GIS-enabled Decision Support System for Promoting Natural Farming Practices in Sustainable Agriculture: Problems and Prospects from an Indian Perspective

Karne Raju[1], Asst. Prof Dr. Sabitha[2]

[1]Ph.D. Research Scholar, [2]Assistant Professor and Head
Department of Geo-informatics, South campus, Telangana University, Kamareddy -503102

Abstract:
Geographic Information System (GIS)-enabled Decision Support Systems (DSS) can be discussed as a groundbreaking solution to the development of sustainable agriculture based on the natural farming practice in India. This essay discusses the adoption of GIS technology in conjunction with decision-making models to streamline the adoption of natural farming in most agro-ecological regions. Precision agriculture, soil health mapping, crop pattern, and resource optimization are enabled by GIS-DSS applications as the organic farming area in India has reached up to 7.3 million hectares by 2024. The paper examines successful projects, such as the Krishi Mapper portal, the Digital Agriculture Mission projects, and state GIS interventions at the state level in Madhya Pradesh, Maharashtra, and Karnataka. The main challenges that were observed are rural farmers experiencing a digital divide, where rural tele-density stands at 59.19 and urban tele-density stands at 133.72, a lack of digital literacy, infrastructure, and high start-up investments. The prospectus suggests that it has good prospects due to the use of public-privately partnering, improving digital infrastructure as part of the Digital Agriculture Mission (₹2,817 crores allocation), applying AI and remote sensing technologies, and developing mobile applications centered around farmers. This holistic study through analysis will offer practical recommendations to policymakers and other concerned parties in order to use GIS-DSS to achieve sustainable agricultural change in India.

Keywords: GIS, Decision Support Systems, Natural Farming, Sustainable Agriculture, Precision Agriculture, Digital Agriculture Mission, India, Krishi Mapper, Organic Farming, Remote Sensing.

1. INTRODUCTION

India continues to depend on Agriculture as the foundation of its economy since it provides livelihood to about 58 percent of the rural community and also makes a huge contribution to the national GDP. Nevertheless, excessive application of chemical fertilizers and pesticides in the last six decades has caused soils to become degraded, groundwater to dry up, and crop production to decrease. Natural farming, based on ecological harmony and the use of traditional skills, has been a solution to conventional agriculture that relies on chemicals. The Government of India has initiated a number of programs, such as Bharatiya Prakritik Krishi Padhati (BPKP) and Paramparagat Krishi Vikas Yojana (PKVY), which encourage the use of organic and natural farming techniques in the country.

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Figure 1: The integration of Geographic Information Systems with agricultural decision-making that includes satellite information, the mapping of the fields, and the technology adoption by the farmers.

Geographic Information Systems (GIS) have transformed agricultural decision-making in that they give the capability of spatial analysis of land resource management, crop planning, and yield estimation. In combination with Decision Support Systems (DSS), GIS will help farmers and policymakers to make data-driven decisions, taking into account real-time data of the state of the soil, of the weather conditions, of the availability of water, and market demands. The integration between the GIS technology and the natural farming concepts presents some historical prospects for sustainable agricultural development in India.

Figure 2: Comparison between the practices of natural organic farming and the chemical-heavy conventional farming method.

By March 2024, in India, there are 1.76 million certified organic farming lands that include 3.63 million hectares of conversion. The country leads second in the world in terms of organic agricultural land and first in terms of the total number of producers of organics. Since these have been attained, the shift towards natural farming encounters a lot of challenges, among them being a lack of technical knowledge, insufficient market connections, difficulties in certification, and a lack of access to digital technologies in rural settings. DSS using GIS can help overcome most of these problems by making farmers receive specific, location-oriented information and recommendations.

In this paper, GIS-enabled Decision Support Systems and their contribution towards natural farming practices in India are discussed in detail. It examines the successful examples of implementation, points out the challenges that continue to exist, and also discusses the future opportunities of technology-driven sustainable agriculture.

2. LITERATURE REVIEW

2.1 GIS Applications in Agriculture

Geographic Information Systems have become an important instrument in contemporary agriculture, and it is possible to gather, analyze, and visualize spatial data to enhance the decision-making process. The studies conducted by the International Federation of Organic Agriculture Movements (IFOAM) prove the fact that in the agricultural world, GIS applications have become a matter of great significance, not only in the last ten years, but 66% of printed research papers refer to the recent six-year period. Its major areas of use are crop yield estimation, soil fertility assessment, monitoring of cropping patterns, drought assessment, pest and disease management, and precision agriculture.

