

The proposed theme for the study is to conduct an overall evaluation of sustainable options in the agriculture sector and technologies/interventions supporting the ecosystem services and biodiversity all over the region. As the TEEBAgriFood initiative is dedicated to the economic evaluation of agricultural and ecosystem services, the following outputs are expected from the TEEBAgriFood Uttar Pradesh project:

- ✓ The study will result in the economic evaluation of OF, AgF and conventional farming practices in terms of ecosystem services (natural, human, social, and produced capitals).
- ✓ Various government schemes promoting and supporting the natural farming practices will be assessed and quantified for future decision support systems and policy planning.
- ✓ Technical outputs to support the scaling up of OF and AgF in the state of Uttar Pradesh.

As such, the final results will deliver an evaluation of agricultural practices and interventions that are already being promoted by the government, which will also provide a comprehensive and universal approach to capturing positive and negative impacts and externalities across the entire agri-food value chain.

5. Project area

5.1 Overview of the Uttar Pradesh State

Uttar Pradesh is the most populous and 4th largest state in the country with a population of 199.8 million (census, 2011), accounting for ~16.5% of the total population of India. The state covers a geographical area of 240,928km^2 and shares 7.33% of the total geographical area of the country. The economy of Uttar Pradesh is the 3rd largest among the states in India. Nominal Gross domestic product (GDP) of the state for the year 2022-23 is ₹20.48 trillion (US $ 260 billion). Uttar Pradesh has an urban population of 4,44,95,063; and as per the 2011 census report, 22.76% of Uttar Pradesh's population lives in urban areas. NITI Aayog based on NFHS-4 (2015–16), estimated that 37.79% of the population was

found to be poor (Poverty estimates). The total literacy rate of Uttar Pradesh is 67.68% which is less than the average literacy rate 72.98% of India[1].

Uttar Pradesh is also a major contributor to the national food grain stock. The state produced 56 million tonnes of food grain in 2020, i.e., ~20% of the total production of the country. This is partly due to the fertile regions of the IGP, and partly due to irrigation facilities such as canals and tube wells.

Aligarh, Bulandshahr, Meerut, Hamirpur and Mirzapur have all been selected as the study districts of the project. The districts Aligarh, Bulandshahr and Meerut fall in the region of western Uttar Pradesh where sugarcane-ratoon-wheat are dominant cropping systems. This system is dominant in the region due to easily available irrigation resources, soil types and the existence of large numbers of sugar factories which function as an added advantage for the farmers. Hamirpur is in the region of Bundelkhand which is one of the underdeveloped regions of Uttar Pradesh. Mirzapur is in the eastern part of Uttar Pradesh and lies under the Vindhyan zone. Agriculture is the main occupation of the population and thus the main source of income. As we compare the region wise value contribution of output from agriculture and allied activities in the state Uttar Pradesh, it is apparent that a major proportion comes from western Uttar Pradesh (49.6%) while the lowest contribution comes from the Bundelkhand region (5.5%).

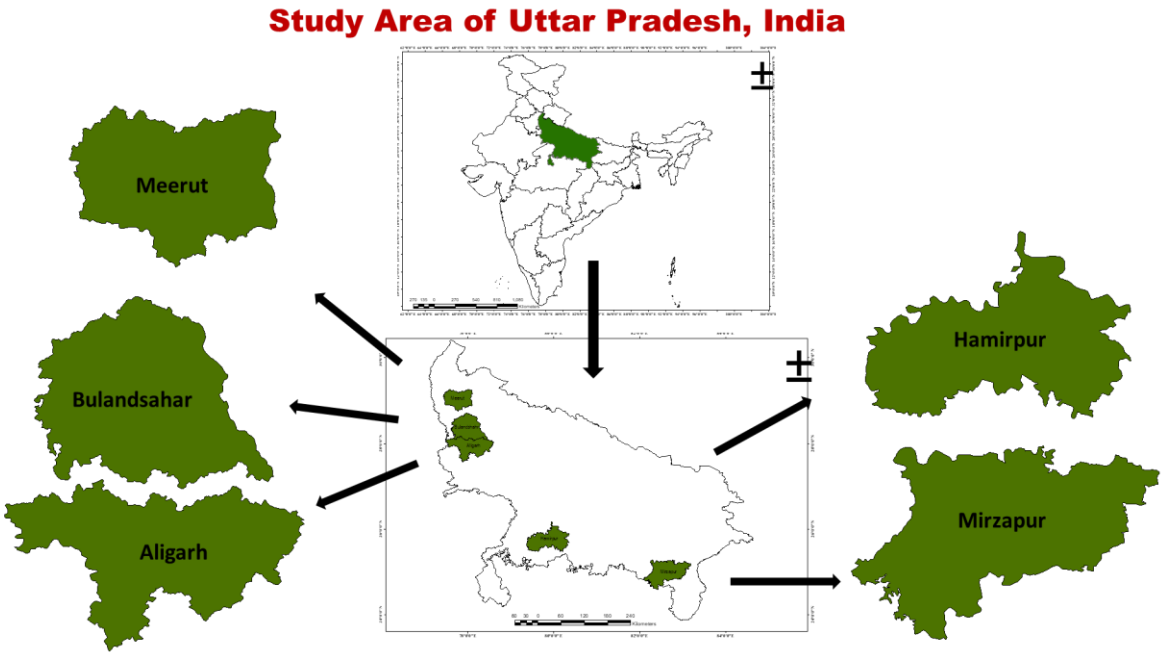

Figure 1. Study districts of the TEEBAgriFood project

5.2 Physiographic information of the state

Uttar Pradesh is one of the largest states and therefore has infrastructural resources which have led to the improvement of the agricultural trade and development in the region. Decent roads, rail-roads, air and water transport systems have been developed for improved connectivity, while groundwater, river-canals and rain are the source of irrigation for agriculture and other household activities. Power supply and demand is fulfilled through grid coverage and other sources especially in rural areas. Sonbhadra is the main power supply district and is known as the energy capital of the region.

[1]Government of India Planning Commission July 2013, Poverty estimates for 2011-12

The major sources of irrigation in the state are groundwater and the Ganga, Yamuna, Gomti, Ram Ganga, Ghagra, Betwa, Ken rivers, the majority of them being Himalayan rivers. Many tributaries' rivers and river canals come from these rivers that help to flourish the Indian agriculture. The rich source of river water helped to cover a gross irrigated area of 80.2% in 2015. Uttar Pradesh has about 74,659km of canals, 28 major and medium lift canals, as well as 69 reservoirs. The major source of irrigation in the state however is tube wells (80.1 %), followed by canal irrigation (17.9 %).

Farming utilizes a large amount of ground and surface water, but they are often not being used in an appropriate way. Over-usage of water is a common phenomenon in crop farming, particularly in the case of rice and sugarcane.

The availability of abundant irrigation facilities, particularly canal irrigation, is one of the most important reasons for agricultural advancement in these study districts, and it has resulted in a radical transformation of the local economy. Water resources are important regulatory ecosystem service of any region/climate zone. We cannot imagine life without water, and water crises is another burning issue of the century and the SDGs agenda. Assessing the impact of organic vs. conventional farming practices on water resources is important for improved implementation of decisions and policies.

Table 1: Source and number of irrigation channels in all the 5 selected districts

Aligarh									
Canal length (Km)	State Nal (nos.)	Pakka Kuwa (nos.)	Pump set (nos.)	Electric	Diesel (nos.)	Other (nos.)	Total (nos.)	Midlle nal (nos.)	Deep Nal (nos.)
1556	650	67	0	22470	47841	124	70435	862	136
Bulandshahr									
1879	503	0	1	33450	42530	271	76251	413	58
Hamirpur									
831	683	3882	2505	463	11890	92	12445	1835	2187
Meerut									
67	345	22	18	26148	31987	484	58619	1001	89
Mirzapur									
367	441	17932	1378	2874	5656	132	8662	297	607

Roads are another important parameter needed for agricultural and rural development. A well-developed road network system helps to reduce transportation costs while accelerating the movement of farm inputs and opportunities for agricultural trade. The total road density increased from 690km per 1000km^2 in 2002 to 1711km per 1000km^2 in 2015. This increase in road transport facility has hugely contributed to the agricultural development in the state.

The state has a vast network of power supply in rural and urban areas under Uttar Pradesh Power Corporation Limited (UPPCL), which is further restructured into 6 distribution companies in different zones to increase efficiency management. The share of agriculture in total power sales of the state remained stagnant from 2004-05 to 2015-16[2]. However, power intensity in the state's agricultural sector has increased from 199kwh/ha in 2004-05 to 483kwh/ha in 2015-16. The power sector in Uttar Pradesh suffers from high

[2]Gulati et al, 2021.

transmission and distribution losses, which amounted to 24.5% in 2015-16. Furthermore, there is an erratic and inadequate supply of power in rural areas for the irrigation pumps, therefore the majority of the farmers depend on diesel pumps to lift the water for their irrigation purposes. As such, the state government needs to address the power shortage issues and replace the diesel pumps.

5.3 Climate profile of the state of Uttar Pradesh

Uttar Pradesh is divided into two regions, Eastern Uttar Pradesh and Western Uttar Pradesh. Given significant climatic differences, Uttar Pradesh has been divided into two meteorological sub-divisions, Uttar Pradesh East and Uttar Pradesh West. The districts selected for this study are Mirzapur (Vindhyan agroclimatic zone having rocky, black and red alluvial soils with 1100mm annual rainfall) in Eastern Uttar Pradesh, and Hamirpur (Bundelkhand agroclimatic zone having rocky soil with 621mm annual rainfall) while districts such as Aligarh (South western agroclimatic zone having sandy, alluvial and clay soil with 750mm annual rainfall), Meerut and Bulandshahr (Central western agroclimatic zone having alluvial and sandy soil with 850mm annual rainfall), fall under the Western part of Uttar Pradesh. The climate of Uttar Pradesh is primarily defined as humid subtropical with dry winters (Cwa) type with parts of Western Uttar Pradesh being defined as hot semi-arid (BSh) type. Variations do exist in different parts of the large state, however the uniformity of the vast IGP forms the biggest section of the state giving it a predominantly single climatic pattern with minor regional variations. With temperatures fluctuating anywhere from 0°C to 50°C in several parts of the state and cyclical droughts and floods occurring due to unpredictable rains, the summers are extremely hot, winters cold and the rainy season can be either very wet or very dry. Based on India Meteorological Department (IMD) classification, Uttar Pradesh has the following three predominant seasons:

1. Winter season – November to February
2. Summer season – March to May
3. South-west Monsoon – June to October

In addition, a retreating Monsoon season also exists, but has a very negligible effect in Uttar Pradesh and only occasional mild showers are experienced in winter. Some of these showers are not even due to the Monsoon but due to western disturbances.

The primary temperature, rainfall and wind features of the three Distinct Seasons of U.P. can be summarised as below:

1. Summer (March–June): Hot & dry (temperatures rise to 45°C; low relative humidity (20%); dust laden winds.
2. Monsoon (June–October): 85% of average annual rainfall of 990 millimetres received from southwest monsoon and usually temperature falls on rainy days.
3. Winter (November–February): Usually the weather in this season is cool (morning temperatures drop to 3–4°C) with clear skies but foggy conditions can occasionally also be seen in some tracts of the state.

5.4 Impacts of climate change on agriculture in Uttar Pradesh

Climate change is affecting Uttar Pradesh in many ways, from reducing its agricultural productivity to increasing its vulnerability to floods. Due to climate change, it is estimated that there will be a high rate

of change of maximum temperature for the kharif season in southern Uttar Pradesh, a high rate of change of minimum temperature in south-western and upper Uttar Pradesh, whereas it is predicted that in the rest of Uttar Pradesh there will be almost similar patterns of rate of change in maximum and minimum temperatures during the kharif season. An increase in ambient CO_2 is usually considered beneficial as it results in increased photosynthesis in several crops, especially those with C_3 mechanism of photosynthesis. However, despite these beneficial effects, the combined increase in temperature and variability of rainfall would considerably affect food production. Some studies indicate a probability of a 10-40% loss in crop production with an increase in temperature by 2080–2100. These assumptions are based on a Business-As-Usual scenario, with no new technology development and with either no or limited adaptation by all stakeholders.

The result of a simulation analysis conducted for Uttar Pradesh indicated that irrigated rice is likely to lose up to 23% of yields in Meerut, Bulandshahr and Aligarh districts where assured irrigation ecosystem prevails. The yield loss is projected to be even higher in high rainfall zones, where rainfall is projected to increase further. This may lead to cloudier days and can thus cause a reduction in yields., as can the high rainfall related soil erosion. The losses are likely to increase if irrigation sources dwindle or sink to lower levels than the current level. Based on the entire region, three probabilities can be drawn according to the model outputs, (1) one out of every three years could have improved yields in comparison to the current yields; (2) in one out of three years the crop loss is likely to be about 10%; and (3) one out of every three years, the crop loss is likely to be more than 10% even extending up to 30%. Wheat yields are particularly projected to be affected by climate change in this region. The loss is projected to be higher in Badaun, Etah, Aligarh, Bulandshahr, Ghaziabad, Meerut, JP Nagar and Muzaffarnagar, with approximately 6-20% loss in various scenarios. In the north-eastern parts of Meerut, JP Nagar and Muzaffarnagar districts, the losses may be less, whereas wheat yields in these areas are projected to increase up to 8%.

