Empowering Decisions in Food, Agriculture, and Land Use:

Scaling up a Collaborative, Resilient and Democratized Ecosystem

The Food and Land Use Coalition
India Country Platform

Authors

Parth Sarathi Roy, Former Director, Indian Institute of Remote Sensing (ISRO), Dehra Dun
Reshma M R, Research Associate
Vinod M Bothale, Former Associate Director, NRSC/ISRO, Hyderabad
Vishnu Chandra, Former DDG, NIC, New Delhi
Rajashree V. Bothale, Former Deputy Director, NRSC/ISRO, Hyderabad
Shalini Dhyani, Principal Scientist, CSIR-National Environmental Engineering Research Institute, Nagpur

Editors

Shalini Dhyani, Principal Scientist, National Environmental Engineering Research Institute - Council of Scientific and Industrial Research, Nagpur
Parth Sarathi Roy, Former Director, Indian Institute of Remote Sensing (ISRO), Dehra Dun

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Executive summary

Food and land use data are indispensable for addressing the challenges of climate change, which disrupt agriculture, threaten food security, and degrade natural resources. India's agriculture sector, comprising small and fragmented landholdings, faces vulnerabilities from climate variability and extreme weather events. Accurate, integrated, and accessible data on natural resources and agriculture are critical to inform policies, optimise resource use, enhance resilience, and achieve sustainable food systems. Such data enable stakeholders to implement precision agriculture, improve decision-making, and foster equitable growth. The availability and quality of data play a pivotal role in shaping strategies for sustainable land use and food security. In India, government bodies such as ISRO, SOI, IMD, and ICAR, along with private agritech firms and international organisations like FAO and NASA, constitute the core producers and providers of vital information. However, data reliability and consistency across these sources remain uneven. Geospatial data often lack sufficient field validation, and tabular formats do not fully capture spatial elements. Many data-gathering initiatives tend to be project-based, compromising long-term continuity when funding cycles end. The absence of robust institutional mechanisms to ensure sustained data collection further weakens the overall data infrastructure and makes it difficult to build upon past efforts effectively. Current gaps in data sharing affect a wide range of stakeholders, including policymakers, farmers, researchers, scientists, and local communities that rely on these datasets for climate research, agricultural planning, and monitoring.

The coexistence of incompatible formats such as tabular and geospatial—and the persistence of institutional silos undermine interoperability. Privacy concerns frequently limit open access, and user-friendly platforms that can simplify the data access process are scarce. As a result, the flow of information is restricted, and crucial insights fail to reach the people and institutions that need them most, impeding progress in the agricultural and environmental sectors. These challenges are further exacerbated by the impacts of climate change on food security and land use. With rainfall patterns becoming increasingly erratic and temperatures on the rise, staple crops are at risk of reduced yields and heightened pest pressures. These environmental stresses directly translate into economic pressures for farmers, who may face declining incomes in the face of unpredictable conditions, as well as for consumers, who encounter elevated food prices and reduced dietary options. Vulnerable populations are most severely affected, intensifying socio-economic disparities and highlighting the urgent need for strategic interventions. To address these mounting issues, real-time geospatial platforms and supportive policy measures have emerged as potential solutions.

Satellite remote sensing is best used to create a national framework for land use mapping and monitoring systems for producing consistent, timely and reliable Land Use and Land Change (LULC) data. Hence, there is need to institutionalise the development of LULC data, crop wise area and production statistics (multilevel) using satellite remote sensing-based nationwide data in very high granularity in regular interval. Machine learning and artificial intelligence algorithms have reduced processing time and increased accuracy levels. There is a need to reconcile the LULC statistics and reporting systems which will support sustainable development and planning policies.

Cloud-based systems can integrate data on soil health, pest risks, and weather patterns, equipping farmers and policymakers with timely, targeted insights that support precision agriculture. Complementary policy reforms, such as the National Geospatial Policy 2022, can foster cross-sector collaboration and alignment, enabling the creation of centralised, interoperable data-sharing mechanisms. These frameworks should encourage multi-stakeholder engagement and reduce redundancy, enhancing the capacity of all parties to respond proactively to evolving agricultural and climate challenges. The present study highlights the challenges of providing farmers with reliable, necessary, and real-time data from data producers. Immediate priorities include enhancing data accessibility by building centralised platforms that assimilate both geospatial and tabular information for real-time analysis.

Standardising formats and establishing a unified national data repository will facilitate smoother data flows and better coordination among diverse entities. Addressing policy gaps is equally critical. Forming an inter-ministerial committee to oversee data governance can streamline procedures, set clear guidelines for data privacy and access, and reduce the institutional fragmentation that currently hinders effective policymaking. Public-private partnerships should be incentivised to establish and maintain robust geospatial platforms, aligning resources and expertise from different sectors for greater efficiency. Capacity building also requires attention at multiple levels. Skilled professionals, including scientists, analysts, and local extension agents, need training in advanced data analytics and geospatial technologies. Farmers similarly benefit from greater access to real-time advisory systems that can guide decisions on planting schedules, irrigation, and pest management. Investing in research and development will bolster these initiatives.

Developing drought-resistant crop varieties and encouraging the adoption of resource-efficient farming methods can build resilience against extreme weather, while innovation in precision agriculture can accelerate the transition to climate-resilient practices. Finally, fostering collaboration at both national and international scales can amplify the impact of these efforts. Strengthening partnerships for knowledge exchange and capacity development not only accelerates learning but also ensures that global and local data resources are harnessed efficiently to address region-specific challenges. By integrating findings from multiple sources, stakeholders can build comprehensive strategies that reflect both the nuances of local ecologies and broader trends in global food systems. Prioritising these actions will position India to transform its food systems, reinforce resilience, and establish sustainable land use practices capable of withstanding the varied challenges posed by climate change.

Chapter 1: Empowering Data Centric Decisions in Food, Agriculture and Land Use: A Collaborative, Resilient and Democratised Ecosystem

Introduction

India is a prominent player in the agriculture sector and a global agricultural superpower with the second-largest agricultural land area in the world supporting livelihoods of around 42.3% and accounts for 18.2% of the country's GDP.[1] Given India's status as a major food provider, the sustainability of its agricultural system is critical to not only India but the larger global community. The country has 195 million hectares under cultivation, with 63% rainfed (125 million hectares) and 37% irrigated (70 million hectares), mainly dominated by small and fragmented land holdings (FAO, 2021). India is the world's largest producer of milk, pulses, and spices, and also has the largest livestock (buffaloes) population. Additionally, it is among the top global regions for growing wheat, rice, and cotton. In terms of production volume, it ranks second globally in rice, wheat, cotton, sugarcane, farmed fish, sheep and goat meat, fruit, vegetables, and tea (FAO, 2021). The Indian Green Revolution in the 1970s demonstrated the success of scale-independent technology in agricultural output. While it improved yields, reduced poverty, developed infrastructure, and increased food availability, its impact was limited to a few irrigation- and fertiliser-intensive crops, with benefits not reaching the eastern parts of India, particularly Northeastern India (Dastagiri et al., 2014).

The Indian agricultural sector is expected to grow by USD 24 billion by 2025. Indian food and grocery market is the world's sixth largest, with retail accounting for 70% of sales.[2] India's rapid population growth is the primary driver of this sector, with rising incomes in both rural and urban areas further pushing the national demand for agricultural products. This growth is accelerating with the adoption of cutting-edge technologies such as blockchain, Machine Learning/Artificial Intelligence (ML/AI), Geographical Information System (GIS), drones, and remote sensing (OECD/ICRIER, 2018). However, economic advancement is constrained by challenges such as small landholdings, limited

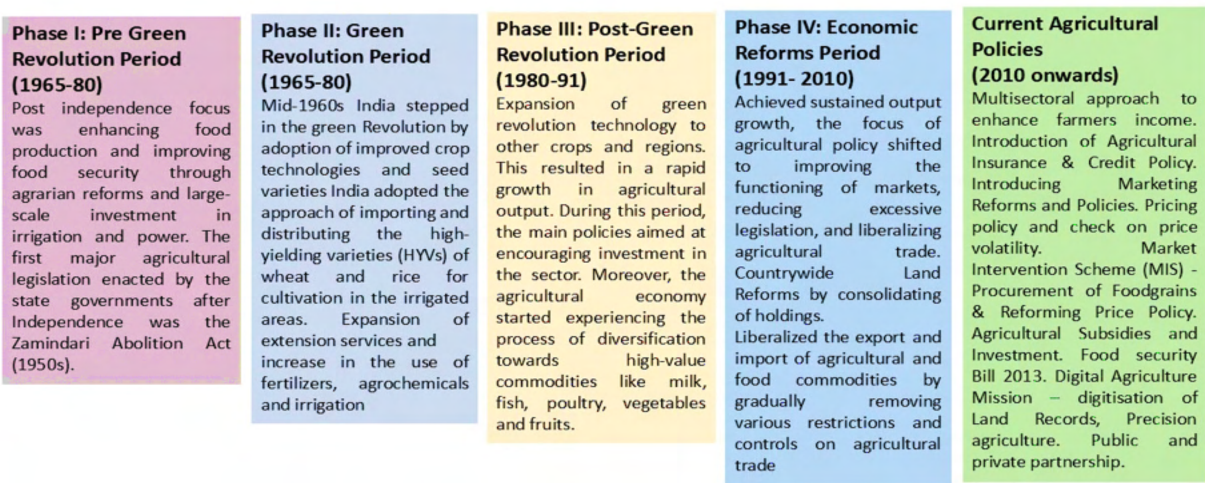


Figure 1. The evolution of agricultural policies and practices

[1]https://pib.gov.in/PressReleasePage.aspx?PRID=2034943
[2]https://mitraweb.in/blogs/agriculture-in-india-industry-overview-market-size/#:~:text=Inc42%20predicts%20the%20Indian%20agriculture,25%25%20of%20the%20world's%20pulses.

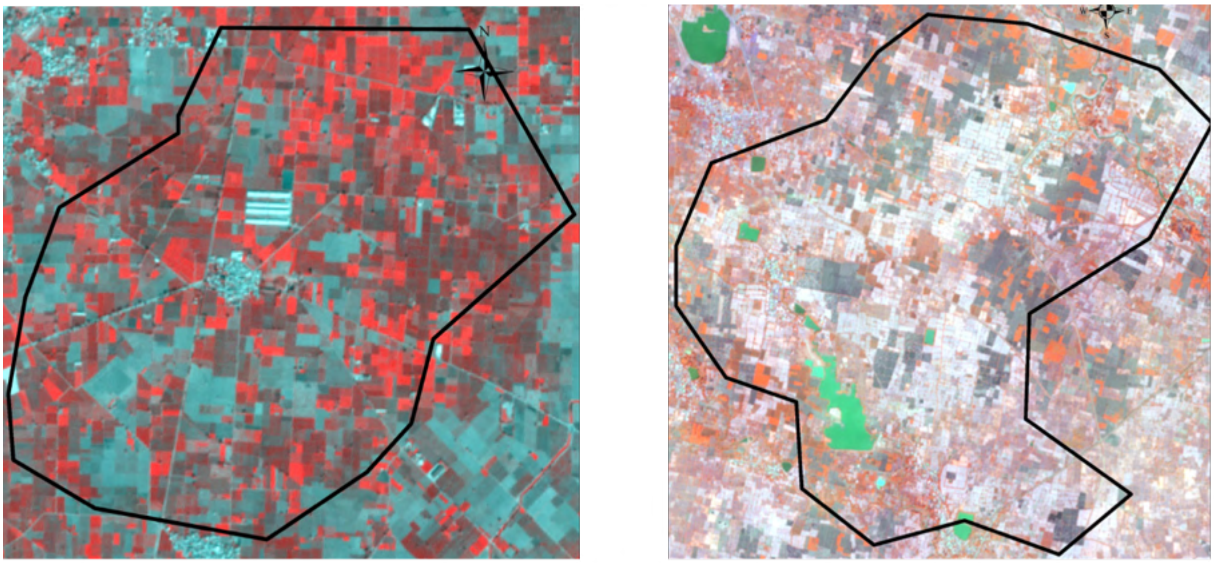
agricultural mechanisation, excessive government control, and reliance on subsidies. Along with this, issues like food price volatility and low farmer income persist despite various government schemes. Efforts to improve farmer incomes have proven difficult, even with the implementation of multiple schemes and programmes (Figure 1).

Challenges faced by Indian agriculture

Most Indian farmers, being small and marginal, face challenges such as inadequate irrigation, price instability, limited access to modern technology, insufficient government support, capital constraints, and climate unpredictability. These issues significantly affect agriculture and livelihoods. Since independence, fragmented landholdings have been a persistent issue, shrinking further due to inheritance laws. The number of agricultural holdings increased from 71 million in 1971 to 146.5 million in 2015–16, while the average operational holding size declined from 2.28 hectares (1970–71) to 1.08 hectares (2015–16). Today, a rural household owns just 0.2 hectares per person. With ongoing population growth, fragmentation and declining land sizes are expected to continue, thereby threatening agricultural viability (Agricultural Statistics, 2023) (Figure 2).

The push for increased agricultural productivity since the Green Revolution has led to a significant decline in soil fertility, posing a major challenge to Indian agriculture. Excessive and unregulated use of fertilisers, insecticides, and pesticides has degraded soil quality, depleting essential micro and macronutrients, resulting in poor yields and declining outputs. India loses an estimated 15.35 tonnes of soil per hectare annually, as reported by National Academy of Agricultural Sciences (NAAS). This translates to a nutrient loss of 5.37 to 8.4 million tonnes per year, with each acre losing an average of 16.4 tonnes of fertile soil annually, severely impacting long-term agricultural sustainability (NAAS, 2018). Groundwater depletion, driven by rising irrigation demands and climate variability, poses a significant threat to food security and agricultural sustainability in India. Agriculture consumes 90% of the country's water resources, making it the heaviest consumer of water among all other sectors. With 51% of net sown area under rainfed agriculture and comprising 40% of the total production, inadequate irrigation infrastructure in these areas exacerbates their reliance on inefficient flood irrigation methods, with an efficiency of just 25–40%. Despite potential increases in precipitation, groundwater loss rates may triple by 2041–2080, reducing cropping intensity by 20% nationally and by 68% in groundwater-scarce regions, severely impacting agricultural productivity (Jain et al. 2021).