Research indicates that GIS technology has the potential to significantly improve the estimates of crop yield and conduct effective analysis of soil amendments. A combination of Remote Sensing (RS) and GIS offers real-time monitoring features of crops, enabling farmers to determine the health of crops, establish when there is stress, and optimize input application. National acid of Agricultural Research Management (NAARM) affirms that precision farming, which is the integration of GIS, GPS receivers, continuous yield sensors, and geo-statistics, is a new form of sustainable agriculture.

2.2 Natural and Organic Farming in India

The state of organic farming in India has had impressive growth, with the state of Madhya Pradesh having more than 1.5 million hectares of land under organic certification, the state of Maharashtra comes next at 1.2 million hectares, Rajasthan, Gujarat, and Karnataka. In the year 2016, Sikkim was made the first fully organic state in India, which transformed about 75,000 hectares of agricultural land. According to the Agricultural and Processed Food Products Export Development Authority (APEDA), by 2023-24, the overall area under the organic certification process had reached 7.3 million hectares, with 4.47 million hectares being under cultivable area.

Paramparagat Krishi Vikas Yojana (PKVY) was created in 2015, and it offers financial aid and technical support to organic farming. Bharatiya Prakritik Krishi Padhati (BPKP) initiative is a particular project under the PKVY that promotes natural farming with the application of on-farm inputs, traditional knowledge, and native practices. India manufactures about 3.6 million MT of certified organic items in 2023- 24, comprising multiple crops such as cereals, pulses, tea, coffee, spices, and fruits.

2.3 Decision Support Systems and Digital Agriculture

Digital Agriculture Mission: the Digital Agriculture Mission is an approved policy with a budget of 2817 crores that is intended to transform the agricultural sector of India by establishing a strong Digital Public Infrastructure (DPI). These are the mission AgriStack, Digital General Crop Estimation Survey (DGCES), and the Krishi Decision Support System. It has been shown that digital technologies such as GIS, Artificial Intelligence, and IoT can be used to streamline the overall farming activity, resulting in higher yields, better decisions, efficient resource utilization, and greater access to the market. Krishi Mapper portal is a GIS-based portal that offers farmers the option of real-time monitoring of crops, mapping of soil health, as well as prediction of yields in multiple agricultural landscapes in India.

3. GIS TECHNOLOGY IN NATURAL FARMING

3.1 Components of GIS-enabled DSS

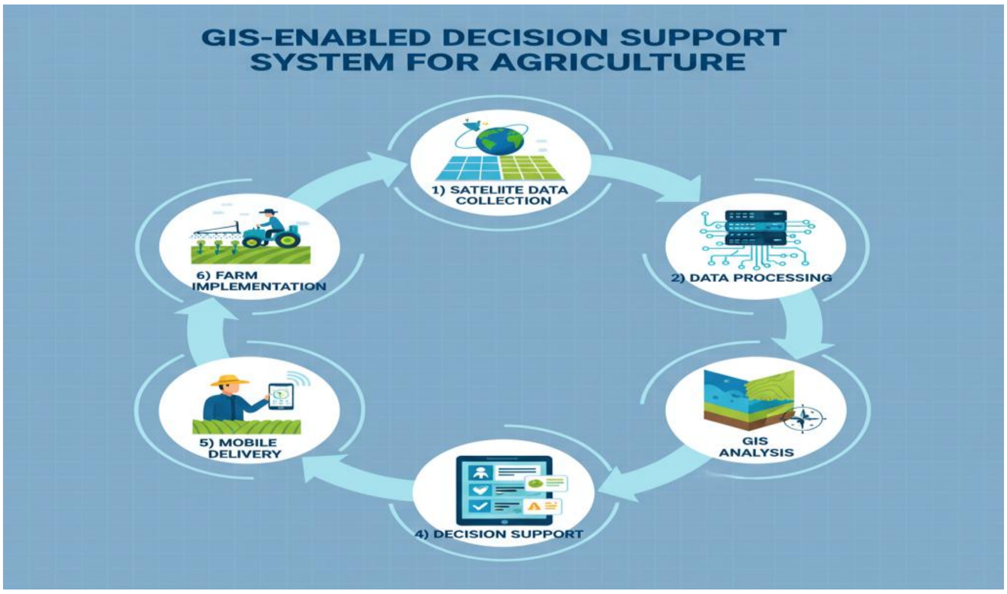

Figure 3: Full flow of GIS-based Decision Support System based on satellite data acquisition through to farm-based application.