5.5 Agrobiodiversity of the study area in Uttar Pradesh

India, with its numerous states, is a biodiversity hotspot. Although Uttar Pradesh is not very ecologically diverse, it does have some biodiversity nonetheless. The major explanation for the state's lower biodiversity is because it is located in a plain area with sparse forest cover (9.01% of total geographical area). Despite this, the state of Uttar Pradesh has worked to preserve its biodiversity through a variety of initiatives, projects, protected areas, and gene banks. The state's flora consists of 3987 species, of which 2711 are higher plants (angiosperms), accounting for 18% of the country's angiospermic flora. Sal, Teak, Sissoo, Semal, Haldu, Tun, Kanju, Mango, Jamun, Neem, Bamboo, Peepal, Gutel, Tamarind, Poplar, Arjun, Babool, Amla, are examples of some of the other common trees.

Any area's vegetation includes trees, shrubs, and herbs, as well as fruit orchards. In India's botanical census, 152 invasive alien species were discovered in Uttar Pradesh. Preliminary observations from secondary data sources in the state revealed that lichens are used as natural air pollution indicators, and with 60 species in the state, crustose lichens predominate throughout the region. In addition, the country's freshwater aquaculture resources include 2.25 million ha of ponds and tanks, including 16,1372 ha in Uttar Pradesh. The state therefore has a total area of 720,000 ha, with 28500km of rivers and a few hundred thousand ha of rice fields, some of which are suitable for fish farming.

These are very important parameters in terms of evaluating the ecosystem services, as biodiversity enriches the availability and use of services which are widespread in the region. The services that are important to recognize and value include the reduction of emissions, providing provisional services such as

food, fuel, fodder and natural biomass, as well as the nutrient recycling in the system by decaying the organic matter and soil conservation in terms of supporting services.

5.6 Economic profile of Uttar Pradesh

Socio-economic development entails improving the quality of life of people which can take place for instance through the creation of appropriate infrastructure, among others, for industry, agriculture and the environment. The Green Revolution in the agricultural sector and commendable progress made on the industrial front has undoubtedly increased the overall growth of the Indian economy. At current prices, the Gross State Domestic Product (GSDP) of Uttar Pradesh stood at ₹20.48 trillion (US$ 294.90 billion) in 2021-22.

The state's labour force is 23.7%, with 65.9% being made up of farmers and 5.6% of industrial employees. According to current prices, the states per capita income is ₹(INR) 13,262 (Govt. of Uttar Pradesh, 2021). State Account Statistics' report states that in 2018–2019 the agriculture sector contributed 24.58% to the total gross state value-added, equivalent to ₹3.6 trillion at current prices which was up from ₹1.8 trillion in 2011-12. Uttar Pradesh is a major producer of a wide variety of crops and is the largest producer of food grains, fruits and vegetables, sugarcane, milk, and meat in India.

5.7 Agriculture in Uttar Pradesh

According to the agriculture household survey conducted by the National Sample Survey Office, agricultural households account for 74.8% of all rural households in Uttar Pradesh (Ministry of Statistics and Program Implementation, Agriculture Census 2015-16). Thus, agricultural activities form an integral part of the livelihoods of most people in rural areas in the state. The highest number of agricultural operational holdings (23.82 million out of 146 million total), operating on 17.45 million ha; 92% of operational holdings are small and marginal and account for 65% of the operational area.

The cropping intensity is higher in Aligarh district followed by Bulandshahr which is in western Uttar Pradesh. This is due to more intensive cultivation of the sugarcane-wheat cropping system. Geographically Mirzapur is larger compared to other districts, while Meerut is smaller. The Aligarh district has the least forest cover, whilst Mirzapur has the higher forest cover.

Table 2: States/districts under different practices in Uttar Pradesh (2021[3])

State/district	Geographical Area	Forest area	Net cultivated area	Cropping intensity (%)	Net irrigated area
Uttar Pradesh (mha)	29.44	1.65 (6.98%)	16.57	153.4	13.3
Aligarh (ha)	371261	2487	305831	168.8	303941
Bulandshahr (ha)	364974	8448	299082	162.4	298951
Hamirpur (ha)	390865	24084	287468	136.5	194573

[3] The state of forest report (SoFR) 2021

Meerut (ha)	270905	21314	196399	152.9	196391
Mirzapur (ha)	442508	109448	210849	138.6	152887

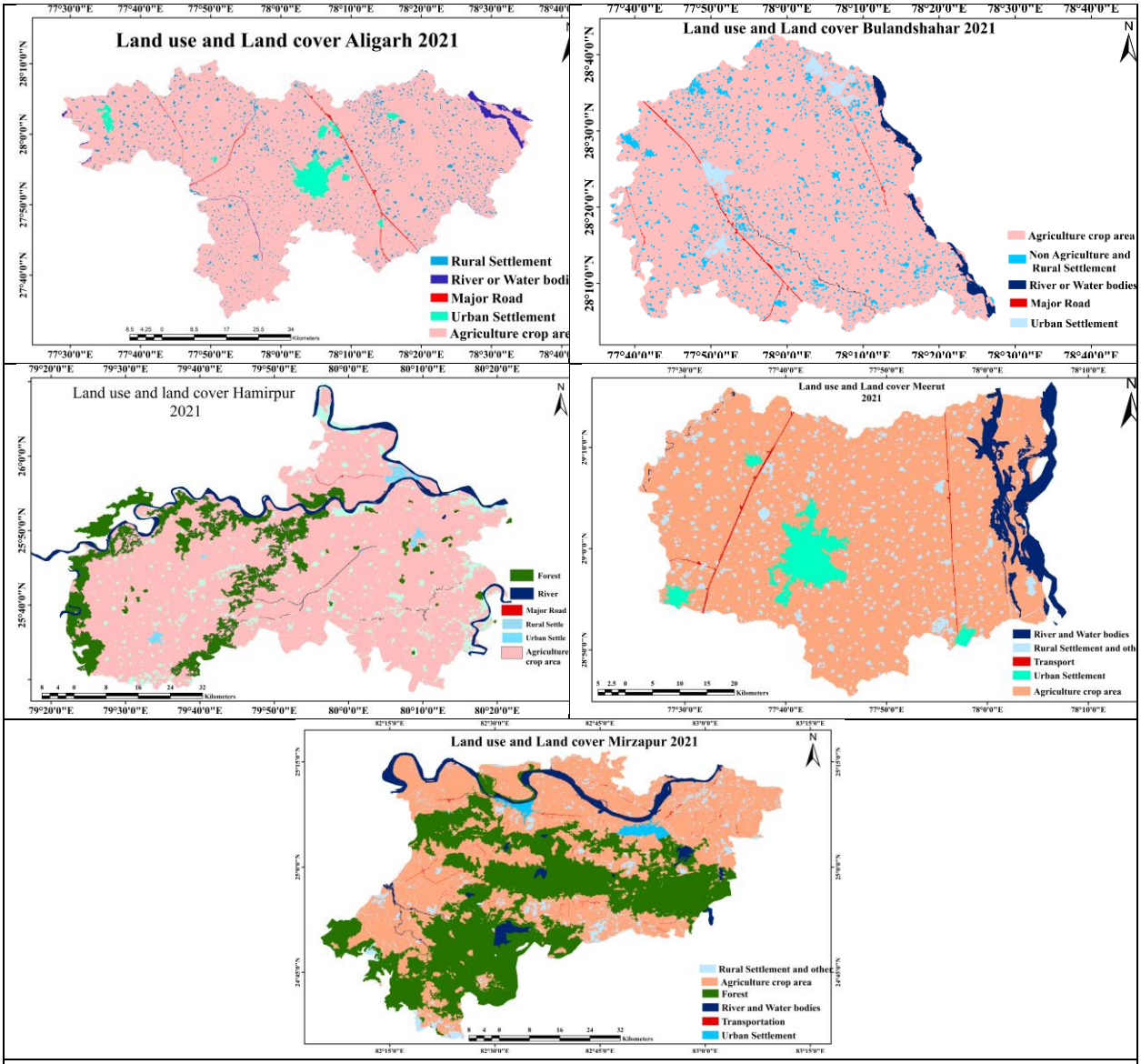

Figure 2: Land use land cover of study area in Uttar Pradesh

The soil, water availability, climatic considerations as well as economic conditions all influence a region's farming patterns. In the kharif season, rice, maize, pigeon peas, and moong bean crops are grown in large quantities. Wheat, lentils, Bengal gram, peas, sesame, as well as peanuts are on the other hand cultivated on residual soil moisture with one or two extra irrigations during the post-rainy (rabi) season. Sugarcane, potatoes, tobacco, chilies, turmeric, and coriander are the region's main cash crops which are grown with supplemental irrigation, while the rice–wheat cropping system is the predominant practice conducted in the state. Wheat is Uttar Pradesh's principal crop, contributing 37% to the total production in India, while rice contributes 14% to the total production in the country. Rice is cultivated under an area of 5.6 million ha and wheat under an area of 9.2 million ha, but the average productivity of both crops is below

the national average productivity. Sugarcane is grown over a 21.5 hundred thousand ha big area with a production of 1255 hundred thousand tonnes, accounting for 35% of the country's total production. Potatoes are grown over an area of 4.5 hundred thousand ha with an estimated production of 38% of the national production. Fruits and vegetables on the other hand accounted for 8% and 20% of the production of the country respectively. The major fruits under cultivation are mango and guava with a cultivation area of 2.47 hundred thousand ha and 15,000 ha respectively.

The state enjoys surplus amounts of paddy and wheat production while there is an acute shortage of pulses and oilseeds. This continuous cultivation of the same crops without rotation or intercropping has degraded the soil resulting in lower soil organic carbon, reduced soil microorganisms and soil health throughout the state. The over-use and unbalanced composition of N_2O, P_2O_5 and K_2O of fertilizers is causing the degradation of land and polluting the air and water.

Over the past few years, the contribution of cereals to the value of output has declined while there has been a rise in the share of the livestock sector. Livestock is most important sector contributing significantly to Uttar Pradesh's agricultural growth and it has the potential to enhance farmers' income in the future. The Department of Animal Husbandry and Dairying announced preliminary statistics from the 20th Livestock Census, where results show that the livestock population climbed by 4.6% from 512.06 million in 2012 to 535.78 million in 2019. Cattle and buffaloes constitute 301.1 million animals.

In 2019, Uttar Pradesh had the highest number of cattle (67.8 million), followed by Rajasthan (56.8 million), and thirdly Madhya Pradesh (40.6 million)[4].. The number of cattle in Uttar Pradesh has decreased from 19.6 million in 2012. The number of buffaloes in the state has increased by 7.81%.

Table 3: Livestock population across the study area (2019)

Districts	Cattle (no.)	Buffalo (no.)	Goat (no.)	Sheep (no.)	Pig (no.)
Aligarh	311298	942498	33375	852	6262
Bulandshahr	304321	972027	26819	1480	6332
Hamirpur	141151	238510	35100	5138	3269
Meerut	244585	515704	8740	1445	8276
Mirzapur	511188	287582	21088	26891	4869

Animal husbandry contributes very significant inputs to organic agriculture. Animals play multiple different key roles in the functioning of the farm and they provide livestock products (meat, milk, eggs, wool and hides) or can be converted into prompt cash in times of need. The cow dung produced by cattle and buffaloes are converted into farmyard manure (FYM) and vermicompost which are rich in nutrients and organic matter and help to reduce the need for applying chemical fertilizers while also improving organic carbon content. The organic matter added to farms functioning under the FYM or vermi-compost techniques, enhances the water retention capacity and soil microorganisms thereby improving the soil nutrient availability to plants. Integrating more than one livestock species with cropping systems can form the basis of a balanced and sustainable farming system, allowing improved nutrient recycling and effective resource use. Farm animals are utilized for weed control in natural and OF, as they can graze down weeds either before the crops are sowed or after crop establishment.

[4] https://www.statista.com/statistics/622721/livestock-inventory-by-state-india/

The non-forest tree cover in the state is under 7421 sq. km which is 3.08% of the total geographical area. These trees are situated outside the forest cover so claim a very important contribution in terms of adding the foliage litters and biomass into the soil. The government is also promoting the adoption of AgF systems through various schemes to increase incomes and livelihood benefits.

6. Broad National policy context

6.1 National Action Plan on Climate Change (NAPCC)

As a part of the United Nations Framework Convention on Climate Change (UNFCCC) to assess the vulnerability and adaptation strategies of climate change, the impact of various thrust areas was studied including for instance water resources, forests and agriculture. Further, the impact of climate change on six main areas, namely water resources, natural ecosystems, agriculture, health, coastal zone management and climate modelling was assessed by the Expert Committee on Climate Change in 2007[5], and these reports provided the basis for the NAPCC.