India is losing productive agricultural land to urbanisation, with built-up land increasing by 573.65% from 1984 to 2021, at an annual growth rate of 15.5%. This loss is driven by economic development, industrial growth, infrastructure expansion, population rise, and urbanization. The decline in agricultural land threatens rural livelihoods, as farmers depend on agricultural sales for their primary income (Molla et al., 2024). Climate change is negatively affecting India's rainfed and irrigated cash crops, driving up food prices and import costs. Since the 1950s, India's summer monsoon has seen a 6% decrease in precipitation, with central India experiencing a 10% drop. This, coupled with increased rainfall, has led to more floods (Roy, Reshma & Bhavani, 2025; Sahastrabuddhe et al., 2023). Rising temperatures harm crops like groundnut, rice, and cotton, while reduced rainfall affects groundnut and cotton yields. Crops like jowar, rice, and cotton are vulnerable to both high and low temperatures. Over the past three decades, unpredictable weather and longer growing seasons have contributed to over 59,000 farmer suicides.[3]



Panipat District/Tehsil – Lalina Village (Punjab)
Sentinel 2 - 9th December 2024, Multispectral Instrument
Showing Intensive irrigated agriculture
(Cropping system: Traditional rice-wheat)

Khairagarh District/Tehsil – Khairbana Village (Chhattisgarh)
Sentinel 2 - 13th November 2024, Multispectral Instrument
Showing Fragmented rainfed agriculture
(Cropping system: Rice - Fallow, Rice - Lathyrus, Gram - Wheat Soybean)

Figure 2. Sentinel images of Lalina Tehsil (Panipat) and Khairbana Village, (Khairagarh) showing intensive irrigated agriculture and fragmented rainfed agriculture

India's agricultural mechanisation stands at 47%, lower than countries like China (60%) and Brazil (75%). The agricultural machinery market is projected to reach USD16.73 billion in 2024 and USD25.15 billion by 2029, driven by favorable government policies, rising farm incomes, and the need for mechanisation.[4] According to the Indian Council of Agricultural Research (ICAR), while seedbed preparation is well mechanised, harvesting and threshing remain the least mechanised, except for rice and wheat.[5] A key barrier to modern technology adoption is the small size of landholdings. Price volatility due to inadequate storage of agricultural produce is a significant concern. Factors like weather conditions, crop arrivals from other regions, season-wise planting patterns, and early arrivals from the next season contribute to fluctuations, especially in Tomato, Onion, and Potato (TOP) crops. Despite the Ministry of Food Processing Industries providing a 50% subsidy for the transportation and storage of notified fruits and vegetables, including TOP crops, to stabilise prices, challenges persist for both farmers and consumers.[6]

A major barrier to evidence-based policymaking in food systems is limited data access. Relevant data is crucial for transforming food systems, building climate resilience, and improving land use efficiency. Despite global efforts to collect agri-food data, disaggregated data at the necessary geographic scale for policymaking is lacking. A lack of coordination among ministries results in duplicated efforts and inconsistent reporting of key metrics. Additional challenges, like changing district boundaries, missing data, and reporting delays, hinder effective use. Establishing an inter-ministerial Agri-Food System Data Governance Steering Committee could standardise data collection and support evidence-based policies for a nutrition-secure India. Agricultural economists argue that the Minimum Support Price (MSP) aims to protect against market risks and create

[3] https://www.washingtonpost.com/news/worldviews/wp/2017/08/01/59000-farmer-suicides-in-india-over-three-decades-may-be-linked-to-climate-change-study-says/
[4] https://www.india-briefing.com/news/india-farm-mechanization-sector-opportunities-challenges-31243.html/
[5] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1896139#:~:text=The%20farm%20mechanization%20levels%20assessed,operation%20is%20the%20least%20mechanized%20(
[6] https://www.pib.gov.in/PressReleasePage.aspx?PRID=1664311

a price stabilisation fund to boost farmers' income. Farmers seek income security to ensure a steady food supply, reduce dependence on imports, and enhance food security (Gulati et al., 2018). However, these goals can be better achieved through diversified agriculture, private sector involvement, crop incentives, and modernised technology (Sharma, 2024). MSP should only be used if market prices fall below a predefined level or due to international factors. Big Data can help farmers make informed decisions on crop selection, weather forecasts, pest control, insurance, and harvest timing, improving yields and profitability. However, data gaps, particularly regarding climate change, remain a concern. This study examines the role of data in building climate-resilient food systems and sustainable food production practices in India. It identifies gaps in food and land use data sharing and proposes a pathway for data democracy in agriculture to create a more efficient data ecosystem. Based on the desk review, the analysis yields insights into the following major areas:

New Geospatial Policy and Data Sharing. We evaluated the new geospatial policy's effectiveness in driving sustainable food system transformation and enhancing national nutrition security. This involved assessing how the policy framework influences data-sharing practices and whether it promotes collaborative, evidence-based decision-making among diverse stakeholders.

Policy and Data Management Landscape. We examined the current policies and practices for collecting, processing, and disseminating geographical and non-spatial data in the food system. Additionally, we evaluated use-cases of data democratisation and the potential benefits it could offer to multiple stakeholders. A concise overview of data-gathering initiatives by key institutions was also conducted to identify current policy gaps, data availability issues, institutional capacities, and coordination mechanisms.

Roadmap to a Sustainable Food System Data Platform. We analysed the growing demand for sustainable agriculture from a socioeconomic and ecological standpoint. We identified the need for new datasets generated through drone technology and field-level sensors to support precision farming. The report also highlights the importance of establishing a cloud-based geospatial platform to visualise and analyse food system data, as well as the need to encourage public-private partnerships for its development and long-term management.

Purpose. The primary objectives of this desk research work are:

a) To analyse the critical role of data in building climate-resilient food systems and achieving sustainable food production practices in India.
b) To assess the efficacy of the new geospatial policy in promoting sustainable food systems and national nutrition security, while exploring the potential to expand its coverage to include non-spatial land use and agricultural production data.

Scope. The project focuses on enhancing geospatial policy and data-sharing frameworks to support sustainable food systems and national nutrition security. Despite challenges like limited data accessibility, inadequate infrastructure, and the need for capacity building, data-driven solutions promise significant benefits in the agriculture sector. We propose an institutionalised agricultural information platform that must be integrated and be interoperable across stakeholders, delivering farmer-centric solutions and services capable of addressing both current and future agricultural needs.

Chapter 2: Findings and Insights

Changing Climate and increasing extreme climate events

Climate change impacts have reached catastrophic levels, with extreme weather events like unpredictable droughts, rainfall, and rising daily temperatures affecting nearly every country. These threats are projected to worsen as global warming nears 1.5°C. A "climate anomaly" refers to deviations from long-term averages, with positive anomalies indicating higher-than-average values and negative anomalies indicating lower-than-average values (van Gevelt et al., 2022). The global agricultural food system and land use contribute 40% to the totalgreenhouse gas emissions, including CO2 from deforestation, CH4 from paddy fields and cattle, and N2O from fertilisers. Climate change accelerates soil erosion and nutrient depletion, linking soil degradation to warming through feedback loops that release Soil Organic Carbon (SOC). Desertification further exacerbates temperature increases, depleting land fertility (Lal, 2012), reducing yields, and driving deforestation and biodiversity loss. Changes in temperature and rainfall alter land suitability and cropping patterns, worsening land degradation and habitat encroachment. By 2050, climate change may reduce essential nutrients like zinc, iron, and protein in crops such as wheat, rice, and soy. Elevated CO2 levels significantly lower the protein content in staples like rice and wheat, potentially causing a 5.3% protein deficit in rural diets, which may affect an estimated 53 million people (Myers et al., 2015).

The Indian subcontinent is at the forefront of experiencing several extreme weather events (Fig. 3). Throughout the year, different parts of the country are impacted by these weather events. The agricultural sector will face significant challenges due to climate change, including:

1. Decreased water availability due to altered rainfall patterns, stream flows, and increased crop water demand.
2. Deteriorating water quality due to intrusion from sea water, salts being transported from deeper soil layers due to overexploitation of aquifers, and improper irrigation techniques.
3. An increase in the frequency and severity of extreme weather events like droughts, floods, and cyclones.
4. Erratic shifts in the pest and disease burden.
5. Heat stress brought on by elevated temperatures during crucial phases of crop development, and
6. Potential for small pests to grow into larger ones.

Floods and droughts accounted for 76% of all damage and 51% of total natural risks in India between 2000 and 2020. Droughts have had a significant impact on India's socio-economic well-being, which has 1.4 billion inhabitants and is dominated by agriculture. The severity, duration, and frequency of droughts in the country have recently increased, and this trend is expected to worsen due to climate change. Drought affects around 77% of India's total area, and drought hits a different section of the country almost every year, according to historical data. The drought in India's Indo-Gangetic Plains and other central regions is becoming more severe (Amarsinghe et al., 2020). These alterations are consistent with the observed decrease in average summer monsoon precipitation.

Large-scale droughts, thoroughly depleting the soil of its moisture substantially limit food production and have historically led to some of India's most devastating famines, resulting in the loss of countless lives. Droughts in India are on the rise significantly in both frequency and geographic extent from 1951 to 2015 and are going to further increase. Households suffer both monetary and non-monetary losses, as well as damages, and the latter issue is frequently downplayed and ignored, despite its significant influence on the country. We explored how effectively open-access earth observation and climate data can be used to monitor geographic and climatic variability. Climate variables, including maximum temperature (Tmax), minimum temperature (Tmin), and precipitation, are analysed for climate anomalies, and annual and summer monsoon time scales are used to calculate average anomalies. The findings illustrate how Indian agriculture is experiencing climate anomalies. Figure 3 depicts the annual Tmax and Tmin anomalies from 1960 to 2021 and Figure 4 depicts the summer Tmax and Tmin anomalies from 1960 to 2021.

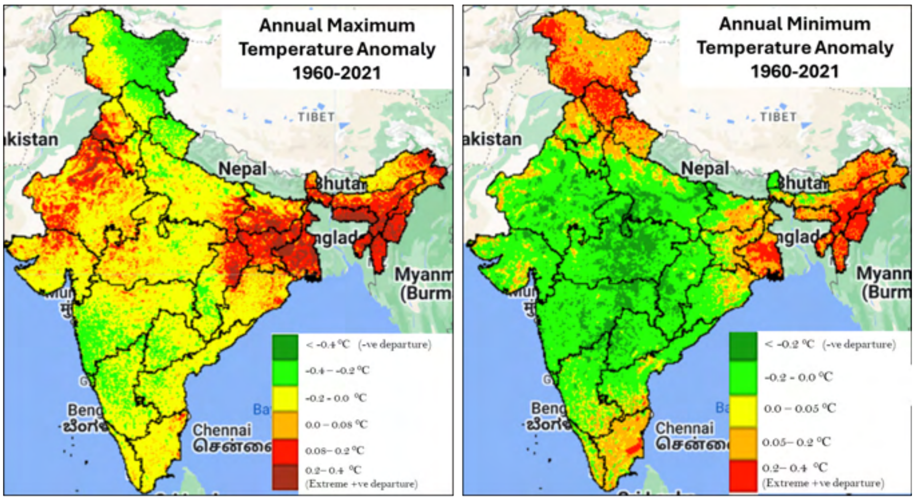


Figure 3. Annual maximum and minimum temperature anomalies over India during 1960-2021 (Source: Roy, Reshma & Bhavani, 2024. (Under publication)

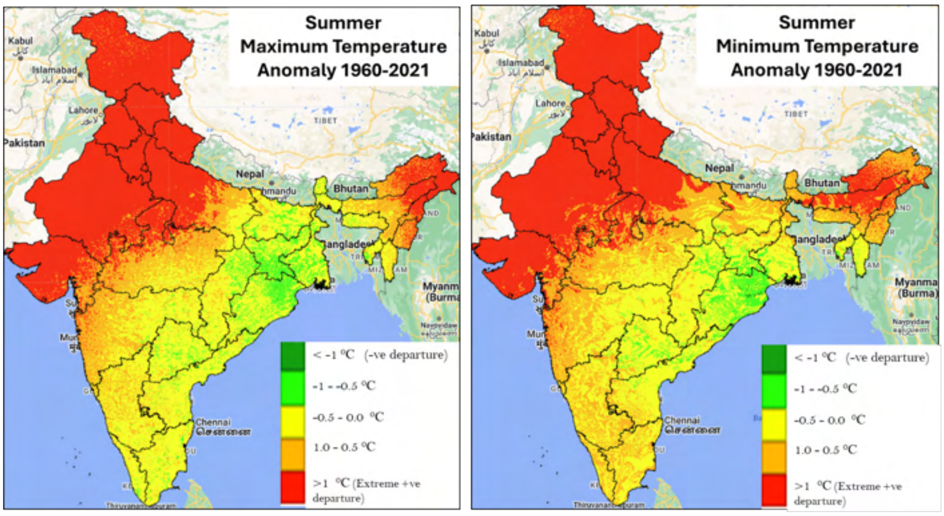


Figure 4. Summer maximum and minimum temperature anomalies over India during 1960-2021 (Source: Roy, Reshma & Bhavani, 2024. (Under publication)

Net cropped area in each category of Tmax anomaly, Tmin anomaly and rainfall anomaly is shown in Figure 5.