A natural farming Decision Support System based on GIS includes several interconnected elements that collaborate to deliver actionable information:

- **Spatial Data Collection:** Integration of satellite imagery, GPS coordinates, and ground surveys to create comprehensive agricultural databases
- **Data Analysis Module:** Algorithms for soil analysis, crop suitability assessment, water resource mapping, and climate pattern analysis
- **Visualization Interface:** User-friendly maps and dashboards displaying spatial information for farmers and policymakers
- **Decision Support Algorithms:** AI and machine learning models providing recommendations for crop selection, planting schedules, and resource allocation
- **Mobile and Web Applications:** Available platforms that can provide information to the farmers via their smartphones and computers.
- **Connectivity with IoT Sensors:** Real-time monitoring of the moisture level in the soil, temperature, and other environmental factors.

3.2 Applications in Natural Farming

Soil Health Mapping: GIS can be used to accurately map the soil type, nutrients, the location of organic matter, and the pH levels of agricultural plots. These geographical data assist farmers in locating favorable fields to plant certain crops, as well as deciding on the amount of organic inputs. The digitized Soil Health Card scheme, which is based on GIS platforms, offers farmers personalized recommendations on soil nutrient management without chemical fertilizers.

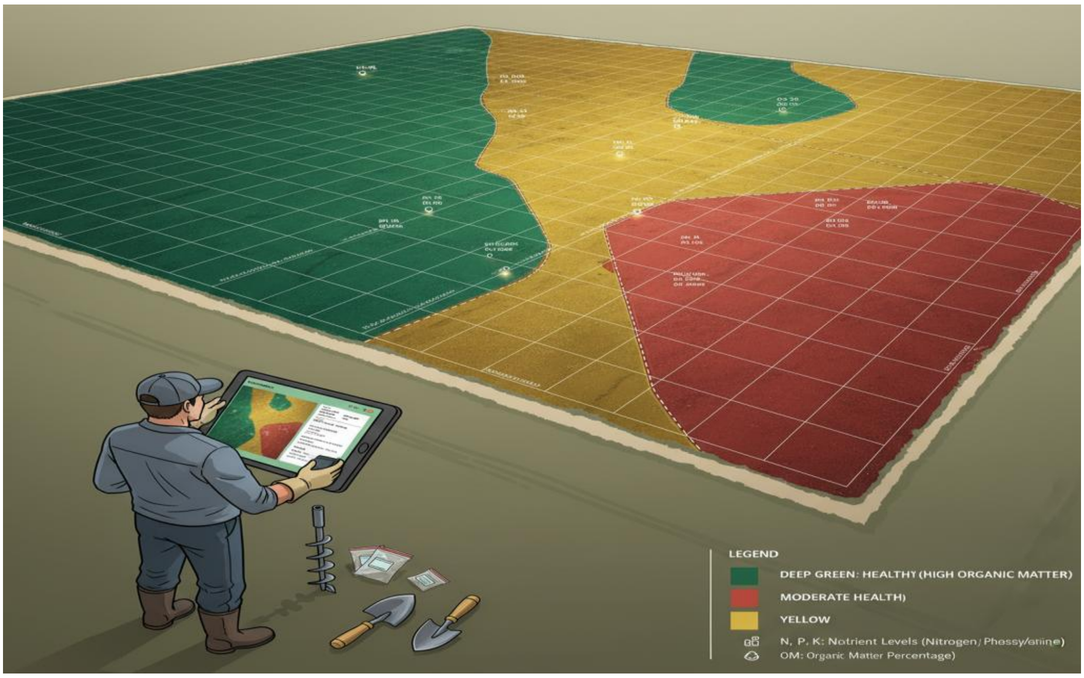

Figure 4: Soil health mapping of the GIS in colored areas of nutrient status and organic matter content.

Crop Suitability Analysis: GIS-DSS determines where particular crops can be grown using natural farming techniques by overlaying soil characteristics, climatic information, availability of water, and terrain of the region. Fuzzy logic and Analytic Hierarchy Process Multi-criteria analysis of land suitability offers trade-off evaluation of land suitability in diverse agro-ecological regions, especially in India, with its variety.