India's NAPCC is a national plan that strategically aims to enable the country to adapt to climate change and enhance the ecological sustainability of India's development path. The plan advocates that maintaining a high growth rate is crucial for uplifting standards of living of a large proportion of the Indian population, and thus, reducing their vulnerability to the impacts of climate change.
Below are the main eight mission/strategies[6] that form the core of the National Action Plan under the climate change impacts. These plans are focused on promoting the understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation among the population.

1. National Solar Mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission for Sustaining the Himalayan Eco-system
6. National Mission for a Green India
7. National Mission for Sustainable Agriculture
8. National Mission on Strategic Knowledge for Climate Chang

The principles of the NAPCC are:

- Protecting the poor through an inclusive and sustainable development strategy, sensitive to climate change;
- Achieving national growth and poverty alleviation objectives while ensuring ecological sustainability;
- Efficient and cost-effective strategies for end-use demand-side management;
- Extensive and accelerated deployment of appropriate technologies for adaptation and mitigation;
- New and innovative market, regulatory, and voluntary mechanisms for sustainable development;

[5]Expert Committee on Impact of Climate Change set up by the Ministry of Environment & Forests in June 2007
[6] https://dst.gov.in/climate-change-programme, http://moef.gov.in/wp-content/uploads/2018/07/CC_ghosh.pdf

- ❖ Effective implementation through unique linkages – with civil society, local government units (LGUs), and public-private partnerships.

6.2 National Mission for Sustainable Agriculture (NMSA)

The NMSA has been operational from 2014-15 under the National Action Plan on Climate Change. The main goal of the mission was to make agriculture more productive, profitable, sustainable, and climate resilient by adopting and promoting location specific integrated/composite farming systems. Additionally, it was also aimed at implementing measures that can conserve soil and moisture; practices that are efficient in water management; soil health management on a comprehensive scale; and mainstreaming rain-fed technologies to the farmers.

The mission strategy is to promote integrated farming systems including crops, animals, plantations and pasture-based composite/integrated farming systems that can enhance livelihood options, ensure food demand/supply/security and can thus minimize the risks of crop failure. The NMSA also aims to popularise resource conservation and agriculture development technologies (both on-farm and off-farm) and introduce practices that will support mitigation strategies under the climate stress and extreme weather events. The NMSA is also dedicated to the promotion of best possible water resources management and increasing the water use efficiency by adopting/promoting improved agronomic practices for increased productivity. Under the multi-pronged strategies for improving soil health and limiting the fertilizer use, the mission is also promoting location/crop specific integrated nutrient management practices.

6.3 National Rainfed Area Development

The National Rainfed Area Development is an area-based approach for the development and conservation of natural resources along with farming systems. The approach explores the potential utilization of natural resources that are available/created through watershed development and soil conservation interventions and activities under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGS), the National Watershed Development Programme for Rain fed Areas (NWDPRA), River Valley Project and Flood Prone River (RVP & FPR), Rashtriya Krishi Vikas Yojana (RKVY), Integrated Watershed Management Programme (IWMP) etc. Multiple components of agriculture such as crops, livestock, fishery, horticulture, forestry with other agro-based livelihood activities and value additions will be integrated to introduce appropriate farming systems to benefit all the different farmers groups. Rainfed Area Development (RAD) clusters should have soil analysis/soil health card/soil survey maps to justify the interventions proposed and at least 25% of the farming system area should be covered under On Farm Water Management.

6.4 Sub-Mission on Agroforestry (SMAF)

The SMAF scheme was launched in 2016-17 with the aim of encouraging increased tree plantation on farmland - “Har Medh Par Ped”, along with crops/cropping systems. The implementation of the sub-mission will help to ensure additional income opportunities for farmers, while increasing tree cover will also lead to higher carbon sequestration. Trees grown on farmland will help in enriching soil organic matter.

6.5 Soil Health Management (SHM)

This scheme is dedicated at promoting the location and crop-based management of soil health in a sustainable manner including residue management, OF practices by way of creating and linking soil fertility maps with macro/micronutrient management, the controlled application of fertilizers as well as the

minimizing of soil erosion/degradation. This strategy will also help to provide the support that is needed for soil reclamation for soils that are acid, alkaline or saline.

In a nutshell, the NMSA program aimed to improve water-use efficiency and nutrient management by shifting to environmentally friendly technologies, the adoption of energy-efficient equipment/interventions, and the conservation of water resources through an Integrated Farming System (IFS) approach while simultaneously promoting sustainability, livelihood options and increased productivity. This helps to promote the sustainable use and preservation of this valuable natural resource and improve the ecosystem services that organic agriculture provides for healthy food production.

Another ambitious plan that the Government of India is pursuing is to restore 26 million hectares of degraded land by 2030. In the UN Convention to Combat Desertification Conference of the Parties (UNCCD COP 14) in 2019, the target of restoring degraded land has increased from 21 million ha to 26 million ha. Degraded lands have the potential to cultivate crops/plants, but due to the impacts and stresses caused by climate change and man-made activities, they have become largely unproductive. The adoption of the TEEBAgriFood framework could play a key role in restoring the lands by evaluating all available natural and physical capital available and demonstrating their values for the betterment of humans and the environment. To address the restoration of degraded land, we need to augment water supply, enhancing the water recharge potential, reduce run-off and erosion, and retain moisture for longer periods with holistic development measures and approaches in place. This study will enable these policy measures to work towards the ambitious plans to achieve the 2030 targets.

India has achieved self-sufficiency in its food production systems and is now looking to improve the farmers' income while simultaneously considering food security. Climate change has been impacting the country's food sector severely, with for instance recent heat waves having reduced the production of wheat in India by 10-12 million tons. If this pattern continues there will be severe impact on farmers' livelihoods as well as on food security. To mitigate these climate aberrations, alternate available coping mechanisms need to be adopted. This study in Uttar Pradesh will be studying the ecosystem services under organic and non-organic scenarios along with an agroforestry component in order to help formulate the necessary policies in that direction. The adoption of mechanisms such as mulching, crop rotation, organic manuring and reduced tillage will reduce the GHG emissions, and at the same time the agroforestry component will act as a sink for carbon storage and will improve the soil fertility. In addition, the farmer's livelihoods will improve due to the reductions in the cost of cultivation as well as through the creation of an additional income source through non-farm activities, which is equally important.

7. Operational National policies/schemes that can lead to transformation in the study area including targets

To address various issues and challenges faced by small and marginal farmers to restore the sustainability in their agricultural practices while improving their monetary returns, the Government of India has been trying to empower farmers in many ways. The government initiated various schemes for safe and sustainable crop production, easy certification and production protocols for organic producers.

7.1 National Programme for Organic Production (NPOP)

Food production and manufacturing procedures of food industries have been a reason of worry in recent years, due to the increasing usage of synthetic chemicals and pesticides in agriculture which has been affecting human health greatly. The toxicity/carcinogenic properties of these substances, combined with

lengthy and high exposure, has been demonstrated to have serious negative consequences to the ecosystem. To combat this two-pronged threat, the National Programme for Organic Production (NPOP) launched in 2001, was the first such quality assurance initiative launched by the Government of India under the Ministry of Commerce and Industry. This national programme launched in order to promote organic agriculture, to produce safe and quality products. NPOP is also dedicated to implementing the National Standards for Organic Production and thus provides institutional mechanisms and helps provide the inspection and certification bodies related information on criteria, systems and procedures for accreditation.

Orientation and likings towards safe, organic and healthier food alternatives have increased tremendously in recent years in order to live a healthy, happy and longer life. Observing the needs of the population and society, NPOP was formed in India under the authority of Agricultural and Processed Food Products Export Development Authority (APEDA). The Government launches plans/schemes and efforts for the development of farmers on a regular basis. These government schemes are farmer oriented and aim to help the farmers around the country by promoting the agriculture business and increasing their revenue. Providing easy accessibilities for practicing organic package and practices helps the farmers, because the accreditation is mostly industry based and too expensive for smallholder farmers. In practice, it is a certification method under the impartial organisation that examines the production and process, handling, storage, packaging and transportation of organic foods. In total, 33 organisations are recognised and authorised for certification under the programme for certifying the organic producers for export purposes. It covers National Standards for Organic Production (NSOP), rules for accreditation of certification bodies and certification, guidelines for the certification of grower's groups as well as rules for the use of the "India Organic" logo. The NSOP follows and runs on the basic standards of the International Federation of Organic Agriculture Movements (IFOAM). They are mainly relevant for organic export products, most organic products for the domestic market are not certified. Apart from examining the end-to-end procedure, the third-party certification method also checks to determine if the organic goods meet the certified organic requirements.

The certification process includes the detailed examination of organic agricultural procedures. Land management, input utilisation, machinery use, pest control, and post-harvest in crops, raising procedures based on natural behaviour, animal welfare, non-use of synthetic feed additives and hormones, and limiting the use of allopathic medications and antibiotics in animal products are examined in detail. The process also includes document examination and on-site physical inspection as part of the processing and handling. The certification emblem appears on the packaging of all certified items to assist consumers and other purchasers in making informed purchasing decisions. Organic goods are cultivated using an ecologically and socially responsible farming strategy that avoids the use of chemical fertilisers and pesticides. The majority of countries have their own rules for determining whether items are organic or not. In India, the National Program for Organic Production (NPOP), Participatory Guarantee System (PGS), and Jaivik Bharat are all used to certify organic products (for organic food products). Jaivik Bharat is an initiative under the Food Safety and Standards Authority of India (FSSAI) to help customers identify authentic organic food for the welfare of the Indian people and to promote food safety and security.

In Uttar Pradesh, the Uttar Pradesh State Organic Certification Agency (UPSOCA) has been active since 2014 and certifies the farmers' organic products for export. UPSOCA recognized 304 Organic Certification Operators for the certification of organic products. These certification agencies certifying the organic products, grow their produce over an area of 1090 ha.

Organic production has been witnessing a steady increase in recent years at a global level. Currently, organic agriculture is reported to be practised in 187 countries, and 72.3 million hectares of

agricultural land were managed organically by at least 3.1 million farmers. International sales of organic food and drink reached 112 billion US dollars in 2019. The market has expanded by 55% since 2013. In particular, the share of developing countries such as China, India, Brazil and Indonesia are likely to grow at a fast rate in the coming years. As of 31st March 2021, the total area under organic certification process (registered under the National Programme for Organic Production) is 4.3 M ha (2020-21). This includes 2.66 M ha cultivable area and another 1.68 M ha for wild harvest collection, while roughly 0.73 million hectares had been brought under the Participatory Guarantee System (PGS). As a result, approximately 2.4% of the net farmed land is currently under certification or in the process of conversion to OF. The Government of India has set a target of converting a minimum of 4% net cultivated area under OF by March 2026 (APEDA, 2021) and it should target 10% of net cultivated area by March 2030. During 2020-21, the total volume of export was 888179.7 metric tonnes. The organic food export realization was around 1040.95 million USD (APEDA, 2021). In 2003-04, the certified organic area was just 0.58 thousand ha and in 2020-21 it increased by 4586 times. The trend of expansion of cultivated area under organic cultivation is shown in Fig. 3.

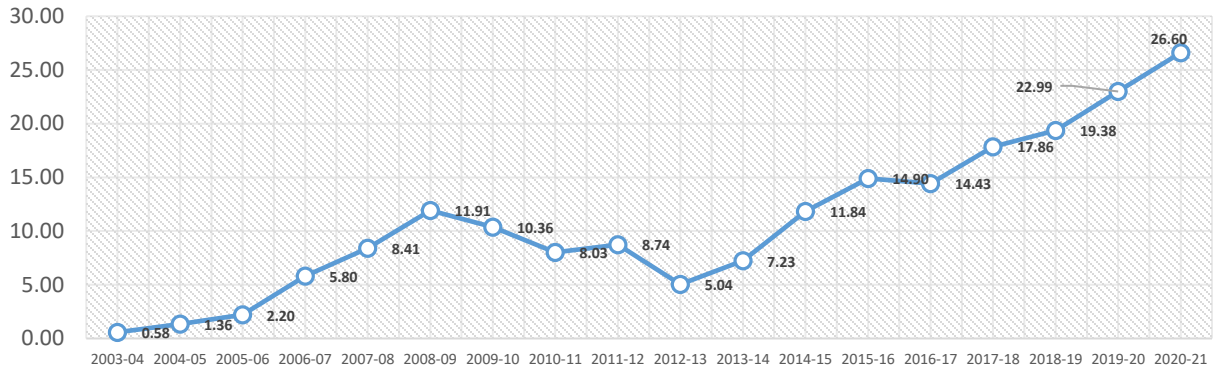

Figure 3: Growth of cultivated area under organic certification in India (APEDA, 2021)

In 2020-21, Uttar Pradesh had 67442.6 ha of total cultivated farm area under OF, which includes 53194.8 ha under organic cultivated farm area and 14247.8 ha area that was converted from traditional farm area to OF. In 2015-16, the total area under organic certification (cultivated + Wild Harvest) was 106292.4 ha while in 2020-21, it increased by 50% (159307.7 ha). The past six year trend of certified organic area (cultivated + Wild Harvest) is presented in Fig. 4.