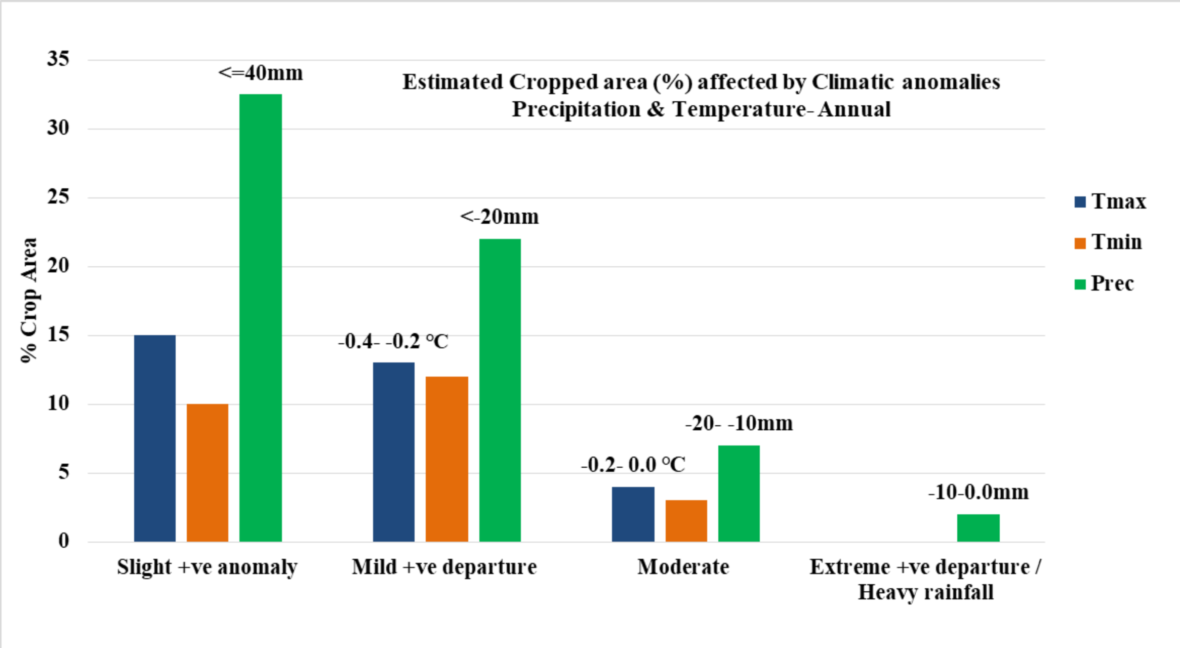


Figure 5. Estimated cropped area (%) affected by climatic anomalies for summer maximum and minimum temperature, and precipitation anomalies (Precipitation and Temperature anomalies are over laid on cropped area maps 2023 (Net sown area and summer monsoon cropped area) to assess the cropped areas already experiencing climate impact during last ~50-60 years of varying magnitude (Source: Roy, Reshma & Bhavani, 2024. (Under publication) [Climate Data source: CRU-TS 4.06 (Harris et al., 2020) downscaled with WorldClim 2.1 (Fick and Hijmans, 2017)]

Groundwater irrigation helped India attain food self-sufficiency, but aquifers have drained in numerous areas of the country. Due to India's reliance on the Indian summer monsoon rainfall, the number of droughts during the shorter summer monsoon is rising. Farmers respond by increasing irrigation as crop water demands rise due to climate change.
Even after accounting for expected increases in precipitation and projected cutbacks in irrigation use as groundwater levels decline, the rates of net groundwater loss by 2041-2080 might be roughly three times the current rates (Bhattarai et al., 2023). Cropping intensity may decline by 20% nationwide and by 68% in places with lower groundwater due to current depletion trends, resulting in decreased agricultural intensity, increased susceptibility to interannual precipitation changes, and increased spatial unevenness.
Whereas 70% of India's annual rainfall falls during the summer, or south-west monsoon, which is critical to the country's agricultural industry and accounts for 11% of its GDP (Jain et al., 2021). India's summer monsoon precipitation has decreased by 6% during the last 60 years. However, the first few weeks of each year's monsoon season deliver unusually high levels of rainfall. Over the last few decades, the country has seen frequent cyclones and erratic monsoon seasons, which have had a negative impact on the agricultural economy.
In South India, water shortage is getting worse, causing severe drought conditions.
The driest three-year period in almost 150 years has resulted from a more than 40% deficiency in the three-year cumulative rainfall (NABARD, 2023). Geographical variability of precipitation over the study period is shown in Figure 6 and Figure 7 shows the rainfall anomaly during summer monsoon for the study period.

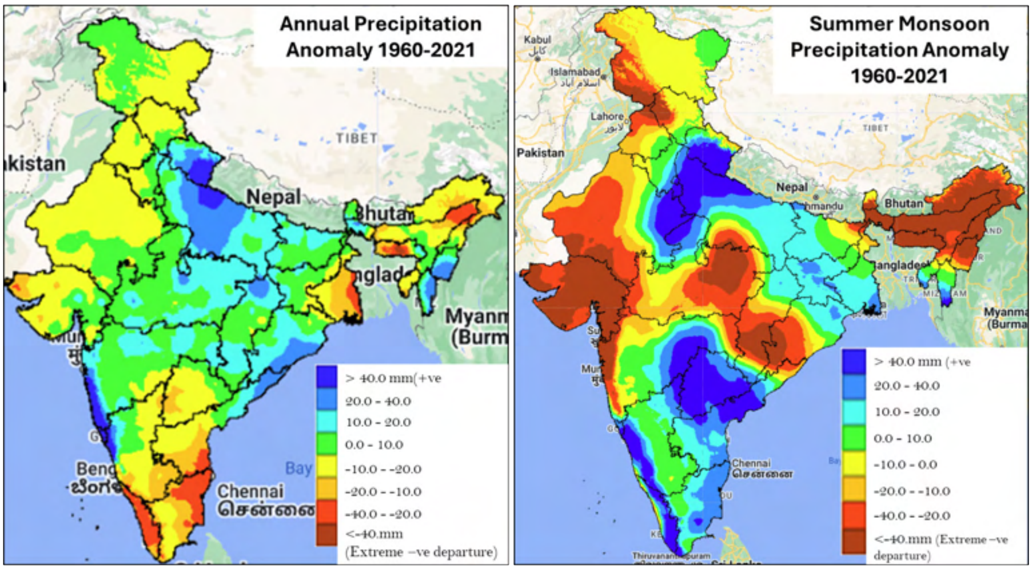


Figure 6. Geographical variability in precipitation anomaly during 1960-2021 (Source: Roy, Reshma & Bhavani, 2024. (Under publication)

Similar analysis for summer and winter monsoon is shown in Figure 7.

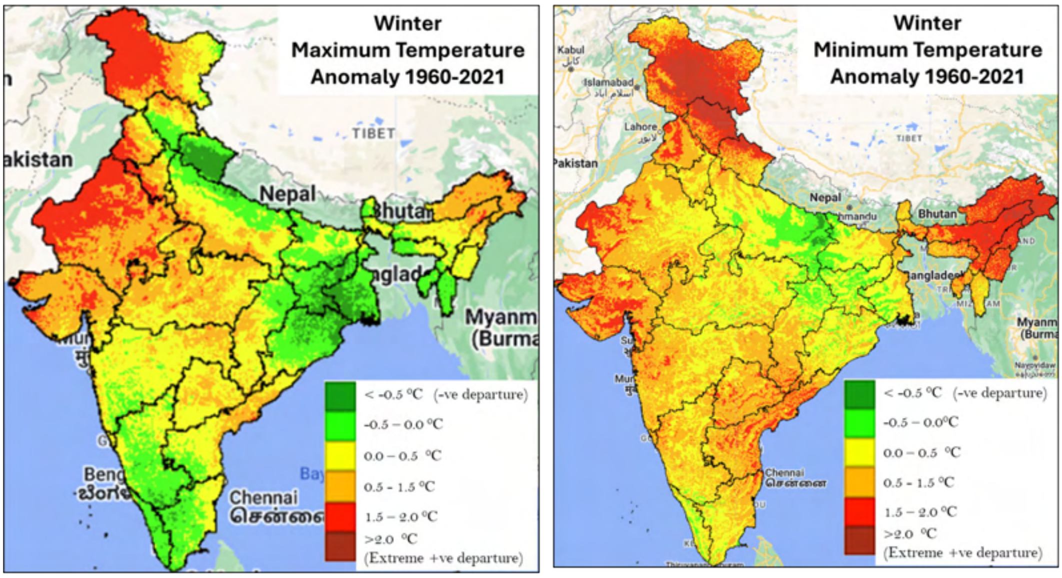


Figure 7. Geographical variability in temperature anomaly during winter monsoon of 1960-2021 (Source: Roy, Reshma & Bhavani, 2024. (Under publication)

Climatic analysis identifies extreme climate change hotspots, with Central India showing the greatest anomalies in rainfall, maximum, and minimum temperatures. Effective climate responses require integrated adaptation and mitigation strategies. Adaptation focuses on increasing agricultural resilience to climate variability and disasters. Precision agriculture, using geospatial data, optimises productivity by scheduling irrigation based on real-time evapotranspiration and applying fertilisers according to soil fertility maps.

GIS tools support climate-smart zoning by integrating crop models, soil properties, and climate projections to guide optimal land use and crop selection. Geospatial tools also monitor mitigation efforts, such as reforestation, by tracking carbon sequestration and forest cover. Collaboration is essential to fully leverage geospatial technology.

Relevance of Geospatial Data in Agriculture

To fulfill the expected food demand of the 9 billion people on the planet by 2050, global food production must increase by 70%.[7] Geospatial analysis plays a vital role in forecasting crop threats, such as pests and diseases, using historical data and meteorological variables. This enables early detection and targeted preventive measures, reducing agricultural losses (Gobinath et al., 2024). The technology also supports monitoring environmental factors like groundwater levels, surface water extent, and precipitation patterns, helping identify water-scarce regions and informing efficient irrigation and conservation strategies. In the context of climate change, geospatial technology has been pivotal in mapping areas vulnerable to droughts, floods, and land degradation. By integrating crop models with climate projections, it helps predict shifts in agricultural productivity and prioritise adaptation in high-risk areas (Jaber et al. 2022). The diverse and varied data required to evolve climate resilient agriculture are mentioned below:

- Geospatial Data: Satellite and drone imageries - weather, soil, crop
- Supply Chain Data: Sourcing, processing, transportation, sale of food products
- Agricultural Data: Crop parameters, agronomy, livestock
- Consumer Behavior Data: Consumer purchasing habits, dietary preferences, and attitudes towards food
- Environmental Data: Climate, water, land, biodiversity
- Socio-Economic Data: Income, employment, equity
- Health and Nutrition Data: Dietary intake, nutritional status, disease

Geospatial AI combines artificial intelligence with geospatial data to revolutionise environmental analysis, enabling the detection of hidden patterns and supporting decisions in resource allocation, disaster preparedness, and sustainable development. Several nations' space agencies offer a range of earth observation information and goods like EarthExplorer, Copernicus Data Space Ecosystem, Bhoonidhi, Earth-graphy etc. (Annexure I).

International organisations like Committee on Earth Observation Satellites (CEOS) and Group on Earth Observation (GEO) coordinate earth observation and data sharing to support sustainable development. United Nations entities, including the United National Office for Outer Space Affairs (UNOOSA), United Nations Platform for Space-based Information for Disaster Management and Emergency (UN-SPIDER), United Nations Satellite Centre (UNOSAT), and United Nations Environment Programme (UNEP), use satellite data for disaster risk reduction and climate resilience. The World Meteorological Organisation (WMO) and Coordination Group for Meteorological Satellites (CGMS) enhance weather and hydrological forecasts, benefiting critical sectors like agriculture and water management (Kavvada et al., 2020). Climate-focused bodies such as the Global Climate Observation System (GCOS), Intergovernmental Panel on Climate Change (IPCC), and Global Framework for Climate Services (GFCS) advance the collection and sharing of climate data to inform policies and adaptation efforts. In food security, the Food and

[7] https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

Agriculture Organisation (FAO) and Food Security Information Network (FSIN) lead efforts to combat hunger, with initiatives like the Global Network Against Food Crises (GNAFC). At the national level, India's National Action Plan on Climate Change (NAPCC) addresses climate challenges with missions targeting renewable energy, water conservation, and sustainable agriculture. Collectively, these initiatives leverage geospatial technology to build a sustainable, climate-resilient future (Annexure II).

Challenges

Land Use data is reported from the village land and agricultural records maintained by the "patwari" or "lekhpal" (village accountant). These datasets are compiled from village level to state and projected nationally by the Department of Agriculture/Land Records (Ministry of Agriculture and Farmers Welfare) and the Directorate of Economics & Statistics as State Agricultural Statistics Authority (SASA). These data sets have strong bias due lack of statistical design and collection methods. Farmers need reliable data and user-friendly technologies to turn geospatial insights into effective strategies. With an estimated 100 terabytes of weather-related data generated daily, managing large geospatial datasets poses significant challenges; collecting, storing, and retrieving these data require high-performance processing and robust internet connectivity. Although some satellite imagery is freely accessible, high-resolution, microwave, and hyperspectral datasets remain expensive to process and demand specialised software and skilled GIS analysts. While open-source software and programming languages such as R, Python, and Java augmented by AI and ML can help, they require advanced analytical expertise. Furthermore, organisations face added complexity from the wide range of geospatial data formats and standards, which must be extensively cleaned and reformatted before meaningful analysis can take place.

Chapter 3: Case Studies and Examples

Successful Implementations:

Use of geospatial data in crop insurance schemes:
Crops are vulnerable to a variety of risks worldwide, making crop insurance a crucial risk management instrument in the agricultural industry. However, the sustainability of area-yield crop insurance programmes has been constrained by the lack of reliable crop yield data. To increase the efficacy of crop insurance contracts, index-based insurance is being investigated. This type of insurance ties payouts to crop performance proxies instead of measured losses. India has long sought to protect its farming community from cultivation risks through various crop insurance schemes, evolving over time to address challenges. The two primary types of crop insurance in India—weather-based and yield-based indices—rely on an area-based approach that excludes individual risks (Murthy et al. 2024).

- **Weather-based insurance** covers horticulture and plantation crops, using historical weather data to indemnify losses caused by anomalies over insured regions.
- **Yield-based insurance** compensates for crop yield losses across insured areas.

Indian farmers face significant challenges in crop insurance, including low awareness, limited coverage, delayed claim settlements, and inaccurate loss assessments. To address these issues, the government has launched several initiatives, notably the Pradhan Mantri Fasal Bima Yojana (PMFBY) for crop failure protection and Minimum Support Prices (MSP) to ensure fair returns. Specialised missions like the National Horticulture Mission, National Food Security Mission, and Rashtriya Krishi Vikas Yojana (RKVY) emphasise production enhancement, diversification, and sustainability. Accurate land records, bolstered by modernisation programmes, are critical to PMFBY's success, enabling precise crop area estimation, better risk assessment, and efficient claim settlements. Infrastructure support, including rural storage under Gramin Bhandaran Yojana (GBY), organic farming through Paramparagat Krishi Vikas Yojana (PKVY), and irrigation initiatives like Per Drop More Crop, complements these efforts. Sector-specific schemes such as the Rainfed Area Development Program (RADP), Livestock Insurance Scheme, and fisheries welfare programmes address broader agricultural needs. Enhanced logistics and market access are facilitated by projects like Kisan Rail and National Agriculture Market (eNAM) (OECD/ICRIER, 2018).