Water Resource Management: GIS is used to map the areas of groundwater potential, watershed demarcation, and irrigation systems. This fact helps in the sustainable management of water in natural farming, where water conservation processes such as mulching and contour farming are imperative. The remote sensing data used in conjunction with the GIS is used to monitor the moisture content of the soil; hence, irrigation can be scheduled accurately.

Pest and Disease Management: The pest surveillance systems are based on GIS, where the spatial distribution and temporal distribution of agricultural pests and diseases are monitored. The early warning systems also inform the farmers on possible outbreaks, and as a result, biological control measures are applied in time in line with the principles of natural farming. Weather information can be integrated to increase the accuracy in the prediction of pests and diseases.

Market Connection and Supply Chain: GIS-enhanced systems such as e-NAM (National Agricultural Market) can provide farmers with spatial knowledge on where their produce can be sold, the prices, and the demand patterns of organic produce. This helps in the ease of accessing the market and proper pricing of natural farming products, which is a critical issue in organic agriculture.

4. STATE-WISE ORGANIC FARMING DISTRIBUTION

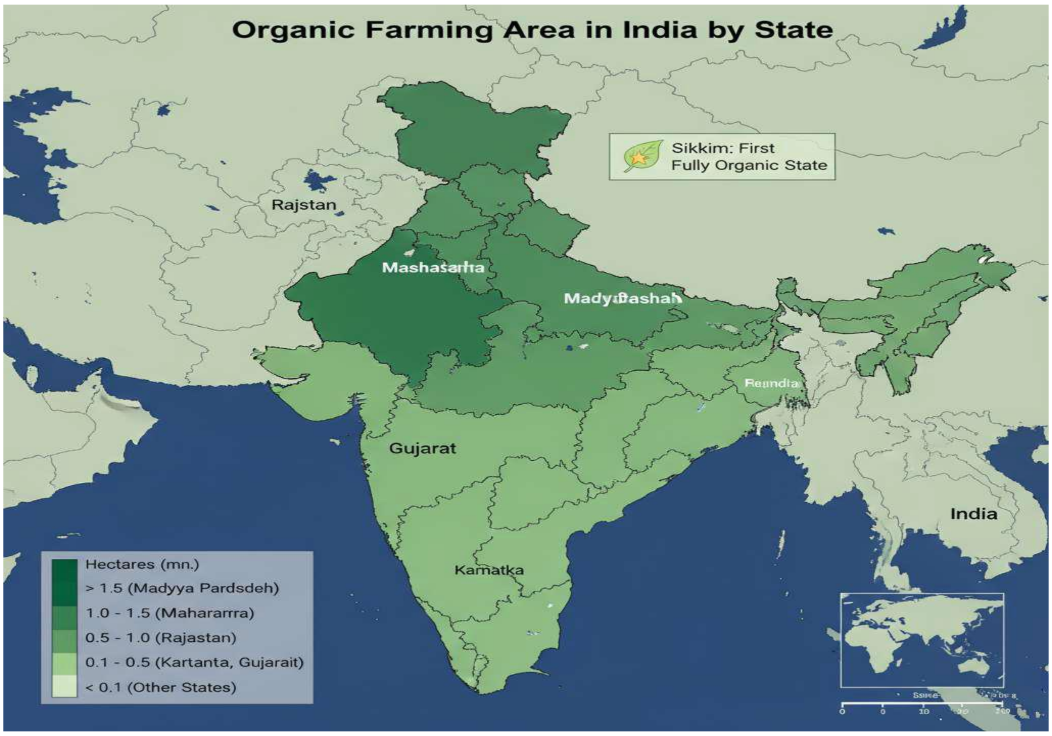

Figure 5: State-wise distribution of organic farming area across India, highlighting the leading states

Table 1: State-wise Organic Farming Area in India (2023-24)

State	Area (Hectares)	% of Total
Madhya Pradesh	1,500,000	20.5%
Maharashtra	1,200,000	16.4%
Rajasthan	900,000	12.3%
Gujarat	150,000	2.1%
Karnataka	100,000	1.4%
Sikkim	75,000	1.0%
Others	3,405,000	46.3%
Total	**7,330,000**	**100.0%**

Source: APEDA (Agricultural and Processed Food Products Export Development Authority), 2024

5. PROBLEMS AND CHALLENGES

5.1 Digital Divide and Infrastructure Constraints

Figure 6: Visual illustration of the existence of a digital divide between the urban and rural agricultural sections in India.