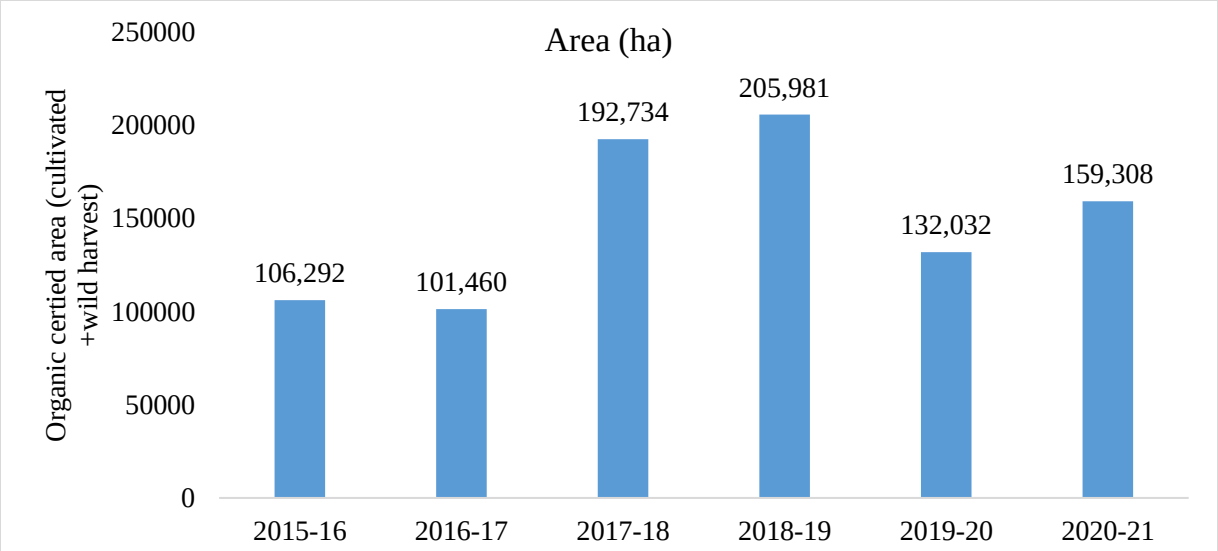

Figure 4: Total area under organic certification process during the past 6 years (cultivated + Wild Harvest) (in ha)

183409.04 MT of total organic production was reported from Uttar Pradesh during 2020-21, 183089.90 MT coming from the existing organic area and 319.14 MT coming from traditional agriculture to converted organic area. Uttar Pradesh also produced ~223.38 MT of various organic products from wild areas during 2020-21. On the other hand, 12141.8 MT of organic produce were exported in 2020-2021 from Uttar Pradesh of a total value of INR 278.6 crores (40.96 USD). Despite the fact that officially, a good quantity is exported from the state, OF farmers are unable to reach the expected value and therefore face various troubles (as per the ICAR-IIFSR survey data from the Meerut district under the UNEP Project).

Problems faced by the farmers:

- Farmers are facing problems in receiving a premium price of their organic products;
- Lack of availability of organic inputs for nutrient, insect, disease and weed management;
- Reduction in yield during the conversion period especially in cereals and in high input use areas;
- Quality of micro-dosing and enriched biofertilizers, botanicals for pest management etc.;
- Establishing infrastructure and mechanisms for certification and marketing (PGS and APEDA);
- Lack of trained human resources on modern concepts of OF.

7.2 Paramparagat Krishi Vikas Yojana (PKVY)

The Paramparagat Krishi Vikas Yojana (PKVY), launched in 2015 as sub-component of SHM, and both schemes are functional under the Centrally Sponsored Scheme, NMSA (discussed earlier). The PKVY scheme is dedicated to support and promote OF practices, helping the farmers in transitioning to OF, and thus, helping to achieve the target of improved soil health and sustainability[7].

[7] Guideline for Model Organic Cluster Demonstration and Model Organic Farm under Paramparagat Krishi Vikas Yojana (PKVY) (April 2017)

The PKVY scheme promotes Participatory Guarantee Systems (PGS) for India (PGS- India)[8] which is a form of organic certification. PGS-India stands on mutual trust, relevancy, and mandates the involvement of farmers and consumers in the certification process for building a trusted bond. PGS Certification facilitates farmers to certify their organic produce, while labelling and marketing their products domestically. Like other states, funding patterns under the scheme in Uttar Pradesh is in the ratio of 60:40 in the Central and State Governments, respectively. In North Eastern and Himalayan States on the other hand, central assistance is provided in the ratio of 90:10 (Centre: State), and for Union Territories, the assistance provided is 100%. The schemes' objective was to form 10000 clusters consisting of 20 ha each and convert nearly 2 hundred thousand hectares of agricultural area to OF by 2017-18.

The total financial assistance available under PKVY for a 20 ha or 50-acre cluster would be a maximum of INR 10 hundred thousand for farmer members, and INR 4.95 hundred thousand for mobilization and PGS Certification with a subsidy ceiling of 1 hectare/farmer. A minimum of 65% of farmers of a cluster should be kept in small and marginal categories, to be fulfilled at cluster level where this rule is not possible to be satisfied at Mandal/Block/Taluka or District level. Further, at least 30% of the allocated budget was fixed for women farmers. Zonal Councils of the National Centre for Organic Farming (NCOF), Participatory Guarantee System (PGS) registered Regional Councils (RCs) and other Public Sector Organisations of the Department of Agriculture and Cooperation & farmers welfare work as implementing agencies under this scheme.

The main objectives of PKVY were to promote OF among rural youth/farmers/consumers/traders, awareness about the latest technologies in OF, getting the experts advice from the public agricultural research systems in India and organizing cluster demonstrations in villages. Active participation of the experts was ensured, and supervision by the experts/scientists from the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), Krishi Vigyan Kendras (KVKs), Central Agricultural Universities (CAUs), National Seed Corporation (NSC), Small Farmers Agribusiness Consortium (SFAC), Farmers Producers Organisations (FPOs) etc. were included for the demonstration. A total of 6211 clusters are formed at village levels and 806 clusters (consist of 20 ha area) were developed in Uttar Pradesh alone.

Currently, the PKVY scheme is targeted in all 25 Ganga Basin districts of Uttar Pradesh with farmer oriented objectives of cross-cutting of production, arranging market-linkages for the farmers, ensuring 100% organic products to consumers, and enhancing the soil health by implementing traditional agricultural practices.

7.3 National Mission on Clean Gange (Namami Gange) (NMCG)

On August 12 2011, the National Mission for Clean Ganga (NMCG) emerged as a society (Societies Registration Act, 1860). The society acts as the implementing body of the National Ganga River Basin Authority (NGRBA) constituted under provisions of the Environment Protection Act (EPA) 1986, to address the pollution issues and challenges in the Ganga River. The operational area of the project comprises of the Ganges River basin and the states through which the river traverses. The NMCG's objective is to reduce the pollution load and ensure the rejuvenation of the Ganga River. For this, inter-sectoral co-ordination for comprehensive planning and strategic management is crucial to ensure a

[8] http://pgsindia-ncof.gov.in/pdf_file/PGSIndia%20Operational%20Manual.pdf

minimum ecological flow in the river. All the related managements and practices should be aimed at ensuring improved water quality and environmentally sustainable development.

About 79% of the of the Ganga River basin is located in India alone. Within this area, 11 states are covered including Uttar Pradesh. In Uttar Pradesh, the Ganga River traverses a distance of 1450km across the 27 districts including the projects study districts Meerut, Bulandshahr, Aligarh and Mirzapur.

The NMCG project has three successive segments/targets, (1) entry-level activities (immediate for visible impact), (2) medium-term activities (to be implemented within 5 years of the time frame), and (3) long-term activities (to be implemented within 10 years). Under the Namami Gange programme, a rejuvenation programme of the river has been set up, with 152 sewerage infrastructure projects sanctioned in 8 states (Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Delhi, Haryana, Himachal Pradesh) till February 2020. These infrastructure projects were aimed at creating 4,857 megalitres per day (MLD) of sewage treatment capacities and developing a sewer network of 4,972km along Ganga and its tributaries with a sanctioned cost of INR 23,305 crores. 56 sewerage infrastructure projects were due for completion in 2021, and a total of 17 sewerage infrastructure projects were completed in the Ganga River basin since Jan 2021 in the States of Uttarakhand (4), Uttar Pradesh (7), Bihar (2), Jharkhand (1) and Delhi (3).

7.4 National Agroforestry policy

The National Forest Policy (1988) advocates the maintenance of at least 33% forest cover of the country's total geographical area, but presently only 24.56% forest cover is reported in the country. To achieve the target of 33% forest cover, the AgF concept can help in achieving the goal and will also help in promoting farmer income. In terms of aiming to achieve sustainability goals, AgF is a promising approach that can bridge the gap in forest cover through bund, boundary and block plantations, thereby appreciating the tree cover separate from the forest area.

India adopted the National Agroforestry Policy (NAP) in 2014 to mainstream AgF practices. The policy emerged as a combined effort between the results of many policies and schemes together which emphasizes AgF, e.g., the National Forest Policy (1988), National Bamboo Mission (2002), National Policy on Farmers (2007), Planning Commission Task Force on Greening India (2001) and National Mission for a Green India (2010).

The AgF policy aims towards;

- Encouraging and expanding tree plantations in a complementary and integrated manner with crops and animals to improve the productivity, livelihood and income generation, especially for the smallholder farmers.
- Protecting and stabilizing ecosystems and related services; and promoting climate resilient cropping and farming systems to minimize the impact/risk during extreme climatic events.
- Meeting the need of raw material for wood-based industries and thus reducing the import of wood and wood products and saving foreign exchange.
- Reducing the pressure on forests by supplementing the availability of AgF products, such as the fuelwood, fodder, non-timber forest products and small timber to the rural and tribal populations.
- Complementing the achievement of the target of increasing forest/tree cover to promote ecological stability, especially in the vulnerable regions.

- Capacity building and strengthening the research and development for AgF; creating movement and awareness on a large scale for achieving these objectives and minimizing pressure on existing forests.

In addition to the above aims, the AgF policy also covered issues such as restrictive legal provisions for harvesting and transporting trees planted on farmlands and the use of non-timber produce, near non-existent extension mechanisms, the lack of institutional support mechanisms, lack of quality planting materials, inadequate research on AgF models suitable across various ecological regions of the country, inadequate marketing infrastructure and price discovery mechanisms, lack of post- harvest processing technologies etc. The value and position of AgF at a national level is undervalued to a large extent, and despite its numerous benefits, AgF is only sporadically mentioned at the national level, due to the lack of appropriate public policy support.

In India, over 180 trees have been listed as multi-purpose trees (MPTs) to date, but their ecological integration into AgF systems needs considerable research and development before taking it onto the farm fields. In farm fields, bund plantations and boundary plantations, is a very common practice throughout the country. Bunds on agricultural lands are considered to be another potential area for AgF practices. In such conditions, mostly multipurpose tree species are likely to be chosen to plant on field bunds to achieve the benefits such as fruits, fibre, fuelwood, food, and medicine. Similarly, the boundary plantations around individual landholding also functions as a demarcation line that acts as a bio fence, timber source, windbreak, shelterbelt among other things. The scope of AgF can be extended for Soil Conservation and Amelioration (planted as biological soil-conservation measures e.g. tree strips, either in combination with grasses or alone); plantation on sloping lands (bund planting can also be done on terrace edges to stabilize the structure to enhance the maximum use of land); riverbank stabilization (erosion prone riverbanks can be protected with vegetation); canal side plantation; windbreaks and shelterbelts (reduce the wind velocity and change the microclimate which are reflected in the growth and development of the nearby crops and ultimately crop yields); bunds for raising nitrogen-fixing plants (*Casuarina* and *Alnus nepalensis*). The suitable tree species that have been recommended by ICAR-CAFRI to be planted in Uttar Pradesh , are *Tectona grandis, Dalbergia sissoo, Acacia senegal, Acacia nilotica, Anthocephalus cadamba, Populus spp., Bamboo, Emblica officinalis, Azadirachta indica, Pongamia pinnata, Terminalia arjuna, Anogeissus latifolia, Melia dubia, Leucaena leucocephala, Casuarina equisetifolia, Syzygium cumini, Aegle marmelos.*

In 2021, India had 21.71% forest cover and 1.42% shrubs (22.33%) of the total geographical area (GA) of the country, which has increased since 2011. The trends of forest cover and shrub cover since 2011 are presented in Fig. 5 and Fig. 6.