Emerging Innovations and Approaches

Comprehensive food and land use data are essential for achieving climate-resilient agriculture and global food security. By leveraging satellite imagery, surveys, and administrative records, policymakers can improve productivity, optimise land use, and mitigate environmental impacts. Collaboration among researchers, policymakers, and farmers ensures impactful, data-driven policies. Innovative solutions from agritech start-ups and global initiatives like the Global Partnership for Sustainable Agriculture (GPSA) and International Food Policy Research Institute (IFPRI) drive precision agriculture and climate-resilient practices. Collaboration among institutions such as ICAR, IMD, CSIR, and ISRO strengthens the foundation for sustainable agriculture. Recent advancements are driving a shift towards more dynamic and precise crop insurance models.
Ongoing efforts focus on farmers' financial security through PM KISAN, the promotion of Farmer Producer Organizations (FPOs), and fostering agricultural start-ups. These

programs collectively aim to enhance food security, boost livelihoods, and promote sustainable practices. The significant potential of satellite remote sensing to revolutionise India's crop insurance landscape, particularly under the PMFBY has already been highlighted by government (Nagendra et al., 2022). Satellite remote sensing has enhanced crop insurance processes in several ways:

- Crop Cutting Experiments (CCEs): Satellite-derived yield data improves sampling accuracy, reducing the need for extensive CCEs.
- Area Adjustment: Satellite imagery identifies discrepancies between sown and insured areas, enabling precise Area Correction Factor (ACF) calculations.
- Resolution of Discrepancies: Remote sensing provides objective data to settle disagreements between state governments and insurers regarding crop yield estimates.
- Yield Verification: Satellite data is used to cross-verify and ensure the accuracy of reported yield figures.
- Crop Loss Monitoring: Satellite data allows for qualitative assessments of crop health and damage, facilitating prompt interventions and claim settlements.
- Emergence and Preventive Sowing Tracking: Remote sensing identifies areas where crops have failed to emerge or where preventive sowing was required.
- Risk Profiling: Long-term satellite data helps assess risks and cluster districts based on vulnerability, guiding targeted risk management strategies.

Advancements in geospatial data integration have greatly enhanced the efficiency, accuracy, and fairness of crop insurance. By combining data from PMFBY and land records, authorities can model risks using historical yields and climate vulnerabilities, identify high-risk areas, refine insurance schemes, and strengthen disaster management. Replacing the traditional "Area-Yield Index," modern systems rely on a composite crop performance index drawn from multiple in-season indicators. Cutting-edge technologies—such as remote sensing, drones, weather data, and IoT—provide real-time insights into crop conditions and environmental factors. Continuous monitoring and CCE ensure consistent yield and quality assessments, improving data precision at both regional and national levels (Gumma et al., 2024).

These innovations represent a paradigm shift, combining technology and data to make crop insurance more precise, equitable, and resilient against diverse agricultural risks. Index-based crop insurance used by Murthy et al. (2024) for potato in India offers significant advantages over traditional yield-based schemes, including greater transparency, objectivity, and simplified implementation. The approach leverages advanced technologies such as satellite-based crop mapping, weather-driven crop health indicators, and field data analytics to enhance accuracy and reliability in insurance loss assessments. By synthesising satellite and weather data into a robust database, this technology-driven index-insurance model has the potential to revolutionise the crop insurance sector. It promotes the development of innovative business models, enhances operational efficiency, and benefits stakeholders, including farmers, insurers, and policymakers, by ensuring timely and accurate insurance settlements.

Data need for operational agriculture services

One of the biggest challenges in using/organising big data in agriculture is ensuring the quality and standardisation of the data. The different data sources have different formats, levels of accuracy, and reliability, which can make it difficult to integrate and analyse the data effectively.

Data sharing ecosystem in India. The Agricultural Data Ecosystem (ADE) is a socio-technical infrastructure that aggregates data from various sources to support sustainable agriculture and digitalisation (Kharel et al., 2020). Data sharing in agriculture is important for several reasons, including:

- Access to appropriate data specifications from satellites, sensors, and weather stations for more informed decisions.
- Farmers can use data to tailor inputs like water, fertilisers, and pesticides to the specific needs of their crops and fields. This can help reduce wastage and minimise environmental impact.
- Researchers can analyse genetic information to identify traits that make crops more resilient to pests, diseases, and environmental stresses. This can help reduce the time to market for new crop varieties.
- Some challenges to data sharing in agriculture include stakeholders' mistrust in the data-sharing process, inadequate data access and use policies, unclear data ownership agreements, and interoperability challenges.

Action to reduce the digital divide. ICT-based extension services do not promote equitable access to information (Singh et al., 2023). Such initiatives can lead to enhanced agricultural productivity and sustainability by bridging the information gap and enabling the use of digital technologies to enhance agricultural productivity, profitability, and sustainability.

Community-driven approaches to landscape restoration

World Resources Institute India (WRII) evaluated the potential for landscape restoration in Madhya Pradesh's Sidhi district of India using the Restoration Opportunities Assessment Methodology (ROAM). The study supported a comprehensive framework to achieve ecological sustainability and socio-economic development through targeted restoration efforts. Approximately 363,000 hectares in Sidhi, accounting for 76% of its total area, are identified for potential landscape restoration. Interventions include agroforestry (trees on boundaries), assisted natural regeneration, bamboo plantations, mixed-species plantations, and pastureland development can be undertaken using community-based interventions. Restoration efforts are expected to generate 3.75 million person-days of employment, equating to ₹710 million in wage income over two years. Restoration in this area has the potential to enhance carbon sequestration by 7 million metric tons over 20 years, supporting India's commitments under the Bonn Challenge and the Paris Agreement. Key ecosystem services to improve include but are not limited to biodiversity conservation, erosion control, fuelwood provisioning, and improved water recharge supporting and providing many co-benefits as well. Livelihood opportunities are projected to expand, especially for marginalised groups, by supporting microenterprises and value chains for tree-based products like bamboo, moringa, and jackfruit (Singh et al., 2020).

***Learning from Global Initiatives*:**

Agriculture practices around the world have been completely transformed by developments in Earth observation, geospatial technology, and information systems, as well as by IT breakthroughs, cloud computing, GNSS, and cellphones. These technologies offer smarter and sustainable solutions for crop insurance, food security, and conscientious land management. Some important international projects are mentioned below:

- UN and Multilateral Organisations: Spatial technologies are emphasised by agencies such as the FAO, World Bank, and Asian Development Bank (ADB) for sustainable farming and food security. To improve farming methods and investment accessibility, UN programmes like Global Geospatial Information Management (GGIM) encourage responsible land administration.

- **GEOGLAM**: Using data from satellites and the ground, the Group on Earth Observations' Global Agricultural Monitoring programme improves agricultural production projections. Under its Agriculture and Food Security topic, NASA's SEDAC provides multidisciplinary data on agriculture, biodiversity, and food security (Schaap et al., 2020).
- **GODAN**: To address issues related to food security, the Global Open Data for Agriculture and Nutrition program makes agricultural data available worldwide (Schaap et al., 2020).
- **FEWS NET**: Maps vulnerabilities using ESRI technology to provide early alerts about food insecurity.
- **Global Forest Watch by WRI**: maps agricultural commodity-related forest data, promoting deforestation and agriculture analysis.[8]

Regional and National Initiatives:

- **Europe's MARS Project** supports EU agricultural policies by using remote sensing to monitor crops.
- Weekly vegetation index imagery is available for crop monitoring through **USDA's VegScape programme**.
- The **G4AW programme** in the Netherlands uses geospatial data to increase the production of smallholder farms in Asia and Africa.
- The Gates Foundation supports **Africa's STARS Initiative**, which investigates the use of remote sensing to enhance agriculture in South Asia and Sub-Saharan Africa.
- **Asian Farmers Association (AFA) Training on Remote Sensing and GIS**: conducts training sessions for its partners from Cambodia, Indonesia, and the Philippines, focusing on equipping them with essential skills in remote sensing and GIS for effective land rights advocacy.
- **Cereal Systems Initiative for South Asia (CSISA)**: promotes the use of geospatial technology combined with remote sensing to enhance agricultural interventions, aiming to improve productivity and sustainability across South Asia.
- **ICRISAT's Geospatial Mapping for Sustainable Agriculture**: regularly highlights use of geospatial mapping and satellite data to boost agricultural productivity and sustainability in South Asia.

Technological applications:

Geospatial technology has revolutionised agricultural practices by enabling real-time decision-making, harnessing powerful satellite tools, and supporting targeted initiatives to improve smallholder productivity. Through georeferenced data, orchards and fields can respond instantly to changing conditions, enhancing both sustainability and profitability. Programmes such as the FAO's ARTEMIS and the integration of MODIS data allow for precise rainfall measurement and worldwide mapping of agricultural productivity, providing critical insights for more effective resource management. Initiatives led by organisations like DigitalGlobe further empower smallholders by delivering geospatial data in tailored applications, ultimately increasing yields and strengthening food systems across the globe.

[8] https://www.wri.org/initiatives/global-forest-watch

***Case studies*:**

Global Food Security Initiative[9]

The sole international partnership for financing food and nutrition security is the Global Agriculture and Food Security Program (GAFSP), which has a portfolio worth USDD2.5 billion. Through more than 300 programs, the effort has impacted 20 million people in the world's poorest countries. The G20 created the GAFSP in response to the 2007–2008 food price crisis with the goal of advancing sustainable and resilient agriculture and food systems in the world's most vulnerable countries. Through investment grants, technical assistance, concessional financing, and consulting services, GAFSP provides demand-driven businesses with financial and technical support from farm to table. Global attempts to lessen the effects of climate change are being aided by GAFSP projects. With 15.4 million tons of carbon dioxide equivalent (tCO_2e) removed, the Program's portfolio is a net reducer of greenhouse gas emissions overall, offsetting its 7.8 million tCO_2e total greenhouse gas emissions.

Restoration of degraded Soils for Food Security Sustainable Land Management (SLM)[10]

SLM measures comprise practices to conserve the soil and water resources in the in Khadgoan village (Bhokardan Tehsil, Jalna District (Marathwada region), Maharashtra, India. The SLM measures enhances agriculture production without losing many resources.

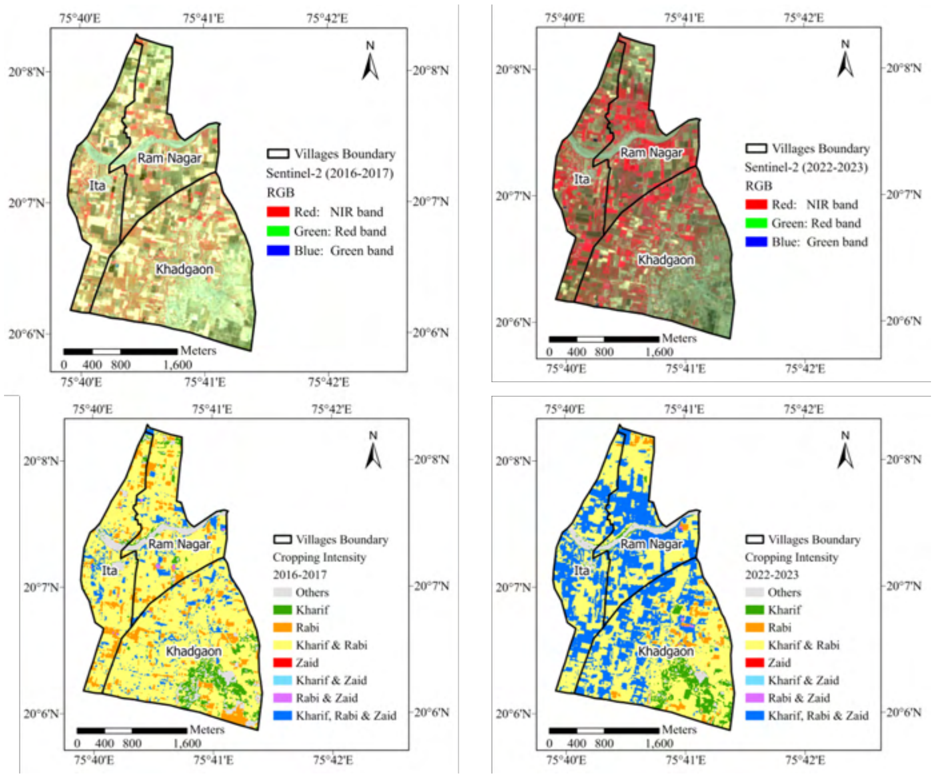


Figure 8. Sentinel-2 satellite images: LHS: 10.04.2017; RHS: 09.04.2023 Crop intensity: using NDVI data (from October to May): LHS: Sentinel-2 images from 2016 – 2017 and RHS: Sentinel-2 images from 2022 – 2023

[Source: Baby, A., Das, P., and Kastir, S.2025. Satellite-based monitoring of agriculture resilience succeeding watershed development interventions. Sustainable Development Perspectives in Earth Observation. Edited by Behera, MD, Behera, S., Barik, S.K., Mohapatra, M., and Mohapatra, T. Elsevier. eBook ISBN: 9780443140730]

[9] https://www.gafspfund.org/#:~:text=The%20Global%20Agriculture%20and%20Food,has%20reached%2020%20million%20people.

[10] https://www.cgwb.gov.in/old_website/AQM/NAQUIM_REPORT/Maharshtra/jalna.pdf

Agriculture and Food Security Project (AFSP), Nepal[11]

With 37% of the population below the poverty line and crop yields 25% below the national average, poverty, malnutrition, and low agricultural production are pervasive in Nepal's Mid- and Far-West regions. These difficulties are made worse by limited access to and availability of food as well as frequent natural calamities. By boosting agricultural and livestock output, promoting diversified diets, and improving feeding techniques, the Agriculture and Food Security Project (AFSP) improved food and nutrition security. In addition to reaching nearly 656,000 people-603,000 of whom were women-the initiative also introduced 30 new technologies and produced impressive productivity gains, with yields of important crops and livestock products rising by more than 100%. There were also reports of improved nutritional results, with mothers and children consuming much more vegetables and protein. The project received a "moderately satisfactory" rating from the World Bank, recognising its accomplishment of development goals. The significance of giving priority to rural women, who are essential to agriculture because of male migration and their greater productivity in particular tasks, is one of the main takeaways from AFSP. Future projects should lessen dependency on expensive foreign inputs, improve grassroots social structures, and match production techniques with local settings to guarantee sustainability. Creating self-sustaining and climate-resilient agricultural systems requires the development of forward-looking strategies.

Building Resilient Commercial Smallholder Agriculture, Bhutan[12]

A $13 million project in Bhutan intends to commercialise agricultural value chains to support resilient food systems and the post-COVID-19 economic recovery. This project tackles systemic obstacles in the agriculture sector and is in line with Bhutan's Renewable Natural Resources Strategy and food self-sufficiency objectives. It builds on previous initiatives like the Food Security and Agriculture Productivity Project (FSAPP), which was funded by the GAFSP. To guarantee compliance with food standards, the project will support small-scale infrastructure development, value chain strengthening, and farm system diversification. These will include establishments such as cold storage, milk chilling centres, and post-harvest processing units. It places a strong emphasis on youth and cooperative capacity building, climate-resilient techniques, and the creation of youth-led businesses for organic inputs. The project, which focuses on equitable growth, provides smallholder farmers—especially women and young people—with access to services, marketing, and production investments for lucrative value chains such as high-value crops, dairy, vegetables, and animals. It aims to improve the production and marketing of wholesome, domestically produced goods, promote climate-smart farming methods, and create jobs. Implementation will be guided by FSAPP and CARLEP insights to optimise impact.