Digital divide is one of the greatest hindrances to the use of GIS-enabled DSS in natural farming in India. By March 2024, the urban tele-density is recorded at 133.72 per cent, with rural tele-density at a low 59.19 per cent, which is a great gap in access to digital technologies. Poor and unreliable internet connectivity and frequent disruption of power supply in rural places are crippling to farmers trying to gather real-time information in GIS sites. An infrastructure such as broadband connections and cell towers is still a problem in remote agricultural areas, which forms a technological divide between urban and rural farming societies. There are other challenges posed by the complexity of the task of capturing multiple agricultural data points. The agricultural environment in India is diverse in terms of crops, geographical climate zones, and soil. The combination of these variables within a single digital framework necessitates complex data processing systems and a large amount of computing capability. The current GIS systems are unable to support the extent and the complexity of agricultural diversity in India to make digital agricultural solutions widely available.

Table 2: Digital Divide Indicators in Indian Agriculture (2024)

Indicator	Value/Status
Urban Tele-density	133.72%
Rural Tele-density	59.19%
Internet Penetration (Rural)	41%
Smartphone Users (Rural)	425 million
Total Smartphone Users (India)	700 million
Digital Literacy Rate (Rural)	Significantly Lower than Urban
Broadband Access (Rural Areas)	Limited
Power Supply Reliability (Rural)	Inconsistent

Source: Department of Telecommunications, Government of India, 2024; World Economic Forum, 2024

5.2 Digital Literacy and Skill Gaps

Low digital literacy levels among agricultural communities are a major problem for the uptake of GIS-DSS. Farmers, especially in isolated locations, are not taught the most basic skills to use smartphones, mobile apps, or understand digital maps and data visualizations. Even simple digital tools such as soil sensors and yield monitoring apps are not used because of the lack of comprehensive training programs. This problem is further exacerbated by educational inequalities, as it is still estimated that the attendance rate in higher education is much lower in rural settings than in urban ones.

Educational systems of extension services and agricultural education are not in touch with technology. The conventional agricultural extension agents are usually not trained in digital technologies; thus, they have fewer opportunities to help farmers work with GIS-enabled tools. This builds an ignorance between the available technology and the application at the farm level.

5.3 Financial Constraints and Investment Requirements

There are high entry obstacles to switching to natural farming and embracing digital technology and particularly for small and marginal farmers, who form more than 86 percent of the farming population in India. The types of investments needed are the acquisition of smartphones or tablets, purchasing IoT sensors to use in precision agriculture, the internet connection, and the payment of organic certification. Such investments are especially difficult because of limited accessibility to formal credit due to poor creditworthiness or because of a lack of collateral.

The three-year transition period involved in organic certification translates to low yields with no price premium benefits, causing financial stress to farming households. The transition period cannot be done without proper financial assistance for many farmers. Although government programs such as PKVY partially help, in many cases, the amount of funding is not enough to cover the entire cost of investments in the transition to natural farming and the deployment of digital technologies.

5.4 Data Quality and Standardization Issues

There are persistent challenges when ensuring that there is a quality and standardization of data in various GIS platforms. Agriculture information gathered from different sources, namely, satellite data, on-ground surveys, IoT data, and paper-based records usually not consistent in terms of their format, measurement unit, and quality standards. This heterogeneity makes it difficult to integrate and analyze the data, making the recommendations of GIS-DSS less reliable. The questions of the accuracy of spatial data are still persistent, especially when dealing with small and fragmented landholdings typical of Indian farming. The high-resolution satellite images needed in precision agriculture are priced at a high-end, and thus, the available freely accessible low-resolution images might not be rich enough to make farm-level decisions. Remotely sensed data are widely implemented due to the requirements for field work to carry out ground truthing and validate the data.

5.5 Policy and Institutional Challenges

Diffusion of the policy structures and lack of coordination between the different departments of the government make the implementation of the GIS-DSS difficult. Several agencies, such as the Ministry of Agriculture, the Ministry of Electronics and Information Technology, state agriculture departments, and research institutions, tend to operate in isolation, resulting in duplication of work as well as incompatible systems. The protocols of sharing data are still unclear and thus do not allow the smooth exchange of information across platforms. Data privacy and security issues should also be taken into consideration, especially considering the personal data and land ownership of the farmers kept in digital databases.