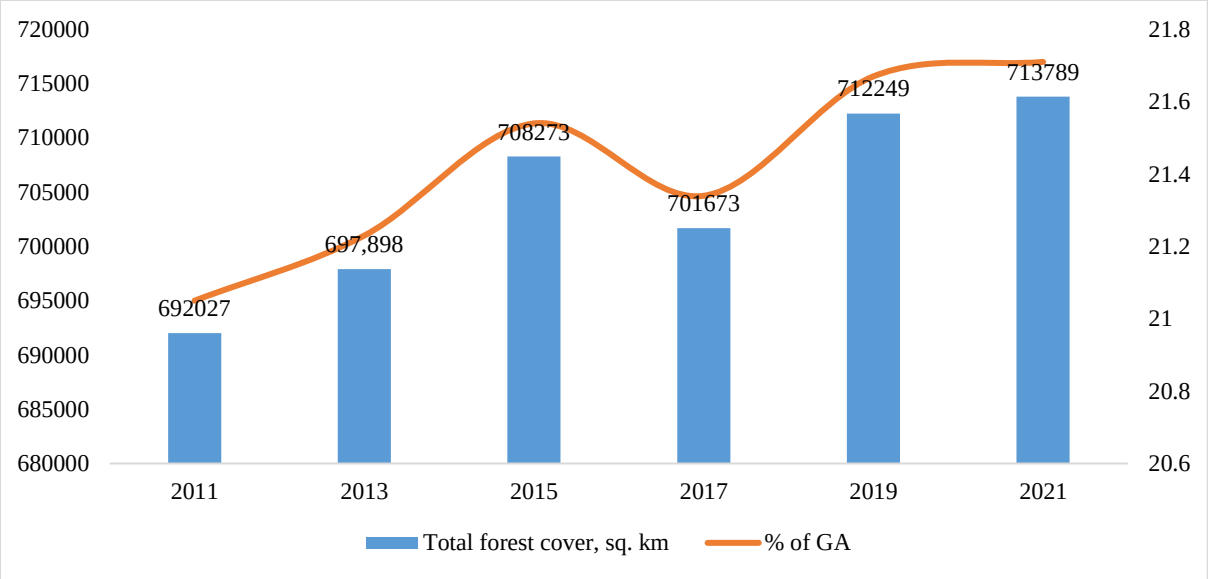

Figure 5: Forest cover in India

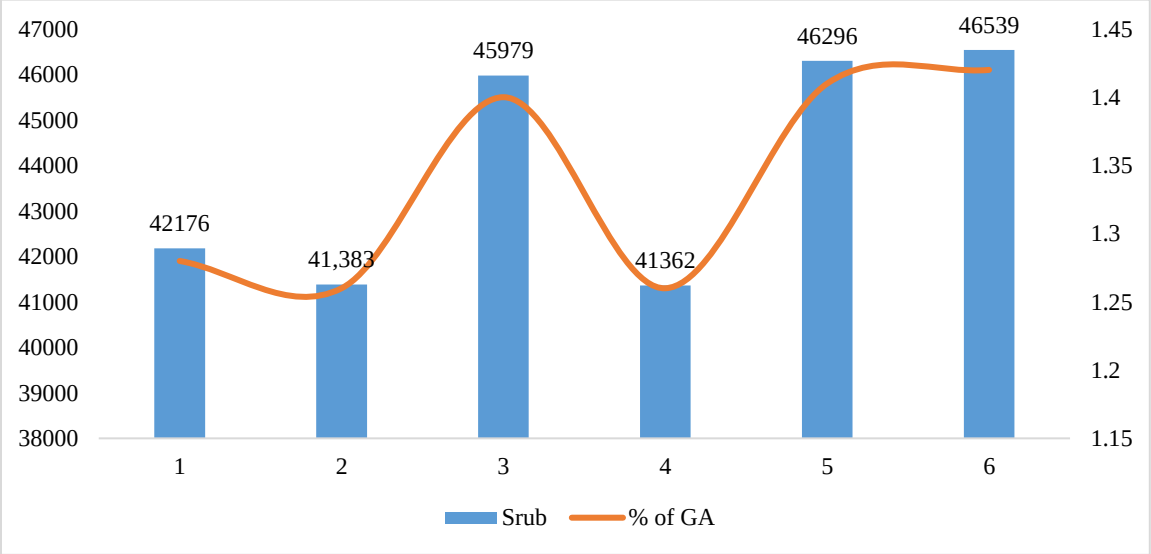

Figure 6: Shrub cover in India

In Uttar Pradesh, during 2021, the total forest cover was 14818 square km (6.15% of the total GA of Uttar Pradesh). In comparison to 2011, it increased by 3.34%. The trends of total forest cover in Uttar Pradesh since 2011 is presented in Fig. 7 below.

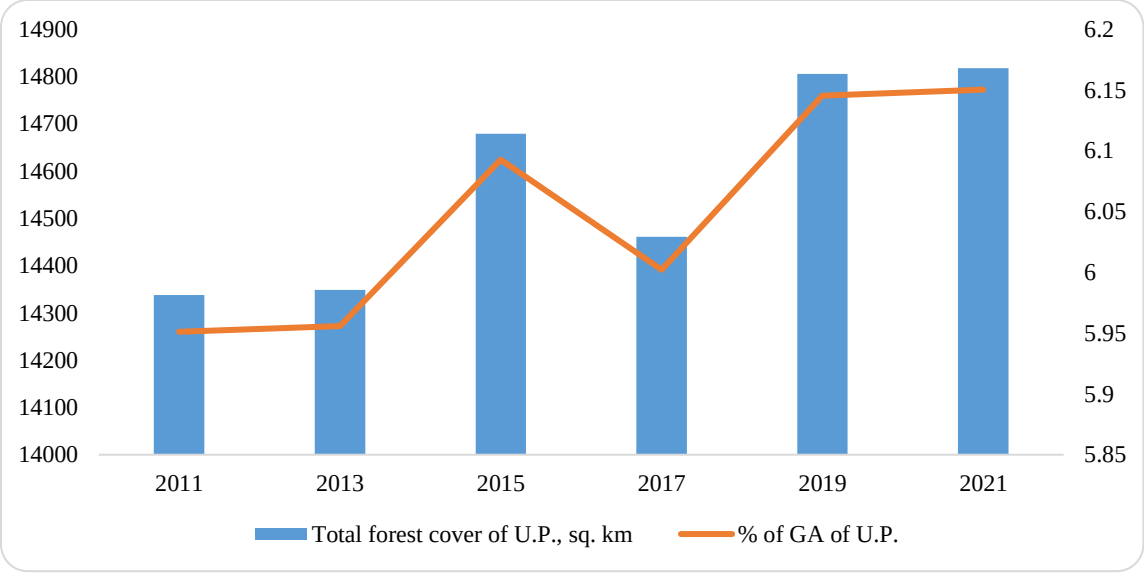

Figure 7: Trends of total forest cover in Uttar Pradesh since 2011

Various different AgF models are being practiced by farmers in Uttar Pradesh, as they are receiving additional benefits in terms of monetary returns from timber as well as improvement of their farm productivity. There are some productive AgF models recommended for Uttar Pradesh as presented below in Table 4.

Table 4: Agroforestry models recommended for Uttar Pradesh

Agroforestry model	Suitable Intercrops			Carbon sequestration (t C/ha)
	Kharif	Rabi	Annual	
Poplar based	Peral millet, cowpea, sorghum (for initial 3 years only)	Wheat, potato, mustard, oats, berseem (up to 6 years)	Sugarcane (for initial 2 years), turmeric and ginger (3rd years onward)	55 (6 years old)
Eucalyptus based	Pearl millet, Cowpea, sorghum, soybean, cotton	Wheat, potato, barley, oats, berseem	Turmeric, ginger	75 (6-7 years)
Melia based	Blackgram, cowpea, greengram, okra and groundnut	Sorghum, vegetables, wheat	Ginger, turmeric, banana, papaya, sandal	70-90 (5-6 years)
Teak based	Paddy, soybean, and pulses	Wheat, mustard, barley	Napier hybrid grass	34 (12 years of rotation)
Shisham based	Paddy, soybean and pulses	Wheat, mustard, barley	-	9.64
Mulberry based	Napier bajra hybrid or Setaria anceps grass, pulses, beans, soybean and wheat can be cultivated			31.10 (20 years)

There are various quantified benefits of agroforestry systems including:

- Crop yield observed to increase by 20 to 60% and the cropping intensity by 35%.
- Long lasting recharge of shallow dug wells with 2-6 meter water columns and regulated streams through the base flow (from 2.2 to 7% of annual rainfall) has been observed.
- Input costs reduced and farmers' net income doubled in a span of 4-5 years.
- Protected and stabilized ecosystems, increasing forest/tree cover.
- Promoted resilient cropping and farming systems to minimize the risk during extreme climatic events.
- Encourage and expand tree plantation in an integrated manner with crops and livestock to improve productivity, employment, income and livelihoods.

8. Driving forces analysis

Natural environmental and socio-economic factors are the two primary types of drivers that impact the web of agri-food systems. When evaluating how agri-food systems might shift in response to varying climate change projections at various levels, it is important to first look at the environment. Population shifts, the pace of urbanisation, the direction of agricultural policy etc., all fall under the umbrella of socioeconomic variables which play a crucial role in driving the food systems. In this study, four capitals (natural, produced, human and social) under the schemes/policies on OF and AgF based cropping systems will be assessed under the project and for target study areas. It is proposed and validated through the findings that OF and AgF have the potential to address various issues including climate, sustainability, environment and social wellbeing through these practices. These include human capitals, produced capitals, social capitals, and natural capitals. Human capital will be analysed through the agri-food value chain, through AgF. Produced capitals will focus on distribution-consumption and nutritional values. Social or socio-economic capitals will be assessed through livelihood opportunities, and the quality and improvement in the living standards of farmers. Natural capitals on the other hand focus on water, land and biodiversity as resources.

In this context, OF is a type of farming that focuses on maximising soil fertility while making the most effective use of available resources. It employs a range of ecological farming techniques aimed at reducing the environmental effects of food production, protecting the soil's long-term viability, and optimising the use of renewable resources. The government is working to make Uttar Pradesh an organic agricultural centre in the country, with plans to establish OF in communities along the Ganga's banks. Cluster farming is being adopted to begin with in order to manage farming in a more organised manner and to provide better quality control. To encourage farmers, the government would also provide a payment of Rs. (INR) 10 hundred thousand for each bunch spanning 50 acres of land over the next three years. Rs. (INR) 330000 will be paid twice in the first and third years out of the total amount. Grants totalling Rs. (INR) 340000 will be distributed in the intervening year.

Whilst AgF has the ability to improve ecosystem services by storing carbon, preventing deforestation, conserving biodiversity, and conserving soil and water, it also helps agricultural land to endure extreme weather events due to climate change such as floods and droughts,, when deliberately planted on a wide scale and with the right mix of species. As such, AgF is beginning to play a larger role in the realm of

environmental services. The technique has been shown to have the ability to reduce the effects of climate change by regulating microclimates and conserving natural resources.

The Policy (National Agroforestry Policy, 2014) also aims to simplify regulations related to tree harvesting, felling, and the transportation on farmlands. It aims to develop a sound base of land records and data for generating an AgF market information system. The National Agroforestry Programme (NAP 2014) aims to ensure that trees planted in agroforestry systems are free from all harvesting, transit, and marketing restrictions. One of the objectives of NAP 2014 is to bring together agroforestry programs, schemes, and missions from several government ministries.

Additionally, the government has some clear objectives as follows:

1. Policy and planning for sustainable agriculture and environment.
2. The GoI has planned to maintain 33% of the area under the forest cover of the country.
3. Aiming to achieve national priorities including: i) water conservation stress, ii) doubling the farmers' income, iii) reducing the use of chemical fertilizers, iv) reducing malnutrition and v) achieving the SDGs.
4. Improvement of soil health and halting land degradation by 2030 (COP14, UN convention)
5. Continuing to work towards improved biodiversity conservation

9. Scenario setting

The Earth's climate is changing in response to both natural and anthropogenic drivers. Anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), and other greenhouse gases now overwhelm the influence of natural drivers on the external impacts of Earth's climate. Climate change and ocean acidification are already happening due to the excess build-up of atmospheric CO_2 from industrial emissions during the industrial era. Even if existing concentrations could be immediately stabilized or even reduced, the temperature would continue to increase by an estimate of 0.61°C in the present century, relative to 1980-1999. By the end of this century, concentrations are projected to increase, and the resulting global temperature increase is projected to range from 1°C (RCP 2.6) to 3.7 °C (RCP 8.5). Here, RCP 8.5 describes the carbon concentration (20% higher CO_2 emissions) contributing to global warming at an average of 8.5 watts/meter^2 across the planet. RCP 4.5 is an intermediate or baseline scenario and it is supposed that CO_2 emissions will reach a peak by 2040 and then start declining by 2045 to reach roughly half of the levels of 2050 by 2100.

As per middle-of-the-road development (SSP2-4.5) scenario of CMIP6 projection using Multi-model Ensemble with 90th percentile, the annual mean temperature of India by the end of this century will increase by 2.70 °C with respect to the historical reference period 1995-2014, and this increase may reach up to 6.52 °C under the fossil-fuelled development (SSP5-8.5) scenario. The maximum temperature may be increased by 6.2 °C compared to the minimum temperature 2.9 °C under the moderate (SSP2-4.5) emission scenario.