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[11] https://www.gafspfund.org/projects/nepal-agriculture-and-food-security-project afsp#:~:text=In%20the%20Mid%2D%20and%20Far,the%20lowest%20in%20the%20world

[12] https://www.gafspfund.org/sites/default/files/inline-files/Bhutan%20Proposal%20to%20GAFSP%20-%20BREC-SA%20-%20Final%20-%208Sep2021_1.pdf

Chapter 4: Policy Landscape and Gaps

With a proven track record of cost-effective and successful missions, India aspires to be a leading player in the global space economy which is reported to be valued at USD 450 billion in 2024. It leverages its robust space programme to drive economic growth, technological advancement, and societal development. The Indian Space Program, initiated in 1969, has evolved into a comprehensive framework encompassing satellite communication, remote sensing, navigation, meteorology, and geospatial data (Rajgopalan and Stroikos, 2024). Landmark initiatives like the Indian National Satellite (INSAT) system and advanced Earth observation satellites have facilitated diverse applications, including natural resources mapping and monitoring, disaster management, agriculture, environmental monitoring, and urban planning. India's space journey has been guided by a series of policies tailored to meet national objectives:

- The Indian National Space Policy (1969) established the foundation for using space technology for national benefit.
- Subsequent policies, like the Remote Sensing Data Policy (2001-2011) and the National Geospatial Policy (2016), emphasised the lawful use of data while safeguarding privacy and security.
- The Space Activities Bill (2017) proposed a legal framework for regulating space activities, ensuring safety and promoting commercialisation.

The Indian government is tirelessly working to fulfil the objectives stated in India's Space Vision 2047. These initiatives concentrate on developing space exploration missions, expanding business sector involvement, international collaborations, and technology breakthroughs. To enable the Indian private sector to participate in space activities, the Government of India implemented space sector reforms in 2020 (Rajgopalan and Stroikos, 2024).

National Geospatial Policy 2022[13]

The National Geospatial Policy (NGP) 2022 aims to transform India's geospatial sector by fostering innovation, improving governance, and driving sustainable growth. Rseplacing the 2005 National Map Policy, it deregulates the sector and promotes geospatial data as a public resource. NGP strengthens Geospatial Data Infrastructure through initiatives like the National Geospatial Data Registry (NGDR), Unified Geospatial Interface (UGI), and the National Digital Twin, along with frameworks for geospatial enterprises, data promotion, and skill development.

Key Features and Vision

- **Deregulation and Data Democratisation**: Simplifies access to geospatial data, positioning it as a shared national asset. Deregulated mapping infrastructure; subsurface and hydrographic infrastructure; subsurface utility collection; and geospatial knowledge infrastructure, which integrates geospatial data, technology, and concepts.
- **Milestones**: Outlines strategic goals, including an enabling policy framework by 2025,

[13] https://www.services.bis.gov.in/php/BIS_2.0/BISBlog/national-geospatial-policy-2022/#:~:text=The%20Policy%20seeks%20to%20create,and%20Solutions%20(GDPSS)%20and%20boost

comprehensive high-resolution mapping by 2030, and a National Digital Twin by 2035.
- **Institutional Support**: Proposes the Geospatial Data Promotion and Development Committee (GDPDC) to oversee implementation and innovation.
- **Private Sector and Startups:** Encourages private enterprises and startups to lead data creation, innovation, and commercialisation.
- **Technological Integration**: Promotes the use of advanced tools like drones, IoT, and location-based services to modernise governance and services.

Strategic Applications and Opportunities
- **Economic Growth**: Aims to grow India's geospatial economy, projected to reach ₹63,000 crore by 2025, and make India a global geospatial hub.
- **Innovation and Skill Development**: Prioritises education and research to address skill gaps and advance the sector.
- **Climate and Resource Management**: Positions geospatial technologies as pivotal for addressing climate challenges and optimising resource management.
- **Blue Economy and SDGs**: Supports initiatives like bathymetric mapping for marine management and aligns geospatial solutions with Sustainable Development Goals.
- **Ecosystem Collaboration**: Advocates for public-private partnerships, geospatial technology parks, and global collaboration to enhance efficiency and innovation.

NGP 2022 aims to boost foreign investments, streamline regulations, and enhance business efficiency. By fostering innovation, it supports startups and private enterprises, creating jobs and strengthening India's global geospatial position. The policy envisions geospatial technologies as central to India's governance, economy, and sustainability, promoting inclusive growth and societal progress.

Indian Space Policy 2023[14]

The Indian Space Policy 2023 establishes a framework to expand India's space capabilities, encourage private-sector involvement, and enhance socio-economic and environmental benefits. It aims to position India as a leading spacefaring nation by allowing Non-Government Entities [NGEs] to participate across the entire space value chain. The policy also raises foreign investment limits in space sectors, promoting India as a hub for space innovation and commercialisation. It sets a roadmap for economic growth, societal benefits, and global competitiveness in space exploration and technology.

Key Features and vision
- **Vision**: Leverage space technology as a driver of national development, security, and innovation, while fostering international collaboration.
- **Indigenous Development**: Prioritises self-reliance by promoting domestic manufacturing of satellites, launch vehicles, and space technologies to reduce foreign dependency.
- **Innovation and Ecosystem Growth**: Encourages R&D, technology transfer, and entrepreneurship to strengthen the space industry and intellectual property base.
- **Societal Applications**: Highlights the role of space technology in agriculture, enhancing land productivity, disaster management, and education, with examples like sustainable farming tools, disaster warning systems, and telemedicine.

[14] https://www.isro.gov.in/media_isro/pdf/IndianSpacePolicy2023.pdf

- **Institutional Reforms**:
  - ISRO: Focusses on advanced research and development.
  - IN-SPACe: Facilitates private-sector participation and ecosystem growth, with over 300 proposals and 1,200 registrations received in three years (2020-2023).
  - NSIL: Oversees space activity commercialisation.
  - NGEs: Encouraged to actively engage in space initiatives.
- **Global Partnerships**: IN-SPACe leverages the Global Networking Forum (GNF) for collaboration with international stakeholders.

The policy ensures public access to high-resolution satellite data, supports open-source platforms, and sets clear norms for Earth observation and geospatial data dissemination. It encourages academia-industry-government partnerships to foster innovation. Guided by IN-SPACe, the policy outlines a decadal vision for the space economy, establishes norms for authorised activities, and promotes technological sovereignty.

Digital Agriculture Mission[15]

The Digital Agriculture Mission (DAM) is a government-backed initiative that aims to improve the lives of farmers by using digital technology. All these programmes are G2G applications and around centralised repositories. The Mission's goals include:

- **Digital ecosystem**: Creating a farmer-centric digital ecosystem that uses digital land records, geospatial, sensor, space, drones and IoT technologies; Digital Public Infrastructure (DPI) will provide information on agriculture, (e.g., Agristack, Krishi Decision Support System (KDSS), comprehensive soil fertility, and profile Maps;
- **Government efficiency**: Improving the efficiency and transparency of government programmes;
- **Evidence-based policymaking**: Supporting the government in making informed policy decisions;
- **Innovation**: Promoting public and private innovation and partnerships;
- **Digital services**: Developing digital services for farmers, such as crop loans, insurance, and procurement;
- **Trustworthy data**: Providing trustworthy data to help government agencies make more efficient and transparent schemes and services; and
- **Customised advisory services**: Developing customised advisory services for farmers on crop planning, irrigation, crop health, and more.

Some of the key targets of the Mission include:

- Creating digital identities for 11 crore farmers over three years;
- Launching the Digital Crop Survey nationwide within two years; and
- Creating detailed soil profile maps for 142 million hectares of agricultural land

[15] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2051719

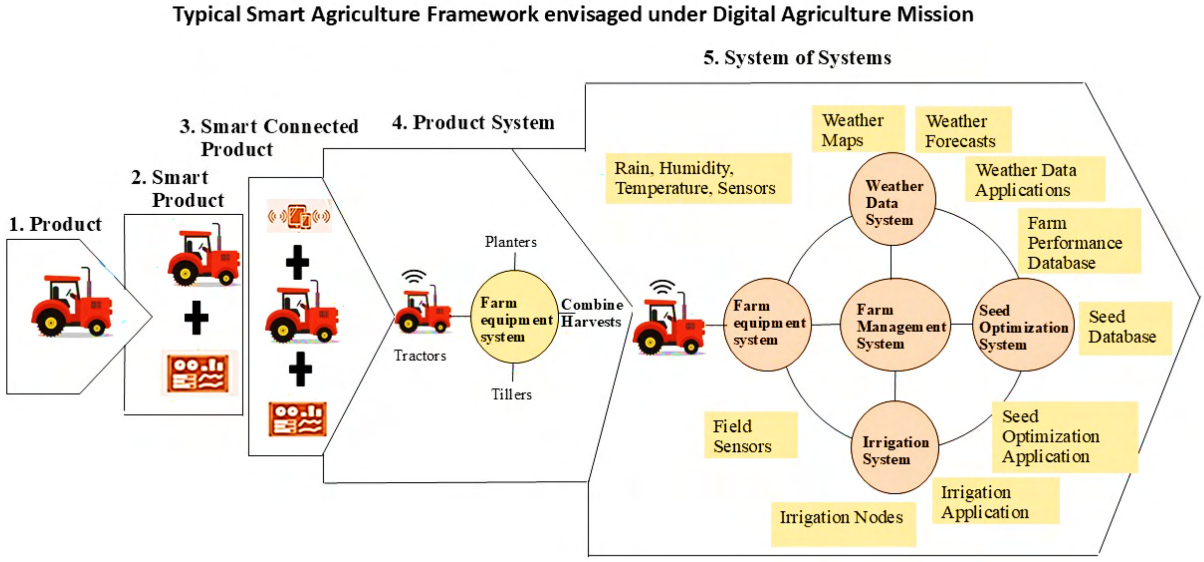

Figure 9. Typical smart agricultural framework envisaged under Digital Agricultural Mission

Equitable Connectivity for Digital Agriculture

In 2024, amid internet access inequalities, especially for women and rural populations, the mission emphasises the need for affordable, equitable connectivity for digital agriculture. Digital technologies are transforming India's rural landscape, with data science serving as the foundation for extracting insights from agricultural data. There is a strong need for capacity in data science to apply these techniques effectively. Key contributors to Digital Public Infrastructure (DPI) include the Indian Council of Agricultural Research, Ministry of Agriculture, Mahalanobis National Crop Forecast Centre (MNCFC), ISRO, CSIR, and private startups.

Key initiatives of MNCFC include:

- FASAL (**Forecasting Agricultural output using Space, Agrometeorology and Land-based observations**): Uses space, agrometeorology, and land observations to forecast crop production for nine major crops at national, state, and district levels using remote sensing data, aiding in timely decision making for food security.
- NADAMS (**National Agricultural Drought Assessment and Monitoring System**): Uses satellite data to monitor drought indicators at district and sub-district levels, providing vital information for mitigation strategies.
- KISAN (**C(K)rop Insurance using Space Technology and geoiNformatics**): Uses satellite data for crop insurance, including loss assessment, area discrepancy resolution, and risk zoning, ensuring accurate and timely compensation for farmers.
- CHAMAN (**Coordinated Horticulture Assessment and Management using geoiNformatics**): Provides area assessment and production forecasting for horticulture to support the National Horticulture Mission.

Digitisation of Land Records (property ownership) in rural India

The Svamitva scheme aims to establish clear property ownership in rural India, providing financial stability, accurate land records, property tax determination, and reducing disputes. Using drone technology, it maps land parcels and issues legal ownership cards. Implemented by the Ministry of Panchayati Raj, State Revenue, and Survey of India, the scheme launched on 24th April, 2020, with a pilot phase in nine states during 2020-2021. It has since been rolled out nationwide with states' participation (Source: https://svamitva.nic.in/svamitva/).

Development of National Framework
Standardising methodologies to mainstream technology solutions into decision-making can unlock more scalable outcomes. Although organisations such as ISRO (under NNRMS) produce extensive spatial and tabular data for food, agriculture, and land use, persistent challenges—particularly around standardisation, interoperability, and collaboration—limit their effectiveness. Existing datasets and portals (detailed in Annexure I and II) operate in silos and are not integrated in a way that non-specialists can easily use, revealing the critical need for improved data sharing and user-friendly access.

Data silos and accessibility barriers[16]
The ISP 2023 emphasises open access to remote sensing data but does not address the fragmentation of data repositories managed by organisations like ISRO, NSIL, and IN-SPACe. This hampers stakeholder accessibility and data sharing. National security restrictions on high-resolution satellite data (Ground Sampling Distance ≤30 cm) limit private-sector innovation. The lack of a centralised geographic data gateway and standardised interoperability further complicates seamless data exchange. While the NGP 2022 encourages the creation of a National Geospatial Data Registry and Integrated Geospatial Interface, it lacks mechanisms to break down existing data silos, hindering integration and real-time data exchange. While aiming for free access to public geospatial datasets, it does not fully address interoperability issues or enforce uniform data formats, making integration challenging. The policy also underemphasises real-time data exchange, crucial for dynamic applications like agriculture, land use monitoring, disaster response, and urban planning.

Insufficient private-sector engagement
The Indian space economy, valued at $8.4 billion (2-3% of the global market), is expected to grow to $44 billion by 2033 with the Indian Space Policy 2023.[17] The private sector will play a key role in achieving this target, with expectations for autonomous end-to-end solutions in satellite production, launch vehicles, satellite services, and ground systems. In 2023, India had 189 space start-ups, up from one in 2014, with $124.7 million invested in these startups. The NGP 2022 acknowledges the private sector's role in geospatial data but lacks incentives and structures to promote active participation. It does not provide clear guidelines for public-private partnerships (PPPs) or address private-sector-led R&D. There are no provisions for incentives like tax breaks or capacity-building programmes to encourage innovation. Restrictions on private access to high-resolution data limit the growth of geospatial enterprises, especially startups and SMEs, hindering their ability to scale and compete internationally. Despite allowing NGEs to operate across the space value chain, the ISP 2023 faces regulatory challenges, with lengthy processes for obtaining licenses and permits through IN-SPACe hindering private-sector projects. The policy lacks sufficient fiscal and non-fiscal incentives for R&D or start-ups, and does not mention tax breaks, grants, or technology-sharing to promote investment in high-risk space technologies. It also overlooks the transfer of cutting-edge technology from ISRO to private entities and fails to specifically promote international collaboration, limiting India's global competitiveness in the space industry.