6. CASE STUDIES FROM INDIA

6.1 Krishi Mapper Portal and Digital Agriculture Mission

Figure 7: Krishi Mapper portal interface with visualization of the agricultural data and decision support through multi-layered agricultural drilling.

The Krishi Mapper portal is a prototype GIS-based platform that is one of the flagships of the Digital Agriculture Mission, which indicates the potential of spatial technology in facilitating sustainable agriculture. The portal will include remote sensing data underlying protective measures of crops, soil, and weather type released by the Krishi Decision Support System in August 2024. The program is expected to develop detailed Soil Profile Maps on 142 million hectares of the agricultural lands in India. Krishi Mapper portal is a portal that offers essential facilities to farmers, such as real-time crop monitoring, satellite imagery, a detailed map of the soil health with the nutrient profile, weather-based advisories to aid in farming activity, prediction models based on the historical and current data on the yield, and a pest and disease surveillance system. The system combines information from various sources- such as ISRO satellites, state agricultural departments, and weather services to offer a complete decision support to natural farming activities.

Preliminary applications in other states, such as Punjab and Haryana, have yielded encouraging satisfaction. The farmers who used the Krishi Mapper portal stated that crop planning, resource use, and adaptation to climate variability could be improved. The possibility of location-specific recommendations of organic inputs and natural methods of farming has helped to make the conversion of conventional farming to organic farming easier with the introduction of the system.

6.2 Sikkim: India's First Fully Organic State

Figure 8: Terraced organic farming landscape of Sikkim, with the first full organic state success in India demonstrated.

Sikkim becoming a 100-percent organic state by the year 2016 can offer a lot of lessons regarding the implementation of large-scale natural farming. The state employed GIS technology inasmuch as it was used to plan and monitor the organic conversion of about 75000 hectares of agricultural land. The land use mapping with the use of GIS revealed appropriate locations of various organic crops and considered the altitude, slope, soil type, and market closeness.

The Sikkim Organic Mission created an all-encompassing GIS database of land cover, crop distribution units, organic input production units, and certification of farms. This space database allowed distributing resources effectively, focusing on training interventions, and monitoring the uptake of organic farming. GIS Applications based on mobile devices gave farmers instantaneous information about organic practices, market prices, and government support schemes.

Some of the success factors were good political commitment, financial support, elaborate training programs, and proper use of technology in planning and monitoring. Nevertheless, some problems were raised, such as difficulties in entering the market, fluctuation in prices of organic products, and constant capacity development. The experience shows the promise and restrictiveness of the change of organic farming, which is enabled by technology.

6.3 Madhya Pradesh: Leading in Organic Farming Area

Madhya Pradesh, with more than 1.5 million hectares under organic certification, has put in place a number of GIS-enabled programs to help in the growth of natural farming. One of the applications of GIS technology is identified in the Dr. Panjabrao Deshmukh Organic Farming Mission, which aims at identifying organic farm clusters in the state, mapping the availability of organic inputs, and tracking the performance of crops throughout the state.

The state has established a Decision Support System based on GIS that consolidates the soil health data, water availability mapping, climatic data, and market intelligence. This system is able to give farmers tailor-made advice on crops to grow, the use of organic inputs, and market connections. The certification

procedures are also made easier through the platform, whereby digital records are kept on the farming practices and input applications.
Mobile apps that are linked to the GIS platform can be used by extension workers to offer on-site assistance to farmers. The data in the field obtained using these applications constantly updates the central GIS database and forms a feedback loop that enhances recommendations in the system as time progresses. The project has been able to show how GIS-DSS may be applied to scale up natural farming adoption on large geographical locations with different agro-ecological settings.

6.4 Karnataka: Market-Based Organic Cluster Development

The Savayava Bhagya Yojane project of Karnataka is a modern example of GIS application in the development of organic farms based on market demand. The Market-Based Specific Crop Organic Cluster Development Program focuses on spatial analysis so as to define the best sites of organic crop cluster development in accordance with the market demand, agro-climatic environment, and availability of infrastructure. GIS mapping will be used to form some clusters of 50-acre units to achieve adequate production levels to match the market needs at all times.

The program takes advantage of GIS in planning logistics by optimizing the routes in terms of input delivery and the collection of produce. Market location, transportation, and storage facilities are spatially analyzed to cut the transaction costs and enhance market accessibility to organic farmers. A similar approach has been employed in Karnataka to assist in the creation of a regional federation of organic farmers' associations by making use of the spatial clustering algorithms to determine potential collaboration between the farmers who are geographically proximate.