9.1 Factors considered for scenario setting:

The agriculture department of Uttar Pradesh and the Government of India had prepared a roadmap to promote chemical-free and sustainable OF in the state and other regions of the country in 2016-17. OF

is supposed to alter/reverse climate change scenarios, control GHG emissions, water management/conservation and improve the soil-food quality as well[9]. In addition to OF, it is also supposed that AgF has significant potential to mitigate climate change, to provide employment to a large number of the population through production, industrial application and value addition avenues. 2014 estimates showed that about 65% of the country's timber requirement was met from the trees grown on farms[10]. AgF also has the potential to generate significant employment opportunities among the farmers. Thus, in this TEEBAgriFood project for Uttar Pradesh India, there are three agricultural farming policy scenarios, namely, a Business as Usual (BAU) scenario, an optimistic policy scenario and a pessimistic scenario. These were set up and crossed with two climate change scenarios - a medium GHG emission scenario RCP4.5, and a high GHG emission scenario RCP8.5, to obtain six future scenario combinations. Scenario setting is conducted in order to assess the governmental policies and its impact on an environmental context like climate scenarios by 2030, 2040 or 2050 under OF and AgF policy implications[11]. In recent years, OF as a cultivation process is gaining increasing popularity[12]. The Government of Uttar Pradesh/India has a target to promote OF all over the country through the schemes that provides subsidy, training and resources to farmers. In 2015-16, there were 106292.39 ha land (cultivated + wild) under OF certification in Uttar Pradesh, and this land area increased by a significant number in 2020-2021 reaching up to 159307.73 ha land, whereas the total cultivated farm area under OF was 67442.61 ha in Uttar Pradesh. In total 1.94 million ha land is currently under organic certification in India and ranks 9th in the world. As such, the report will address the evaluation of food production systems (Agricultural Ecosystems) and their impact and complex linkages to the environment, society and human health under the OF and AgF systems.

9.2 Scenarios adopted in the proposed study:

1. District: Aligarh (Crops: Rice, Wheat, Mustard, Finger Millet);
2. Bulandshahr (Crops: Rice, Wheat, Mustard, Sugarcane);
3. Hamirpur (Crops: Rice, Wheat, Chickpea, Pea, Sesamum);
4. Meerut (Crops: Sugarcane, Rice, Wheat);
5. Mirzapur (Crops: Rice, Wheat and Maize, Pigeon pea)

Table 5: Scenario setting under BAU, pessimistic and optimistic scenarios under OF and AgF

Scenario 1 (BAU + RCP 4.5 Climate Scenario) - Organic Farming – Expansion of organic farming @ 10%/year) - Agroforestry – 10% of the cropped land - RCP 4.5 – Medium GHG Emissions Scenario	**Scenario 2 (BAU + RCP 8.5 Climate Scenario)** - Organic Farming – Expansion of organic farming @ 10%/year) - Agroforestry – 10% of the cropped land - RCP8.5 – High GHG Emissions Scenario
Scenario 3 (Optimistic Policy + RCP 4.5 Climate Scenario)	**Scenario 4 (Optimistic Policy + RCP 8.5 Climate Scenario)**

[9] NATIONAL AGROFORESTRY POLICY, 2014
[10] Ibid
[11] Ibid
[12] Dangour et al., 2010

- Organic Farming – Expansion of organic farming @15% growth rate/year) which will cover 23.61% of the net cultivated area in 2050 - Agroforestry – 33% of the cropped land - RCP4.5 – Medium GHG Emissions Scenario	- Organic Farming – Expansion of organic farming @15% growth rate/year) which will cover 23.61% of the net cultivated area in 2050 - Agroforestry – 33% of the cropped land - RCP 8.5 – High GHG Emissions Scenario
Scenario 5 (Pessimistic Policy + RCP 4.5 Climate Scenario) - Organic Farming – Reduction of area under organic farming @ 5% per annum which will reduce the net cultivated area under organic farming to 0.09% of the net sown area. - Agroforestry – no increase/no decrease – no change in area under agroforestry - RCP 4.5 – Medium GHG Emissions Scenario	**Scenario 6 (Pessimistic Policy + RCP 8.5 Climate Scenario)** - Organic Farming – Reduction of area under organic farming @ 5% per annum which will reduce the net cultivated area under organic farming to 0.09% of the net sown area. - Agroforestry – no change in area under agroforestry - RCP 8.5 – High GHG Emissions Scenario

The distinction between the districts will be made in the crops that are assessed within each of the districts. Some crops are high input intensive which may not be suitable for OF and thus a scenario analysis, whereas the new crops that have been identified are more conducive for OF and have also been promoted by the Government of India, especially oil-seeds and pulses. Some crops are grown in less than 5% of the crop/cultivated area, and have therefore been removed to avoid any error in the study.

As already mentioned, there are multiple TEEBAgriFood projects running globally including this one in India, in Uttar Pradesh. Uttar Pradesh is a well flourished and agriculture rich region by the Ganga, Yamuna and their tributaries rivers. These are the key national policy priorities and areas of action, and some of the national schemes also targeted in these states include: the National Mission for Clean Ganga, Paramparagat Krishi Vikas Yojana (PKVY) and the National Agroforestry Policy-2014. The main aim of the TEEBAgriFood initiative for Uttar Pradesh is to help decision-makers recognize, demonstrate and capture the values of ecosystem services and biodiversity worldwide and come up with promising and sustainable solutions under the various scenario developments and analyses under the OG and AgF farming practices.

Table 7: District wise traditional and new crops under the subject of study for the project

District	Crops in SSFA	Potential new Crops identified for study
Aligarh	Rice, Wheat, Mustard	Pearl millet, wheat
Bulandshahr	Rice, Wheat, Mustard	Sugarcane, wheat, mustard
Hamirpur	Rice, Wheat, Chickpea, Pea	Rice, Wheat, Chickpea, Pea
Meerut	Sugarcane, Rice, Wheat	Sugarcane, Rice, Wheat, vegetables* and fruits*
Mirzapur	Rice, Wheat and Maize	Rice, wheat, maize, Pigeon pea

*Area under these crops is minimal (<4% of the net cultivated area). However, as per the stakeholder consultation these crops are considered to value the ecosystem services depending upon the data set available.

9.3 Specific scenario settings

The specific scenarios under BAU, Optimistic and Pessimistic scenario settings under OF and Agroforestry systems are as shown below in Table 8:

Table 8: Organic farming and agroforestry systems under the different scenarios – Business as Usual, Optimistic and Pessimistic scenarios.

S. No.	Particulars	Rationale in policy context
9.3.1.	**Business as Usual (BAU) Scenario**	
A.	**Organic Farming (OF)**	
	Currently the net sown area under organic agriculture in Uttar Pradesh is 67442.6 ha. In the BAU scenario, we have taken into account the growth rate of the total area under organic certification processes (cultivated + Wild Harvest) (in ha) during the last 6 years for Uttar Pradesh. This amount increased by 10% approximately for the period 2015-16 to 2020-2[13]. OF is being upscaled at large scale under ongoing national schemes such as NPOP, PKVY, and Namami Gange Mission etc. Considering the existing policies of the state govt. under the BAU scenario, we postulate that 6.46% of the net sown area will be covered by OF practices by 2050 which is about 1069848.4 ha.	
B.	**Agroforestry (AgF)**	
	In Uttar Pradesh AgF has enormous potential in terms of cultivation, covering 9.23% of the net cultivated area. The Uttar Pradesh Government's vision is to increase the state's green cover through agroforestry from current area of (9.23 ha) to 15%. As a result, the Forest Department, in collaboration with the Agriculture Department and other relevant agencies, is implementing AgF programmes such as the establishment of large-scale nurseries of high-quality tree/plant material, free plant distribution to farmers etc. Extension and support services are made accessible through research and other activities such as visits by Forest Department officials, AgF specialists/research scientists and the organization of trainings for post-plantation care from the National Research Centre for Agroforestry (NRCAF) and other sources such as centres/universities. A total of 1641700 ha are currently under active agriculture. To improve the tree cover, the department will heavily push AgF. Considering the same situation will continue, under the BAU scenario we postulate that the area under agroforestry continues to remain at 10% of the net cropped area (1657347.8 ha).	
9.3.2	**Optimistic Scenario**	
A.	**Organic Farming (OF)**	
	The vision of the Government of Uttar Pradesh is to encourage organic farming within a radius of 10km on both the banks in 27 districts of the Ganga rivers. The Ganga rivers flow in Uttar Pradesh ~1140km, which is expected to cover 1,14000 hectares of additional organic farming area in the state. In organic farming, chemical fertilisers and toxic pesticides are replaced by completely organic products in order to increase the yield and protect the soil. Since the soil of the Gangetic plain changes due to floods every year, there is a lot of potential for organic farming in the entire region. In the post-pandemic situation, the consumer is looking for clean and healthy food options and organic food is one of them. Organically grown vegetables, staples, fruits and	

[13] https://apeda.gov.in/apedawebsite/organic/data.htm#Total_farm_area_2021

	seeds etc. have started witnessing demand in the market. Uttar Pradesh has also taken initiatives to make the State a hub for organic farming in India. It has introduced cluster farming and the government has also decided to fund each cluster over the next three years to encourage organic farming. In this scenario we consider that the Government has simplified the Organic Certification systems for the expansion of the area under OF. Other possible reasons for the expansion of the organic farming area in Uttar Pradesh include the following: • The trend during 2021–2026 in the organic food market is expected to grow at a Compound Annual Growth Rate (CAGR) of about 20.5% to reach about USD 2601 million by 2026[14]. • The cultivable land area under organic farming (organic certification process) in India has increased from 0.58 M ha in 2004 to 1.183 M ha in 2014 and 2.66 M ha in 2021 due to the implementation of central schemes in addition of 1.68 M ha for wild harvest collection. Therefore, Uttar Pradesh has an enormous potential and a huge demand for organic products. • Organic production and trade have evolved as an attractive sector in India and other parts of the developing world. Moreover, most of the farmers in India are adopting this practice motivated by attractive markets and price margins. Presently, India ranks ninth in terms of area under organic agricultural land (2018-19) as per the Research Institute of Organic Agriculture (FiBL) Survey, 2020. • In 2020-21, Uttar Pradesh has 67442.6ha of total cultivated farm area under OF, which includes 53194.8ha under organic cultivated and 14247.8ha area that was converted from traditional to OF. In 2015-16, the total area under organic certification (cultivated + Wild Harvest) was 106292.4ha while in 2020-21, the area increased by 50% (159307.7). Therefore, given the context of Uttar Pradesh and considerations of Land Use Land Change (LULC) and the promotion of cow-based economies by the Government of Uttar Pradesh, under the optimistic scenario we postulate a growth rate of 15% per year and an expected expansion of the organic farming area of 3883038.88ha (23.6%) by 2050.
B.	**Agroforestry (AgF)**
	The national agroforestry policy aims to improve the production, employment, income, and livelihoods of rural families, particularly smallholder farmers. For the promotion of AgF products, value chain growth, technological development, market knowledge, and soon, industries, will be encouraged to act as end-users. The government continues to promote tree planting through various initiatives (MGNREGs, RKVY, National Horticulture Mission, Bamboo Mission, specific plantation drives like those in Uttar Pradesh, and so on). Farmers are coming to WIMCO, ITC, and other similar organisations working on private land planting in cooperation with existing knowledge from ICAR institutes, State Agricultural Universities, and private firms on AgF. The goal for the next 20 years should be to convert 1/3 of the land area to AgF. In light of this, our annual goal should be to bring around 80000 acres under AgF. This may be accomplished by providing farmers with seedlings (600 plants per hectare). With this background, under the optimistic scenario, we postulate the area coverage of 33% of the total geographical area to be

[14] https://foodsafetyhelpline.com/reasons-for-the-increase-in-the-demand-of-organic-food-worldwide/

	converted to agroforestry, which is also in line with the National Forest Policy targeting to bring 33% of the total geographic area of India under forest and tree cover.
9.3.3	**Pessimistic Scenario**
A.	**Organic Farming (OF)**
	Chemical fertilisers and pesticides can be used in conventional farming, as mentioned previously as they help produce higher yields and ensure food security. At the same time however, they can have detrimental consequences for both the environment and the human body, and there is still a huge gap in organic farming to fulfil the immediate demands of nutrients through organic fertilizers (because of the slow release in nature). Further, the investment costs required for developing the requisite infrastructure for transporting and processing the post-harvest of organic produce is higher, coupled with low yields due to climate change effects. The lack of easy certification and premium price of their produce also adversely affects the expansion of the organic farming area. Under the pessimistic scenario, we postulate a conservative negative growth rate of 5% by shifting organic farms to conventional systems which may result in the reduction of the current area under organic i.e. 67442.61ha to only 15237.7ha in 2050, which will be only 0.09% of the net sown area of Uttar Pradesh.
B.	**Agroforestry (AgF)**
	Under the pessimistic scenario, we postulate no further change in area under agroforestry based on a study carried out by ICAR-IIFSR, Modipuram on poplar based AgF systems. This study indicated a reduction in the timber value of poplar as well as increased pest infestation in sugarcane. The possible reasons may be attributed to: ✓ Very small holdings – absentia farmers go for AgF; ✓ Weak practical aspect and knowledge of AgF among farmers; ✓ The complex process of sell and purchase through a partnership between farmers and industries; ✓ Negative interaction between crop and AgF components.