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[16] https://pib.gov.in/PressReleasePage.aspx?PRID=2005538
[17] https://www.thehindu.com/sci-tech/science/indias-space-economy-has-potential-to-reach-35200-crore-44-billion-by-2033-with-about-8-of-global-share/article67403193.ece

Recommendations

• Create a national framework to enforce interoperability standards for sharing and services;
• Develop an institutional framework to Digital Public Infrastructure for providing a single window for operational system (with contribution of multi-institutional
• Evolve geospatial digital land records of agriculture landscapes with utmost priority to achieve farmer/field level outreach of digital services;
• To draw in private investment, present PPP models with transparent revenue-sharing arrangements with an understanding of sharing the data in public domain with fair principles;
• Simplify commercial entities' access to high-resolution geospatial data while providing sufficient security measures to offset security concerns;
• Create a consolidated space data gateway to guarantee that stakeholders have real-time, interoperable access to all datasets and data generated on natural resources as geospatial services;
• To promote ease of doing business, NGE license and operational processes should be streamlined and made clearer;
• Provide financial support, tax breaks, and subsidised access to public infrastructure as incentives for R&D headed by the private sector; and
• Develop focussed initiatives to improve public-private collaboration frameworks and ease ISRO's technology transfer to commercial entities and research/academic organisations.

Chapter 5: Proposed Framework and Roadmap

To improve India's land use and agricultural assessments, high-resolution, ground-truth GIS data and multistage sampling techniques are needed. Existing data from initiatives like the Mahalanobis Centre, though valuable, lack the granularity for detailed analysis at the state and district levels. Combining this with medium-to-coarse data from ISRO and advanced technologies like drones and high-resolution satellites (e.g., Sentinel, Landsat) enables a comprehensive understanding of land use. Integrating localised data on soil, farmer incomes, and ecosystem health supports climate resilience and enhances decision-making for agriculture and resilience initiatives.

Cloud-Based Geospatial Platform

For developing a Sustainable Food System Data Platform Roadmap, it is important to examine the increasing demand for environmentally and socio-economically sustainable agriculture for the country and larger regional context. There is a pertinent need for examining the possibilities of artificial intelligence, cutting-edge geographical data technology, and future developments. Government agencies, academic institutions, agritech companies, and global projects can work together to improve the integration of these datasets to enable crop monitoring, climate-resilient agriculture, and sustainable land management.

Real-time data, API integrations, precision agriculture tools

Developing new datasets using field-level sensors and drones for precision agriculture (e.g., microclimate, pest detection, soil moisture) is essential. A cloud-based geospatial platform for visualising and analysing food system data requires a cost-benefit analysis. Public-private partnerships are key to creating and managing this platform. The Indian Space Policy 2023 supports using open-source cloud-based satellite data, with platforms like JAXA Earth API for Python, Google Earth Engine, ArcGIS Online, Microsoft Azure, Amazon SageMaker, R studio cloud, Mapbox, Microsoft Planetary Computer to name a few. Bhuvan and Bharatmaps also uses APIs that are consistent with OGC to expand "Map as Service". Integration of NNRMS programmes into government projects promotes responsibility in the use of satellite data and the involvement of the private sector in important areas. Through cloud-based online processing tools, free satellite data (including microwave, SENTINEL, and Landsat time series multispectral data) is accessible.

Fulfilling diverse stakeholder requirements

A collaborative cloud-native platform is the best option for decision-making in food and land use systems when data is owned by different stakeholders and stored by multiple providers. It offers a centralised and scalable way to manage and analyse data in food and land use systems, empowering stakeholders to make better decisions based on thorough and current information. Some benefits of the proposed platform are discussed below:

Data Accessibility and Integration: Regardless of a stakeholder's location, a cloud-native platform facilitates the smooth integration of data from many sources. This guarantees that those who make decisions have access to thorough and current information to help guide their choices.
Flexibility and Scalability: Cloud-native platforms are easily scalable to meet changing

user needs and massive data volumes. Additionally, they provide flexibility in terms of incorporating additional functionality or data sources as the demands of the stakeholders change over time.

Collaboration and Co-Creation: By offering resources for data exchange, analysis, and visualisation, these platforms help stakeholders collaborate and co-create. To make better decisions, stakeholders can collaborate in real time and benefit from one another's knowledge and data insights.

Security and Privacy: To safeguard sensitive information and guarantee adherence to data privacy laws, cloud-native platforms usually have strong security capabilities. They provide encryption techniques and fine-grained access controls to protect the information shared by several parties.

Cost-Efficiency: Stakeholders can avoid the up-front expenses related to creating and maintaining their own data infrastructure by utilising cloud technology. Pay-as-you-go pricing models can also help them because they let them scale resources based on their budget and demands.

Interoperability: Cloud-native platforms are made to work with a variety of systems and data formats, enabling smooth integration with pre-existing tools and technologies that are utilised by many stakeholders. By encouraging data interchange and interoperability, this raises the general efficacy of decision-making procedures.

Cloud-Based Food and Land Use System WebGIS Platform

Climate vulnerability and risk analysis, farmer support systems, agricultural management, which necessitates data analytics and model simulation, and meteorological and remote sensing data are the main components of the decision support system for climate resilient food and land use systems (Figure 10).

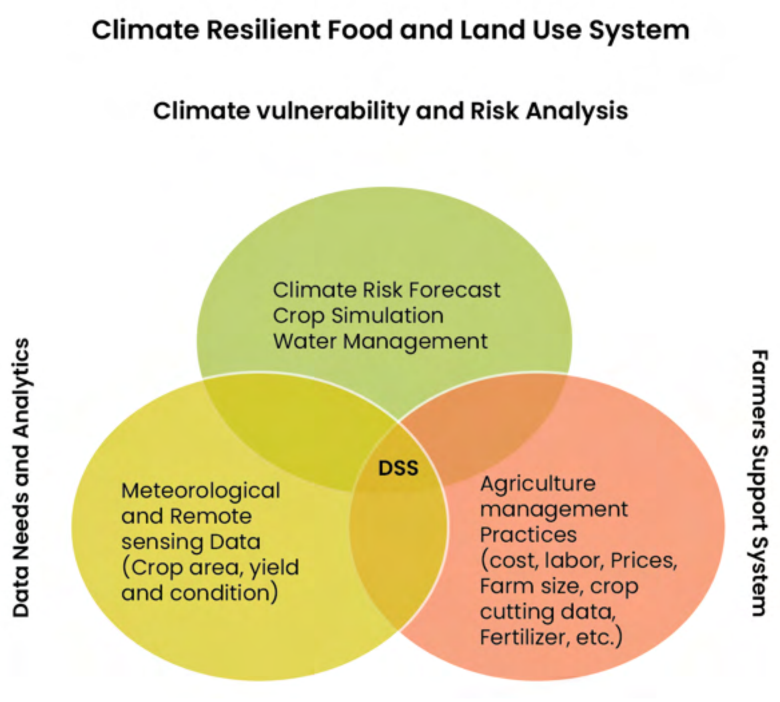

Figure 10. Smart DSS or Spatial DSS (SDSS) for climate resilient food and land use system

Complexity of the chain of information and knowledge processing that must be integrated as a practical tool for researchers and the farming community (Figure 11). In the context of the Food and Land Use System (FoLU), the data requirements must be explained in terms of Resource Management Areas (RMAs), Resource Management Activities (RMAs), and Resource Management Functions (RMFs) at various levels of decision making, namely Strategic, Tactical, and Technical. Stated differently, it is necessary to implement the RMAs-RMAc-RMF Data Matrix, which defines the multi-scale, multi-resolution framework of the Geospatial Platform for Food & Land Use System. The geographic data granularity at these levels (Strategic: 1:250K–1:M, Tactical: 1:10K–1:50K, Technical: 1:10K–1:4K) is linked to the Data Content Framework, with data sources mapped accordingly. Data Sources must be used to further map the RMAs-RMAc-RMF Data Matrix. This workflow-based framework ensures comprehensive, multi-dimensional data management is depicted in Figure 12.

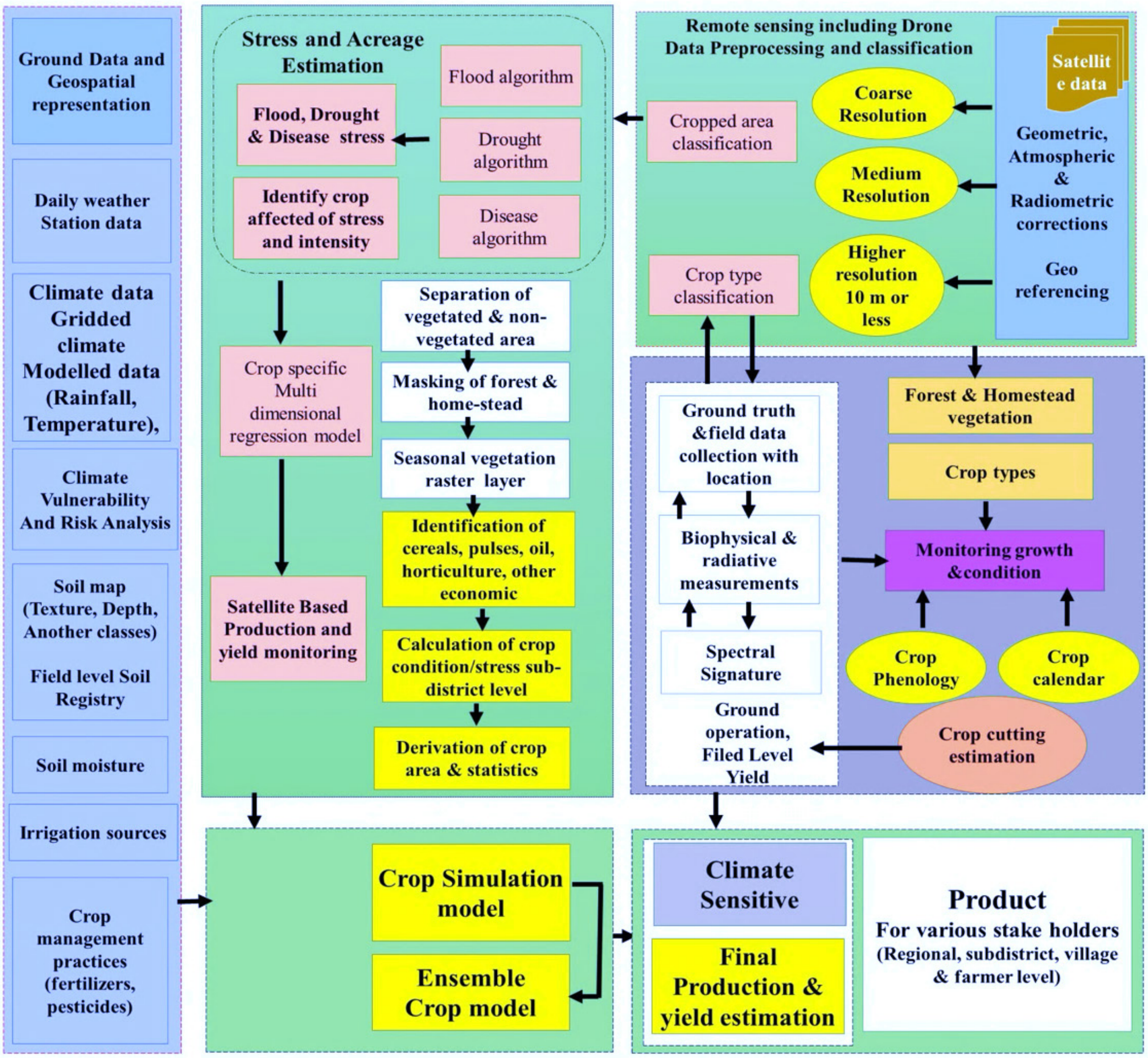

Figure 11. Chain of information and knowledge processing that must be integrated as a practical tool for institutions, researchers and the farming community

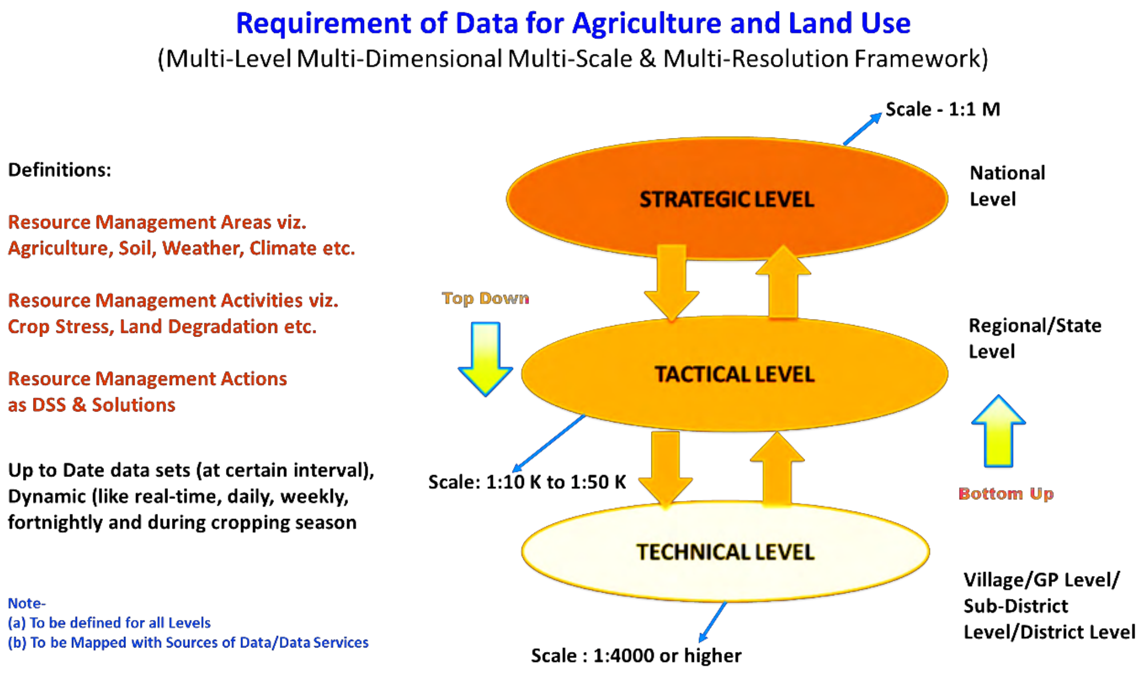

Figure 12. Multi-Level, Multi-Dimensional, Multi-Scale, and Multi-Resolution Workflow Based Framework

While, existing geo-platforms are promising, they do not fully address the needs of the food and land use system. Each contributes separately, but a cloud-native WebGIS system is essential for accessing, visualising, analysing, and interacting with geographic data. WebGIS platforms typically use a three-stage architecture to provide a seamless and intuitive user experience. Microservices should be integrated into cloud-native apps for scalable, continuous services. A cloud-native collaborative platform ensures easy data sharing, analysis, and visualisation, utilising scalable infrastructure for accessibility and growth. It prioritises interoperability with various data services and strong security to protect sensitive information.