Table 3: GIS-DSS Applications in Natural Farming

Application Area	GIS Functions	Benefits
Soil Health Mapping	Spatial analysis of soil properties, nutrient mapping, and pH distribution	Optimized organic input application, improved soil fertility
Crop Suitability Analysis	Multi-criteria evaluation, climate-soil overlay	Better crop selection, increased yields
Water Resource Management	Groundwater mapping, watershed delineation	Efficient irrigation, water conservation
Pest and Disease Surveillance	Spatial distribution tracking, early warning systems	Timely biological control reduces crop losses
Market Linkage	Market location mapping, logistics optimization	Better market access, fair pricing
Certification Support	Digital record keeping, traceability mapping	Simplified certification, transparency

Source: Compiled from MDPI Sustainability Journal, 2022; NAARM Research, 2024

7. PROSPECTUS AND FUTURE DIRECTIONS

7.1 Enhanced Digital Infrastructure Development

The 2817 crore allocation granted to the Digital Agriculture Mission offers unprecedented prospects for the development of a globalized GIS-DSS infrastructure. Some of the priority areas are to provide rural communities with broadband connectivity, such as BharatNet, bring about agriculture-driven data centers with cloud computing, roll out IoT sensor networks to monitor the real-time environment, and have integrated platforms that can unite farmers, researchers, and policymakers.

The AgriStack project will be an attempt at establishing a single digital infrastructure for Indian agriculture that combines land records, crop data, farmer data, and intelligence on the market. GIS is the cornerstone of the AgriStack, and it gives the agricultural data a spatial layer. This integration will facilitate a smooth flow of information among different government programs, research organizations, and farming societies, and this will greatly improve the success of the natural farming promotion programs.

7.2 Integration of Artificial Intelligence and Machine Learning

The AIGM technologies have transformative potential when applied to natural farming with the GIS-DSS. The AI algorithms can process large volumes of spatial and time data to detect patterns, make a prediction, and offer personalized advice. Some examples are automated detection of crop diseases based on satellite photography and computer vision, models of yield prediction based on weather, soil, and management practices, resource allocation and crop planning optimization algorithms, natural language interfaces to queries and advice to farmers, and natural language processing.

The feedback provided by the real performance of farming processes can keep on tuning the machine learning models that can generate more accurate decision support systems. It can be proposed that the combination of AI and traditional ecological knowledge integrated into natural farming techniques can result in new solutions that can be both scientifically accurate and based on indigenous wisdom.

7.3 Public-Private Partnerships and Innovation Ecosystems

Government agencies, private technology firms, research facilities, and farmer groups can work together in order to hasten the adoption of GIS-DSS. Effective models of partnerships involve technology firms that offer platforms and infrastructure, research institutes that offer experience and validation, Producer Organizations of Farmers that support the provision of adoptions and feedback, and government agencies that offer support of policies and financial resources.

Indian digital agriculture has come to consider agriculture technology startups as a significant player in the ecosystem. Among the companies, such as CropIn, AgroStar, and Ninjacart, GIS and data analytics are used to deliver services such as crop tracking, market connections, and more. By combining these innovations of the private sector with government programs, it is possible to develop holistic ecosystems to aid the transition to natural farming.

7.4 Capacity Building and Digital Literacy Programs

GIS-DSS can be used to its full capacity in natural farming through systematic capacity-building efforts. Top priority activities will involve the implementation of special training programs, extension workers, and agricultural officials, interfaces in vernacular languages, and voice-based interfaces to the use of GIS programs, demonstration farms, displaying integrated technology-natural farming systems, and the use of the Krishi Sakhis network as a means of technology support at the grassroots level.

The Krishi Sakhis project that trains women on agricultural activities provides a good avenue for digital literacy interventions. Such trained women can emerge as technology ambassadors within their communities and help in introducing GIS-DSS into their community, as well as enhancing natural farming practices. The project intends to train Krishi Sakhis to become Para-extension Workers, and the estimated earnings per year are over 50,000 rupees, making economic incentives for the extension of technologies in agriculture.