9.4 Selection of Ecosystem Services

As discussed, OF is supposed to alter/reverse climate change impacts, control/limit the GHG emissions, increase/improve ground water recharge/water management/conservation and improve the soil and food quality as well. The long lasting recharge of shallow dug wells with 2–6m long water columns and regulated streams through the base flow (from 2.2 to 7% of annual rainfall) has been observed. AgF has a significant potential to mitigate climate change impacts in terms of carbon sequestration, while providing employment opportunities to a large number of the population through production, industrial application and value addition avenues. The selected study areas fall under the different soil and climate conditions and as such, the study would help by analysing the impact of various farming systems on the ecosystem services. The selected indicators of ecosystem services shown in Table 9 play a vital role in improving natural, provisioning, human and social capital in Uttar Pradesh. Maintaining the quality of air and soil, preventing flood control and the proper pollination of crops are some of the important ‘regulating services' provided by ecosystems. These regulating services are often invisible and are therefore typically taken for granted. When these services are damaged, the resulting losses can be substantial and difficult to restore. Agriculture, forestry, livestock and fisheries can be influenced due to various disturbances of these ecosystem services.

Uttar Pradesh's Groundwater Department conducted a study on 820 blocks in 75 districts of Uttar Pradesh and they reported that in 77 blocks, the groundwater table (i.e. the upper level of an underground surface in which the soil or rocks are permanently saturated with water) declines by more than 60cm per year and there are 147 blocks where the decline of the ground water table is between 1 to 10 cm/year[15]. In another report from Uttar Pradesh, it was reported that in the alluvium Ganges soils of Uttar Pradesh, erosion rates varied from 5-10 Mg/ha/year[16]. Due to sediment loss, the ability of topsoil to hold nutrients, regulate water flow, and combat pollutants may decrease. Sediment loss through erosion can lead to soil degradation and lower land productivity, while also putting a strain on agricultural production and food security. Furthermore, runoff and sediment can carry pollutants that have a negative impact on the environment and socioeconomic development in areas surrounding erosion regions, such as through water eutrophication, habitat destruction, and the exacerbation of drought and waterlogging disasters in downstream areas. Soil erosion control is an important part of environmental protection, ecological safety, long-term economic growth, and coexisting with nature. On the other hand, agricultural production plays a vital role in terms of GHG emissions, currently accounting for 18% of total GHG emissions in India[17]. Therefore, carbon sequestration through agriculture and agroforestry practices stores the carbon in the soil and hinders it from entering the atmosphere which will reduce the greenhouse gas effect. Agrobiodiversity also plays a crucial role in reducing the pressure of agriculture on fragile areas, forests and endangered species. It ensures farming systems are more stable, robust, and sustainable. Agrobiodiversity conserves soil and increases natural soil fertility and health. Employment in agriculture (% of total employment) in India was reported to be 41.49% in 2020 (modelled ILO estimate). Economically, employment provides income to poor families, revives domestic demand for goods and services, and stimulates overall growth. Women empowerment is also one of the factors for enhancing per capita income through family labour engagement in the agriculture sector. Women partaking in decision-making processes within the agricultural sector can play a significant role in improving livelihood security as well as employment generation. Therefore, the Government of India's vision is to double the farmer income by 2022-23 in order to promote farmers' welfare, reduce agrarian distress, increase women empowerment and bring parity between the income of farmers and those working in non-agricultural professions.

To combat the aforesaid challenges, the Government of India initiated many centralized schemes to restore ecosystem services through the implementation of organic farming and agroforestry practices. Vegetation restoration and biomass recycling through green manuring as well as the application of enriched carbon sources such as farmyard manure, vermicompost/compost and non-edible oil cakes etc. under organic farming is an effective measure for preventing and controlling soil erosion, improving water recharge, water holding capacity, soil organic carbon, agrobiodiversity and ecological security. Based on the All India Network Programme on Organic Farming (AI-NPOF), the water holding capacity increased to 27% under OF which saves a large quantity of water. These findings are based on the research for multi-centre experiments in India. Therefore, to analyse and simulate these ecosystem services under the BAU, optimistic and pessimistic scenarios, the following indicators of ecosystem services were selected to

[15]https://timesofindia.indiatimes.com/city/meerut/declining-trend-of-groundwater-in-last-decade-70-of-up-is-over-extracted/articleshow/72420052.cms
[16]http://www.ciesin.columbia.edu/docs/002-413/002-413.html#:~:text=Erosion%20rates%20on%20alluvial%20Indo,Mg%2Fha%2Fyr).
[17]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5268357/#:~:text=Agricultural%20production%20is%20a%20major,CTA%2DCCAFS%2C%202011).

determine their impact under organic farming and agroforestry practices, which is required to be able to bring attention to the matter at the policy level.

9.5 Linking of Malarial infestation with land use/land cover patterns under six scenarios of studies under Human capital

Landcover is a critical variable in the field of epidemiology. The spread of malaria and its intensity is determined by climate and other environmental factors that affect the presence of mosquitoes and *Plasmodium* at a given time, in addition to ecological alterations over time[18]. Ecosystem changes resulting from natural phenomena or anthropogenic factors on a local or global scale, can alter the ecological balance and environment in which vectors and their parasites develop and transmit diseases[19]. According to Patz and Olson (2006)[20], changes in temperature patterns due to global climate change in combination with variations in local land use practices, may alter the risks of contracting malaria. Some authors directly relate environmental alteration to cases of malaria. Olson *et al*. (2010)[21] studied malaria in Mâncio Lima County, Brazil and reported that a 4.3% increase in deforestation between 1997 and 2000 was associated with a 48% increase in the risk of contracting malaria. Vittor *et al*. (2006, 2009)[22],[23] suggested that deforestation and other human environmental alterations favour the presence of both *An. darlingi* larvae and adults in the Peruvian Amazon.

In this case, malarial infestation may be studied using the breeding suitability index developed based on land use land cover patterns that emerged under six scenarios of the study. The index is available in Individual sample datasets for InVest (http://releases.naturalcapitalproject.org/?prefix=invest/3.12.0/data/).

Table 9: Ecosystem service indicators, data sets, sources and tools to be used for the analysis

Sl. No.	Ecosystem Services (ESs)	Indicators of ESs	Data sets & sources	Tools to be used
1.	Natural Capital	i. Water quantity modelling	**Parameter:** Depth to Water Level (water depth) **Source:** State Ground Water Departments, Lucknow/ Central Ground Water Board, New Delhi	SWAT Model

[18]Stefani, A., Dusfour, I., Corrêa, A.P.S. *et al.* Land cover, land use and malaria in the Amazon: a systematic literature review of studies using remotely sensed data. *Malar J* 12, 192 (2013). https://doi.org/10.1186/1475-2875-12-192.

[19]Patz JA, Graczyk TK, Geller N, Vittor AY: Effects of environmental change on emerging parasitic diseases. Int J Parasitol. 2000, 30: 1395-1405. 10.1016/S0020-7519(00)00141-7.

[20]Patz JA, Olson SH: Malaria risk and temperature: influences from global climate change and local land use practices. Proc Natl Acad Sci USA. 2006, 103: 5635-5636. 10.1073/pnas.0601493103.

[21]Olson SH, Gangnon R, Silveira GA, Patz JA: Deforestation and malaria in Mâncio Lima County, Brazil. Emerging Infect Dis. 2010, 16: 1108-1115. 10.3201/eid1607.091785.

[22]Vittor AY, Gilman RH, Tielsch J, Glass G, Shields T, Lozano WS, Pinedo-Cancino V, Patz JA: The effect of deforestation on the human-biting rate of *Anopheles darlingi*, the primary vector of falciparum malaria in the Peruvian Amazon. Am J Trop Med Hyg. 2006, 74: 3-11.

[23]Vittor AY, Pan W, Gilman RH, Tielsch J, Glass G, Shields T, Sánchez-Lozano W, Pinedo VV, Salas-Cobos E, Flores S, Patz JA: Linking deforestation to malaria in the Amazon: characterization of the breeding habitat of the principal malaria vector, *Anopheles darlingi*. Am J Trop Med Hyg. 2009, 81: 5-12.

		ii. Soil health (sediment yield, physical properties)	**Parameter:** Sediment yield **Source:** Ministry of water resources/NRAA **Parameter:** Water holding capacity **Source:** ICAR-NBSS&LUP, Nagpur	SWAT/InVest Model APSIM/SWAT/InVest
		iii. Carbon sequestration	**Parameter:** Soil organic carbon **Source:** ICAR-NBSS&LUP, Nagpur	SWAT/InVest model
		iv. Agrobiodiversity	**Parameter:** Diversity index **Source:** Primary though field survey and secondary data from published records of the Govt. of Uttar Pradesh	InVest model/Statistical tool
2.	Produced capital (Biomass)	Crop Provisioning Services	**Parameter:** Economic Yield & Biomass **Source:** Primary data from field survey, Secondary data from Published records of the Government of Uttar Pradesh/India	APSIM/SWAT/InVest Model
3.	Human capital	Malaria infestation, Employment Generation, women empowerment.	The methodology for the study of human and social capital is already standardized by ICAR-IIFSR, Modipuram. It will be studied through primary survey data as illustrated in Ravisankar et al., 2022[24] for formulating a comprehensive indicator to reflect the ecology-economic-equity interface of sustainable development. Parameters are listed in Annexure I. Women empowerment parameters are given in Annexure I.	Econometrics tools
4.	Social capital	Sustainable livelihood security,		

[24]Ravisankar et al. (2022). https://doi.org/10.1002/ldr.4358

			Parameters for capturing changing consumption pattern are given in Annexure I.	
		Human health	**Parameters:** LULC based Malaria infestation **Source:** ICAR-NBSS&LUP, Nagpur	InVest model

10. Methodology used for computation for social and human capitals

10.1 Employment generation

Family labourers and other labourers engaged throughout the sowing and harvesting of organic farming and agroforestry activities will consider employment of labour. As per the standard norms, 8 hours for men and 6 hours for women would be considered to be a normal work day. Primary survey data will be used for the employment generation calculation.

10.2 Women empowerment

Decision making is one of the key aspects of women empowerment. Women are described as being great multitaskers. However, their importance is neglected in many societies.The women in these areas inherently have the knowledge to cook, perform gardening tasks, as well as organic farming and agroforestry, as well as rearing poultry and engaging in livestock farming. Although their knowledge might not be considered to be scientific in nature, it holds great value.. Farming systems are comprised of not only crops, but also livestock, poultry, fish and secondary agriculture, where women farmers can play a greater role. With this background, the survey will be undertaken to analyse the participation of women in the decision making on various aspects of farming systems (Annexure I). Women empowerment data will be generated from the primary survey and ranked based on the econometrics used for calculation.

10.3 Sustainable Livelihood Security Index (SLSI)

The SLSI will be measured after combining the weighted index of an Ecological Security Index (ESI), the Economic Efficiency Index (EEI) and the Social Equity Index (SEI), as illustrated in Ravisankar et al. (2022). In this study, the authors formulate a comprehensive indicator to reflect the ecology–economic–equity interface of sustainable development. Parameters used for the development of the ESI, EEI, and SEI will be generated from the primary survey shown in Annexure 1. The SLSI has three component indices, i.e. ESI, EEI, and SEI. SLSI is derived from equations (1) and (2) below.

$$SLSI_{ij} = \frac{XL_{ij} - Min_j X_{ij}}{Max_j X_{ij} - Min_j X_{ij}}; i = 1,2,...,I; j = 1,2,...,n \quad \text{.....(1)}$$

$$SLSI_j = \frac{\sum_{i=1} a_{ij} SLSI_{ij}}{I}; j = 1,2,...,n \quad \text{..... (2)}$$

Where SLSI*ij* is the index for the i^{th} component of SLSI related to the j^{th} entity (households), and let X_{ij} be the value of the variable representing the i^{th} component of SLSI related to the j^{th} entity.

The a_{ij} in (2) denotes the weight assigned to the i^{th} component of SLSI of the j^{th} entity and has the property that: $a_{1j} + \ldots + a_{Ij} = 1$.

11. Supplementary study

During a stakeholder meeting held on September 20, 2022 for the Scoping and Scenario Setting Report titled "The Economics of Ecosystems and Biodiversity: Agriculture and Food initiative in Uttar Pradesh, India", health professionals and progressive farmers presented their resounding support for the investigation of Agrifood-related human health problems, in particular cancers. The health professionals argued that the number of cases have been geometrically increasing, and that this phenomenon has to be studied in conjunction with medical science. They expressed that the use of agricultural chemicals was growing, and that policies must be developed for to produce cleaner agrifood.

Currently, in India, non-communicable diseases such as cancer are quickly becoming among the country's most pressing issues in terms of public health and has emerged as a potential threat to humankind. These diseases are tied to lifestyle choices and have a long period of time during which they are dormant. The treatment for them also requires specific infrastructure and human resources. Based on the cancer registry data it is estimated 2.7 million people (2020) are affected by cancer annuallyand every year 13.9 hundred thousand people register as cancer patients[25]. In 2020, nearly 8,51,678 deaths were attributed to cancer. The major source of cancer is associated with tobacco from 35 to 50% of all cancers in men and about 17% of cancers in women26.