The proposed cloud native decision support system

The proposed cloud-native decision support system integrates PMFBY and land record data, enhancing agricultural analytics and geoportal development. By combining land parcel and crop insurance data, it improves risk assessment, identifies crop failure patterns, and supports informed policymaking for disaster management and insurance optimisation. However, data privacy and security must be ensured.

System Design and Architecture of proposed system

The proposed Centralized Analysis of Cloud-Native Geoportal Architecture combines data from various sources into a reliable, multi-phase system. It includes data acquisition from crowdsourcing, geospatial portals, government agencies, and IoT devices. Data is processed, cleansed, and stored in local or cloud databases, with quality monitoring and orchestration pipelines. The system provides a user interface for web-based and API access, while an analytics engine offers insights through data analysis and visualisation. Key features include security, scalability, and advanced analytics for estimating production and yield, considering crop varieties, stressors, and management techniques (Figure 13).

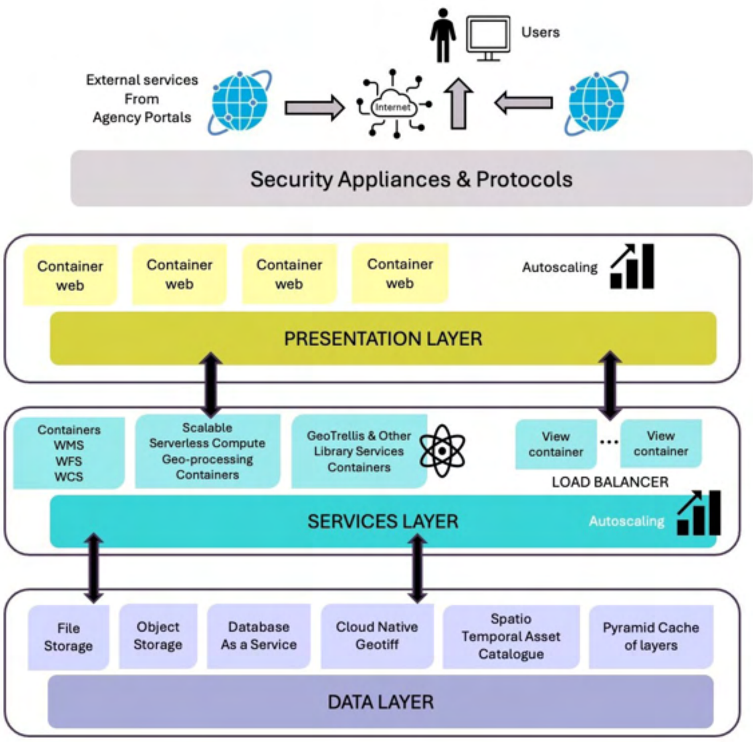

Figure 13. Concept of the proposed system

The centralised cloud-native Geoportal can transform India's land use and agricultural systems by integrating data and applying modern analytics. Proposed features include Risk-Adjusted Crop Suitability Mapping (to advise farmers on climate-resilient crops), Yield Gap Analysis (to pinpoint productivity gaps and encourage best practices), Predictive Modelling for Crop Failures (to enable prompt interventions), and Impact Assessments of agricultural programmes (to gauge their efficacy). A SWOT analysis identifies challenges like reliance on external services, data security, and inconsistent quality, while emphasising strengths such as data richness, real-time insights, and scalability. The geoportal can empower farmers, improve food security, and promote public-private partnerships, though issues like internet connectivity, cybersecurity, and funding sustainability must be addressed. With strategic planning, it can revolutionise India's agricultural and food security.

Chapter 6. Recommendations

Short-Term Actions

Enhance training and capacity building:

- India's agricultural extension system is essential for equipping farmers with the newest techniques and technologies, but its efficacy is hampered by large training and outreach gaps. Farmers who have limited access to extension services are more susceptible to financial difficulties, pest outbreaks, and low yields. They are also unable to make use of government programmes and financial resources. To close these gaps, government agencies, research institutions, and the corporate sector must work together and strengthen their institutions for data collection, administration, and dissemination.
- Precision farming and resource management could be revolutionised by geospatial technologies like GIS and remote sensing. By providing training programs, cutting-edge tools, and platforms to give stakeholders the skills they need for data-driven decision-making, organisations like ISRO and initiatives like Bhuvan and MANAGE have made tremendous progress in capacity building. Effective user engagement and practical use of technology in natural resource management are demonstrated by ISRO programmes like remote sensing and Geo-ICT training.
- Empowering farmers through training in data gathering technologies, sensors, and mobile apps, coupled with accessible platforms for geospatial insights, can support informed decisions in crop selection and sustainable practices. To guarantee that data ecosystems are sensitive to farmer demands and allow for a more inclusive and flexible agricultural framework, feedback mechanisms should be incorporated. These programmes will improve resource management, resilience, and sustainable development in India's vibrant agriculture sector when paired with capacity-building activities.

Facilitate better access to geospatial tools:

- Satellite remote sensing is best used to create a national framework for land use mapping and monitoring systems. A mandated national institution needs to produce land use statistics using multiresolution satellite remote sensing-based nationwide land use or cover mapping in very high granularity. Machine learning and artificial intelligence algorithms have reduced processing time and increased accuracy levels. There is a need to reconcile the LULC statistics and reporting systems and can support sustainable development and planning policies.
- By maximising land usage, controlling resources, expanding market access, and encouraging innovation, data significantly improves food security in India. However, growth is hampered by inadequate infrastructure, restricted access to cutting-edge technologies, and stringent data-sharing procedures. With the support of ISRO and IMD, geospatial technologies have made great strides and now offer detailed information that is essential for resource management, climate resilience, and sustainable farming methods. Enhancing data accessibility and digitisation is the goal of policies like the Digital India Land Records Modernization Program (DILRMP), the National Geospatial Policy (2022), and the Indian Space Policy (2023). But their usefulness has been limited by selective and laborious sharing procedures, and their execution has fallen short, especially for think tanks, universities, and minor players.

- Open-access data systems that incorporate many datasets, such as land use, soil quality, crop yield, and climate impacts, are desperately needed to address these issues and facilitate participatory methods for sustainable development. Models for centralised and easily available data ecosystems are offered by platforms such as India-WRIS WebGIS and PM Gati Shakti. Furthermore, public-private sector cooperation must guarantee inclusion, streamline procedures, and give priority to stakeholder rights. Building a resilient food system, enhancing farmer livelihoods, and promoting sustainable development in the face of climate change all depend on comprehensive data policy and efficient access systems.

Long-Term Actions
Invest in R&D for resilient agricultural technologies.

- To maintain long-term food security, R&D investments are crucial for creating drought-resistant crops and climate-resilient agricultural technologies. Because agricultural data is so complicated, platforms that are transparent, standardised, and interoperable are necessary to let farmers, researchers, and policymakers share knowledge. Through capacity-building programmes, academic institutions, business, government, and non-governmental organisations can work together to improve localised solutions and encourage the adoption of best practices.

- Farmers and agriculture suffer greatly when government funding on research and development (R&D) is cut; productivity declines, expenses rise, and profitability declines. Farmers are compelled to rely on their own resources in the absence of breakthroughs like better crop types and cutting-edge technologies, which drives up production costs and lowers competitiveness. To overcome these obstacles, the agriculture industry must strategically prioritise big data integration, sustainable farming methods, and cooperative R&D initiatives that promote resilience and innovation.

- India's Natural Resources Data Management System (NRDMS) and space policies, among other initiatives to modernise agriculture, place a strong emphasis on developing geospatial technology, conducting research and development in new fields, and creating innovation hubs. Together with sector-wide strategic alliances, these programmes seek to advance sustainable development and strengthen technical sovereignty. Improving data accessibility, developing talent, and utilising interdisciplinary skills are essential to achieving these objectives and converting agriculture into a resilient and sustainable ecosystem.

Promote international collaborations for knowledge sharing:

- To improve data availability, accuracy, and usability for tackling global issues including disaster management, food security, and climate change, cooperation between governments, international organisations, and the business sector is essential. Increasing data sharing and offering a thorough picture of the Earth's health are the main goals of groups like the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS). Geospatial technologies are used by the United Nations Satellite Centre (UNOSAT) and the United Nations Office for Outer Space Affairs (UNOOSA) to reduce the risk of disasters and promote sustainable development.
- In a similar vein, the IPCC and the Global Climate Observing System (GCOS) offer crucial climate observations and projections to inform policy and resilience

planning, while the World Meteorological Organization (WMO) and the Coordination Group for Meteorological Satellites (CGMS) prioritise enhancing meteorological and hydrological data to assist vital sectors.

- With the help of organisations like the Food Security Information Network (FSIN) and the Global Network Against Food Crises (GNAFC), which concentrate on assessing food insecurity and directing humanitarian efforts, the Food and Agriculture Organization (FAO) spearheads initiatives to end hunger and guarantee access to wholesome food. By encouraging knowledge exchange, tackling inequality,and advancing sustainable development goals, other UN agencies like UNESCO and UNDP also make a contribution. Together, these groups stress the value of open data exchange, international collaboration, and the use of cutting-edge instruments and regulations, like the Paris Agreement, to fight climate change, improve food security, and create resilient ecosystems.

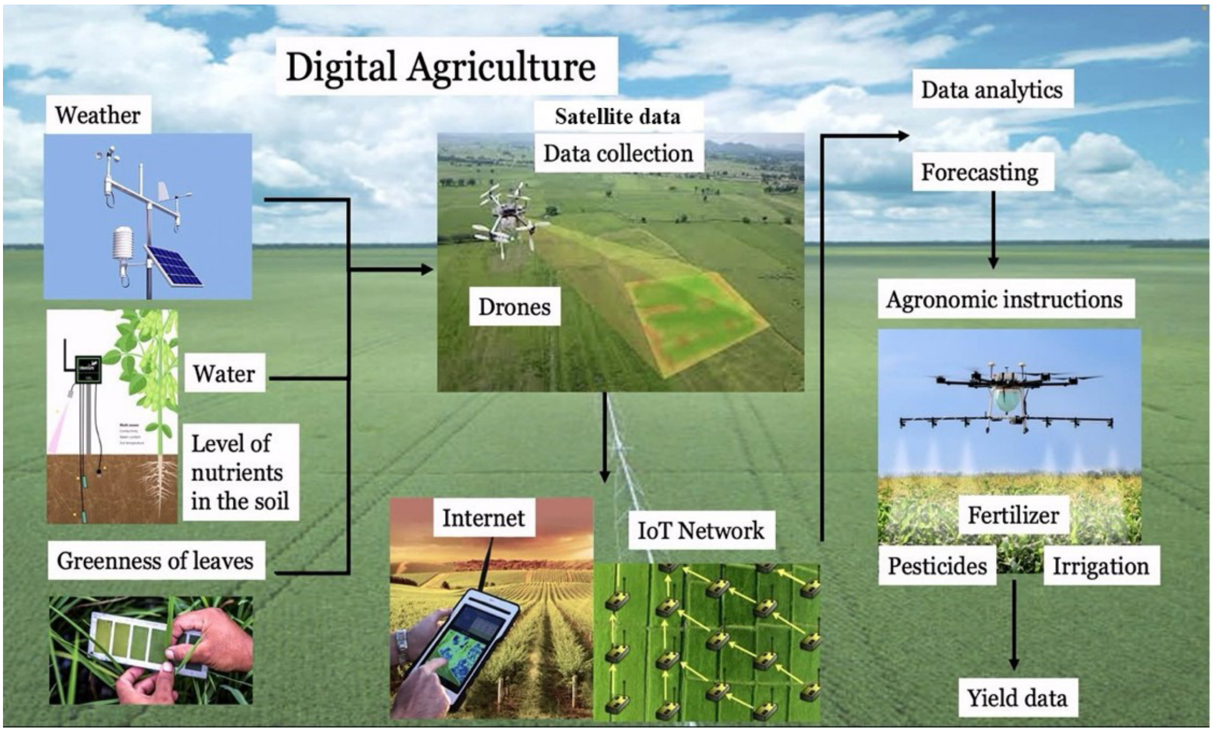

Figure 14. Operationalising digital agriculture

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Annexure I

1.1 Satellite data, thematic and topographical data by lead National and International Space Agencies – their characteristics and sharing mechanisms

Sl. No	Satellite Data	Data Type	Specifications	Sharing status
Indian National Remote Sensing Satellites Indian Space Research Organisation, Government of India				
1	Resourcesat AWiFS LISS III LISS IV	Multispectral (µm) 0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.77 0.52-0.59 0.62-0.68 0.77-0.86	AWiFS 56 m Revisit 5 days LISS III 23.5 m Revisit 24 days LISS IV 5.8 m Revisit 5 days	Sharable on BHOONIDHI portal (https://bhoonidhi.nrsc.gov.in). Sharing as per Indian Space Policy (2023). The downloaded data is NOT Analytics Ready Data (ARD)*. *Diverse groups use the satellite data (image processing specialists and non-specialists).
2	CARTOSAT 1 (Panchromatic)	0.5-0.85	PAN 2.5 m	Sharing as per Indian Space Policy (2023).
	Cartosat - 2S,	Multispectral and Panchromatic	1 m or better	G2G information sharing and priced for rest users.
	Cartosat 3	Multispectral and Panchromatic	1 m or better	Sharable of the areas which is having coverage by the satellite The product is priced for all.
3	Digital Elevation	Panchromatic stereo data used Cartosat 0.5-0.85 µm	30 m	Sharable on BHOONIDHI portal (https://bhoonidhi.nrsc.gov.in).
			10 m	Sharing as per Indian Space Policy (2023)
			2.5 m	Sharable and priced for all

1.2 List of Major Remote Sensing Satellite Data, their characteristics and sharing mechanisms of International Space Agencies