The application of excessive use of agricultural chemicals including synthetic fertilizers and pesticides increased the evidence of non-lymphoma, Hodgkin's leukaemia, multiple myeloma, soft-tissue sarcoma, and brain, stomach, prostate, skin, and lip cancers in farmers. Agricultural workers are at risk for contracting hematologic malignancies due to zoonotic viruses, agricultural chemicals, and prolonged antigenic stimulation. Lymphohematopoietic, melanoma, prostate, and brain tumours are also common. Commercial pesticide applicators and farmers have an increased risk of lung cancer related to chlorpyrifos, diazinon, metolachlor, and pendimethalin exposure. Mutagenicity, immunotoxicity, and hormonal disruption by pesticides may cause cancer[27]. Agricultural exposure increases the cancer risk differently, depending on work and farming lifestyles. Types and intensities of exposures suggest a high risk of leukaemia among farmers. Leukaemia among dairy and poultry farmers suggests the involvement of zoonotic viruses, while agricultural production is linked to pesticide use. Crop-duster pilots have a greater risk of contracting skin cancer than pesticide applicators and farmers. Hodgkin's or non-lymphoma, Hodgkin's soft-tissue sarcoma, multiple myeloma, and brain, stomach, and prostate malignancies are unknown. The intensive physical activity of farming reduces colorectal cancer[22]. Farmers, farmworkers, and ranchers who are overexposed to UV radiation are also at risk of getting skin cancer and should use sunscreen, sunglasses, and full protective clothing. High plant-based food consumption may prevent cancer.

[25] http://cancerindia.org.in/cancer-statistics/
[26] https://main.mohfw.gov.in/sites/default/files/Cancer%20Prevention%20And%20Control%20In%20India.pdf
[27] https://www.jliedu.com/blog/agriculture-cancers/#:~:text=Types%20of%20Cancers%20due%20to,prostate%2C%20skin%2C%20and%20lip.

Organic agriculture on the other hand eliminates synthetic pesticides and chemical fertilizers, creating a healthy work environment and improved yields.

In Uttar Pradesh, cancer is increasing at a growth rate of 102.4% (4-year trends shown in Fig. 8)[28]. In the last 5 years chemical fertilizer consumption trends increased by 11.56% (2018), 13.91% (2019), 29.41% (2020) and 37.13% (2021) as compared to 2017[29]. Similarly, the consumption of chemical pesticides has also increased by 7.4% in 2020-21 as compared to the average of the last 4 years[30]. Subsequently, the excessive use of fertilizers and pesticides by farmers on the Yamuna's floodplains, is contributing to the poisoning of the river water, its floodplains and groundwater, reported by the Central Pollution Control Board (CPCB) of India in 2019[31]. Due to the fact that groundwater is the primary supply of potable water, contamination of this resource can result in a number of adverse effects on human health. The adoption of organic farming and towards organic approaches as well as agroforestry systems are alternative options as sustainable agricultural practises and mitigation tools for minimizing groundwater contamination caused by these agrochemicals. These practises and procedures also help protect the environment and purify the groundwater for the improvement of ecosystem services and human capitals. Therefore, in view of the aforementioned facts and data, a supplementary study should also be undertaken focusing on the risk of cancer under different scenarios in Uttar Pradesh.

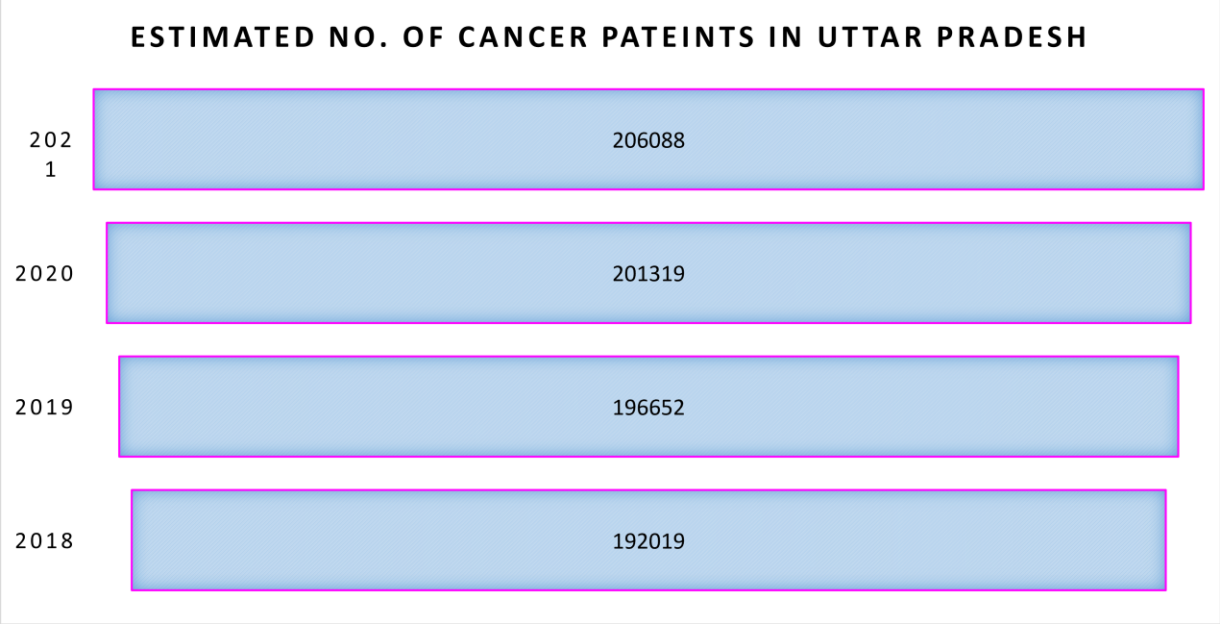

Figure 8. Trends of cancer cases in Uttar Pradesh

[28] https://www.researchgate.net/publication/361001493_Incidence_Estimate_of_Cancer_Cases_in_StateUT_of_India_from_2018_to_2021-v-1
[29] https://www.ceicdata.com/en/india/chemical-fertilizers-nitrogen-phosphate-and-potash-npk-consumption-by-states/chemical-fertilizers-npk-consumption-uttar-pradesh-nitrogen
[30] http://ppqs.gov.in/statistical-database
[31] https://www.hindustantimes.com/india-news/excessive-fertiliser-use-is-poisoning-yamuna-river-cpcb/story-sxP0QO3csxGg5uoawhwHjN.html

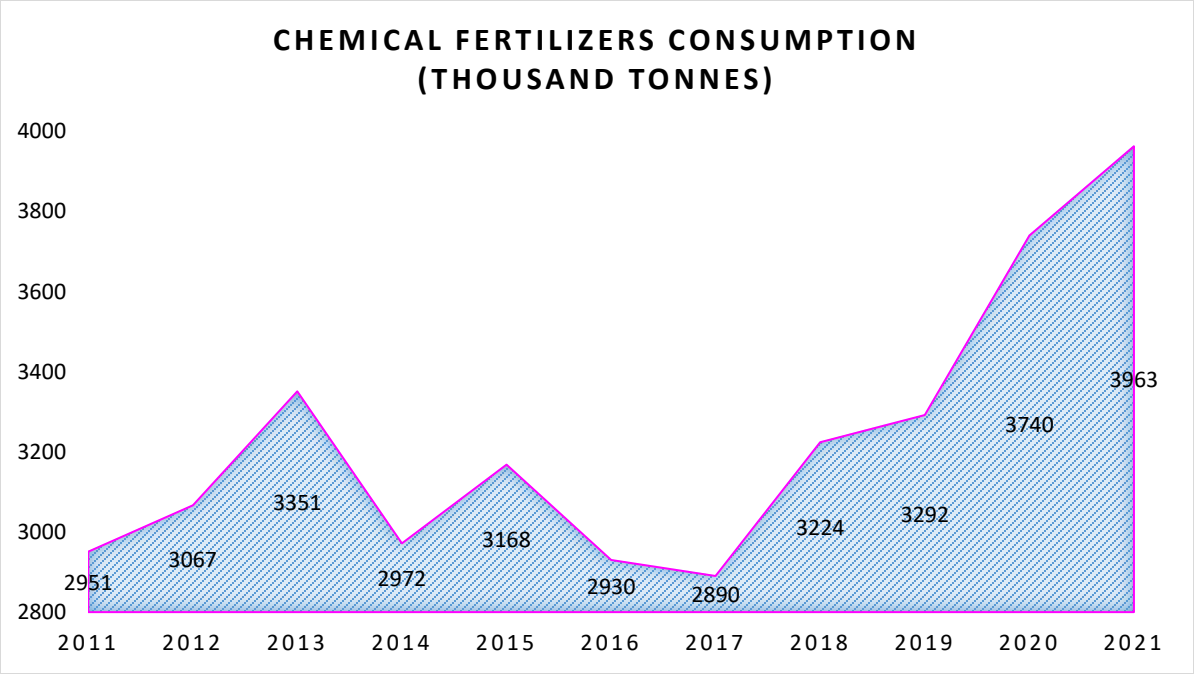

Figure 9. Chemical fertilizer consumption patterns in Uttar Pradesh

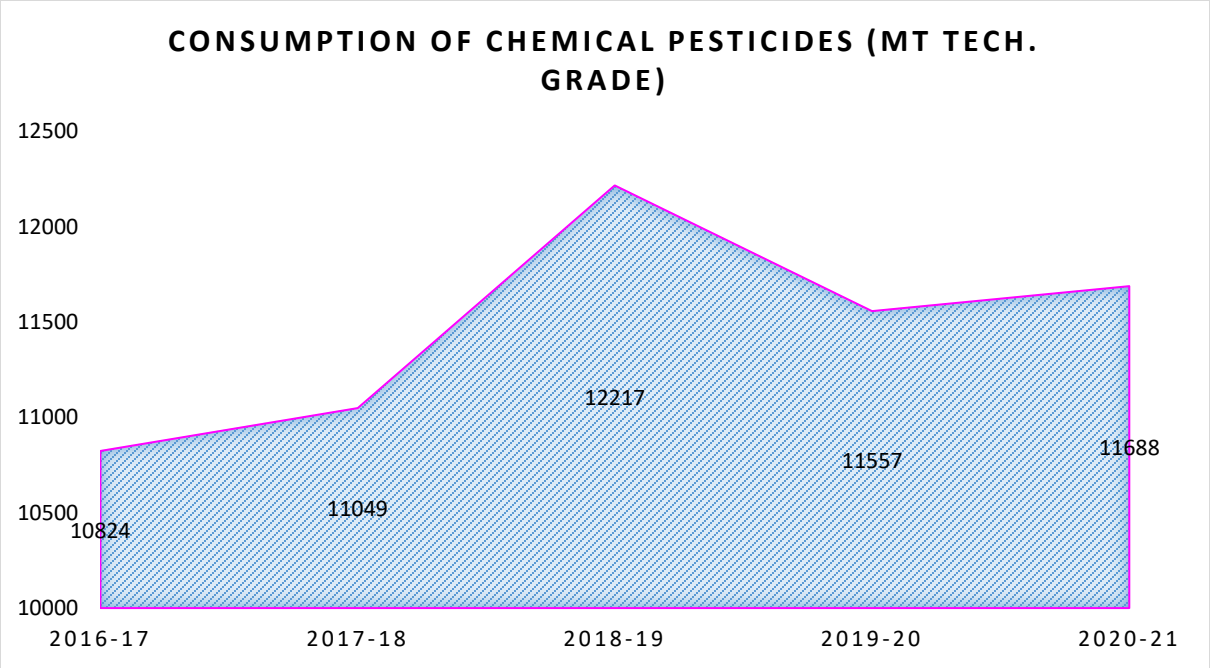

Figure 10. Trends of the use of chemical pesticides in Uttar Pradesh

Supplementary details about the various performance indicators at the state selected district of Uttar Pradesh are given in Annexure II to XXX.

Annexures enclosed (separate file):

Annexure I: Primary data collection Survey Proforma
Annexure II. Characteristics of Agro-climatic zones of the state
Annexure III. District wise forest type and change assessment
Annexure IV. Distinct Species of Plants used by tribes in Uttar Pradesh
Annexure V. National or Sanctuary Park of Uttar Pradesh
Annexure VI. Tribes in Uttar Pradesh Census, 2011
Annexure VII. District wise Rice area and production 2019
Annexure VIII. District wise Wheat area and production 2019
Annexure IX. District wise Mustard area and production 2019
Annexure X. District wise Maize area and production 2019
Annexure XI. District wise Sugarcane area and production 2019
Annexure XII. District wise cattle 2019
Annexure XIII. District wise Sheep 2019
Annexure XIV. District wise Pig 2019
Annexure XV. District wise Buffalo and Goat 2019
Annexure XVI. Agroforestry practices of Uttar Pradesh
Annexure XVII. Agroclimatic zones of Uttar Pradesh
Annexure XVIII. River basin of Uttar Pradesh
Annexure XIX. River Basin and Water bodies of Uttar Pradesh
Annexure XX. Forest Cover of Uttar Pradesh
Annexure XXI. Land use and Land Cover Uttar Pradesh, 2021