Sl. No	Satellite Data	Data Type	Specifications	Sharing reference
		National Aeronautics and Space Administration US federal government		
1	Landsat 1, 2, 3, 4&5 MSS	Multispectral 0.5 – 1.1µm	68 m × 83 m Revisit 18 days	Sharable on USGS EarthExplorer portal (https://earthexplorer.usgs.gov).
2	Landsat 4&5 TM	Multispectral 0.45 – 12.5 µm	30 m (120 m – thermal) Revisit 16 days	Sharable on USGS EarthExplorer portal (https://earthexplorer.usgs.gov).
				Analytics Ready Data (ARD) - Science data.
3	Landsat 7 ETM+	Multispectral 0.45 – 12.5 µm	30 m Revisit 16 days	Sharable on USGS EarthExplorer portal (https://earthexplorer.usgs.gov).Analytics Ready Data (ARD) - Science data.
4	Landsat 8&9 PAN OLI - TIRS	Panchromatic 0.50 - 0.68 µm Multispectral 0.43- 2.29 µm 10.6- 12.51 µm	15m 30m 100m Revisit 16 days for all three sensors	Sharable on USGS EarthExplorer portal (https://earthexplorer.usgs.gov).Analytics Ready Data (ARD) - Science data.
		Copernicus program European Space Agency (ESA) and the European Union (EU)		
1	Sentinel-1A&1B SAR	Microwave Bandwidth 0-100 MHz	SM mode: 5 m IW mode: 5 m x 20m EW mode: 25 m x 100 m WV mode: 5 m x 20 m. The repeat cycle is 12 days for a single satellite and 6 days when both satellites are operating	Users can access Sentinel data stored in native format and bundled (zipped files) for one month following their publication date through Copernicus Data Space Ecosystems. All data is being shared on Open Cloud based portal. Analytics Ready Data (ARD) - Science data.
2	Sentinel-2 A&B MSI	Multispectral Blue (~493nm), Green (560nm), and Red (~665nm), NIR ~833nm (~443nm for aerosols and ~945nm for water vapour) and cirrus detection (~1374nm)	VNIR-10m NIR-20m SWIR-60m Revisit 10 days	Users can access Sentinel-2 data stored in native format and bundled (zipped files) for one month following their publication date through Copernicus Data Space Ecosystems. All data is being shared on Open Cloud based portal. Analytics Ready Data (ARD) - Science data.
3	Sentinel-3 OLCI	Multispectral 400-1020 nm	300m Revisit 1 day	Users can access Sentinel-3 data stored in native format and bundled (zipped files) for one month following their publication date through Copernicus Data Space Ecosystems.
	SLSTR	VIS (not ATSR-1): 0.555; 0.659; 0.865	1km Revisit <1 day	

		SWIR: 1.375; 1.610; 2.25 MWIR/TIR: 3.74; 10.85; 12 Fire-1/2: 3.74; 10.85		All data is being shared on Open Cloud based portal. Analytics Ready Data (ARD) - Science data.
Japan Aerospace Exploration Agency (JAXA)				
1	ALOS AVNIR-2 PALSAR PRISM	0.42-0.89 µm SAR-L 1.3GHz 0.52-0.77 µm	10m 10 and 100m 2.5 m Revisit 14 days	eoPortal. All data is being shared on Open Cloud based portal. Analytics Ready Data (ARD) - Science data.
Centre national D'études spatiales – the French space agency				
1	SPOT 1,2 &3 HRV1 HRV2	Panchromatic 0.51-0.73 µm Multispectral 0.50- 0.89 µm	10 m 20 m Revisit 2-3 days	ESA User Services cloud portal by registration login and costed. Analytics Ready Data (ARD) - Science data.
2	SPOT 4 HRVIR1 HRVIR2	Panchromatic 0.51-0.73 µm Multispectral 0.50-1.75 µm	10 m 20 m Revisit 26 days	ESA User Services Cloud based portal by registration, login and costed. Analytics Ready Data (ARD) - Science data.
3	SPOT-5 HRG	0.48-0.71 µm	2, 5 m panchromatic and 10m multispectral. Revisit 2-3 days	ESA User Services cloud based portal by registration login and costed. Analytics Ready Data (ARD) - Science data.
4	SPOT-6&7 NAOMI	PAN 0.45-0.75 µm MS 0.45- 0.89 µm	PAN: 1.5 m MS: 6 m Revisit 1-3 days	ESA User Services cloud portal by registration login and costed. Analytics Ready Data (ARD) - Science data.

1.3 Indian Thematic data- Thematic Data (under National Natural Resource Information System - NNRMS)

Sl. No.	Themes	Format/ Year	Scale/Thematic information	Shareability
1	Land Use and Land Cover	Digital Vector (state wise) 2005-06 2010-11 2015-16 2020-21	1:50 K Level Three Classification Four cycles completed at 5-year interval	Sharable from BHUVAN portal G2G Sharable in the Area of Interest (AOI) with defined purpose for other users. (Not available)
2	Land Use and Land Cover	Digital Raster	1:250 K Level one classes Annual – Three cropping seasons From 2005-06 onwards	Sharable from BHUVAN portal G2G works well. Sharable in the Area of Interest (AOI) with defined purpose.
3	Land Use and Land Cover	Digital Vector	1:10 K (2015–16) Level Three/Four	Sharable from BHUVAN Panchayat. Sharable from BHUVAN portal Government to Government (G2G).
4	Land Degradation	Digital Vector	1:50 K	2005-06 - Sharable from BHUVAN portal. Jointly with Ministry of Rural Development. For others sharable in the Area of Interest (AOI) with defined purpose.
5	Waste Land	Digital Vector	1:50 K, 1980-82 (1: 1 million scale- 8 classes) 2000 (1: 250K scale – 13 classes)	Jointly with Ministry of Rural Development. Sharable from BHUVAN portal Government to Government (G2G). For others sharable in the Area of Interest (AOI) with defined purpose.

			2003-04 (1:50K scale-28 classes) 2005-06 (1:50K scale-28 classes) Change mapping during 2008-09, 2015-16.	
6	Biodiversity Characterisation (at Landscape level)	Digital Raster	1:50 K (2002-1010) 30 m pixel	Not sharable. Neither available on BHUVAN. Jointly with Department of Biotechnology and ISRO -MMRMS. IBIN Portal (not online) Out puts: • Vegetation Type and Land cover • Fragmentation • Disturbance Regimes • Biodiversity Richness • Field sample plots (>18K)
7	Geomorphological/Land form/Lineament map	Digital Vector	1:50 K	Jointly produced with Geological Survey of India and ISRO-NNRMS. Sharable from BHUVAN portal. For others sharable in the Area of Interest (AOI) with defined purpose.
8	Wetland	Digital Vector	1:50 K	Sharable from VEDAS portal Government to Government (G2G). For others sharable in the Area of Interest (AOI) with defined purpose.
9	Soil Map NBSS&LUP	Digital Vector	1:250 K Class wise soil physical and chemical characteristics	National Bureau of Soil Survey and Land Use Planning (ICAR) portal. Sharable Government to Government (G2G). For others sharable in the Area of Interest (AOI) with defined purpose.
		Digital Vector and Tabular data	Detailed Soil Survey and Land Resource Mapping 1:10K mostly in the intensive agriculture areas	Sharable G2G only

Annexure II

Important National Portals for improved coordination (on Food Agriculture and Land Use)

Sl. No.	Portal	Available datasets	Sharing portal
1.	PM Gati Shakti	Digital platform for holistic and integrated planning of projects. It interconnects ministries of Indian Roadways, Indian Railways, Indian airway and Indian waterways for easy movement of goods. It leverages technology and spatial planning tools with ISRO. It enables transparency in monitoring current projects and provide information about upcoming connectivity projects to the community.	https://pmgatishakti.gov.in
2.	Bharatmaps MEITY-NIC	Depicts core foundation data as "NICMAPS", an integrated base map service from Survey of India, ISRO, FSI, and RGI and so on. Bharat maps services Platform aims to provide access to GIS data as a service to various e-gov projects of NIC at Central and State level. The service cover large number of layers at various scale including Administrative boundaries, transport layers such as roads & railways, forest layer, settlement locations etc., including terrain map services. Base maps, satellite imagery, and hybrid maps aligned with worldwide geospatial standards.	A multi-layered GIS platform/web service Scale from 1:50,000 to 1:10000 scale with large amount of Point of Interest Data of Government Assets and Infrastructure. It is a key component of the Digital India programme for efficient and cost-effective government (https://bharatmaps.gov.in/). OGC compliant APIs facilitate developers in various ministries to consume and integrate map services in e-governance workflows using NIC GIS Cloud. (https://mapservices.gov.in/). It controls many Digital Public Infrastructure Platforms like PARIVESH (Pro-Active and Responsive facilitation by Interactive, Virtuous, and Environmental Single Window Hub) – Green Clearance by MoEFCC, GramManchitra – Gram Panchayat Spatial Planning Platform, BHARATNET GIS – National Optical Fiber Network and so on. Additional NIC GIS Services are used by SVAMTIVA Scheme, DLRMP and many flagship schemes of Government at Central as well as State Level.
3.	BHOOMI ICAR-NBSS&LUP	Administrative units, Socio economic, Livestock, Terrain, satellite data, physiography, Agro-ecology, Soils, Soil fertility, Land degradation, Watershed Planning, Land use planning, Aspirational districts, Soil Health Card	Systematically develop, organize and deploy the soil information through collating geo-referenced soil and allied resources database in Geographic Information System (GIS). http://www.bhoomigeoportal-nbsslup.in/
4.	IMD - MoES	Meteorological Data	Exclusive Division of Agricultural Meteorology provide direct services to the farming community of the country to minimise the impact of adverse weather on crops and to make use of crop-weather relationships to boost agricultural production. https://mausam.imd.gov.in/imd_latest/contents/meteorological-agriculture-services.php
5.	MNCFC SLUSI e-Atlas-Micronutrients ICAR-IISS	Crop and Weather Condition Maps, Vegetable Maps, Fruit Maps, Spices Maps Detailed Soil Survey and Land Resource Mapping. Soil micronutrients	Provide in-season crop forecasts and assessment of drought situation. https://ncfc.gov.in/maps.html National level soil surveys in India. Perform Soil Survey and Land Resource Mapping. https://slusi.dacnet.nic.in/index_English.html#s2 Taluk wise soil micronutrients in India soils. https://iiss.icar.gov.in/e-Atlas/index.html

6.	BHUVAN NRSC-ISRO	Satellite & Thematic data	Web-based utility which allows users to explore a set of geographic content prepared by the Indian Space Research Organisation. Provides access to thematic maps. • Provide satellite image basemap with High resolution, Natural resource's theme maps for visualisation and download, digital elevation data and their data of climate and environmental sciences • Bhuvan OGC compliant services power mobile and web applications • Disaster risk reduction portal. Portals for various verticals. • State wise g-governance portals and governance portals of many central ministries https://bhuvan.nrsc.gov.in/home/index.php
7.	BHOONIDHI	Satellite Remote sensing data	Provide access to Remote Sensing data from 44 satellites, including Indian and Foreign Remote Sensing sensors acquired since 1986. Also facilitate the regional distribution of Sentinel, Landsat (8 & 9) data in India. https://bhoonidhi.nrsc.gov.in/vista/index.html
8.	Vedas – SAC ISRO	Agriculture, Land use, Photogrammetry, Forestry and Environment, Coastal & Marine Resources, Hydrological Studies, Climate Change Studies, Urban & Infrastructure, Cryosphere, Spatial Data Infrastructure, Atmospheric and Ocean Sciences, Early Warning and Disaster Management Support, Planetary Sciences etc.	Research and applications of optical and microwave remote sensing data in a large number of disciplines. https://vedas.sac.gov.in/en/
9	India-WRIS Ministry of Jal Shakti, GOI	Water resources	A repository of nation-wide water resources data, providing a 'Single Window' source of updated data on water resources & allied themes as a part of the National Hydrology Project. India- WRIS acts as a data dissemination platform for hosting static, dynamic, and semi-dynamic water resources spatial and non-spatial data under 130 GIS layers for the entire country. https://indiawris.gov.in/wris/

Important International Portals on Food Agriculture and Land Use			
1.	Measuring the World's Croplands	The Global Food Security-support Analysis Data (GFSAD) collection provides detailed maps of agricultural croplands around the world at 30-meter spatial resolution.	The development of the dataset was led by Dr. Prasad Thenkabail, research geographer at the USGS, with the help of funding from NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program. MEaSUREs are a competitive program through NASA's Earth Science Data Systems (ESDS) Program that supports projects focused on the generation of new data products that meet the needs of the Earth science community. Freely sharable on following portal. https://www.earthdata.nasa.gov/news/feature-articles/measuring-worlds-croplands
2.	GCI30: a global dataset of 30 m cropping intensity using multisource remote sensing imagery	The global distribution of cropping intensity (CI) is essential to our understanding of agricultural land use management on Earth. Optical remote sensing has revolutionized our ability to map CI over large areas in a repeated and cost-efficient manner. Previous studies have mainly focused on investigating the spatiotemporal patterns of CI ranging from regions to the entire globe with the use of coarse -resolution data, which are inadequate for characterising farming practices within heterogeneous landscapes. To fill this knowledge gap, in this study, we utilised multiple satellite data to develop a global, spatially continuous CI map dataset at 30 m resolution (GCI30). Accuracy assessments indicated that GCI30 exhibited high agreement with visually interpreted validation samples and in situ observations from the PhenoCam network.	The GCI30 dataset is available on Harvard Dataverse: https://doi.org/10.7910/DVN/86M4PO (Zhang et al., 2020)
4	FAO SOILS PORTAL – UN	Soil – Geospatial Data	Data and maps compiled using field surveys backed up by remote sensing and other environmental data, expert opinion and laboratory analysis. https://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/en/
5	CLMS portfolio - Copernicus	Thematic layers of land cover, built up, tree cove density etc.	Transform this wealth of satellite and in situ data into value-added information by processing and analysing the data. https://land.copernicus.eu/en/map-viewer?product=333e4100b79045daa0ff16466ac83b7f
6	CRU University of East Anglia	Climate	High-resolution gridded datasets of global land data for multiple variables on a 0.5° x 0.5° or finer grid. https://www.uea.ac.uk/groups-and-centres/climatic-research-unit/data
7	Esri Land Cover	Land use/land cover	10-meter resolution land cover using Sentinel-2. Each year is generated with Impact Observatory's deep learning AI land classification model. https://www.arcgis.com/home/item.html?id=cfcb7609de5f478eb7666240902d4d3d

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folu.india@folu.org
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