7.5 Advanced Remote Sensing and Precision Agriculture

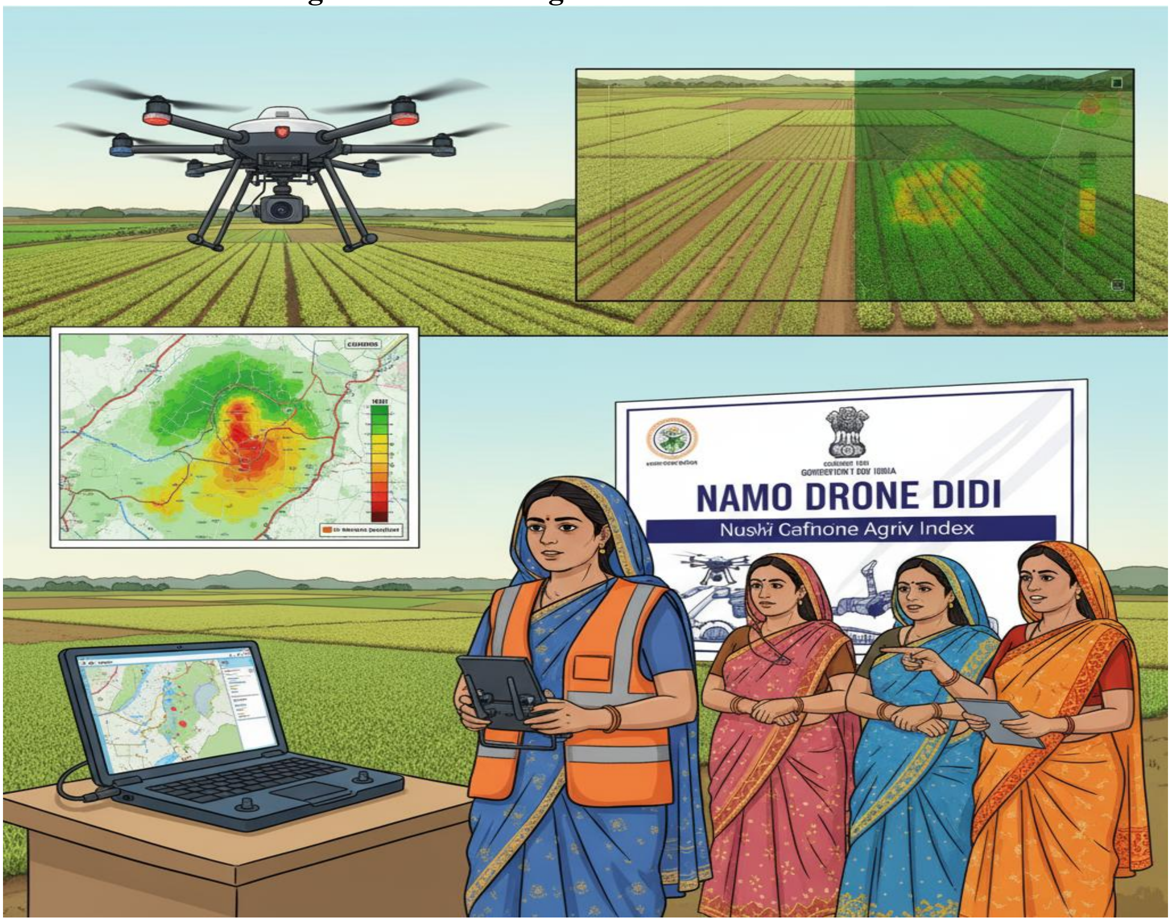

Figure 9: The Namo Drone Didi program of precision agriculture by drone technology, depicting the adoption of agricultural technologies by women.

New remote sensing technologies are also going to increase the capabilities of the GIS-DSS. The high-resolution satellite networks, such as those launched by ISRO, give consistent, high-resolution images of the agricultural lands. The scheme of farm-level ultra-high-resolution monitoring is facilitated by drone technology, which is encouraged, such as Namo Drone Didi (which aims to equip 15,000 women SHGs with 500 crore), to direct the allocation of funds towards the use of drone technology. These technologies facilitate precision natural farming, which detects the spatial variation in the fields, application of organic inputs, early pest or disease stress, and crop health during growing seasons.

The Digital General Crop Estimation Survey (DGCES), which will be rolled out nationwide between 2024-25, will have the benefits of giving the proper estimates of the yield on time using satellite data and ground verification. This information system will assist farmers to make proper decisions on natural farming transition since realistic expectations of yield and market conditions will be provided.

7.6 Climate Resilience and Adaptation Strategies

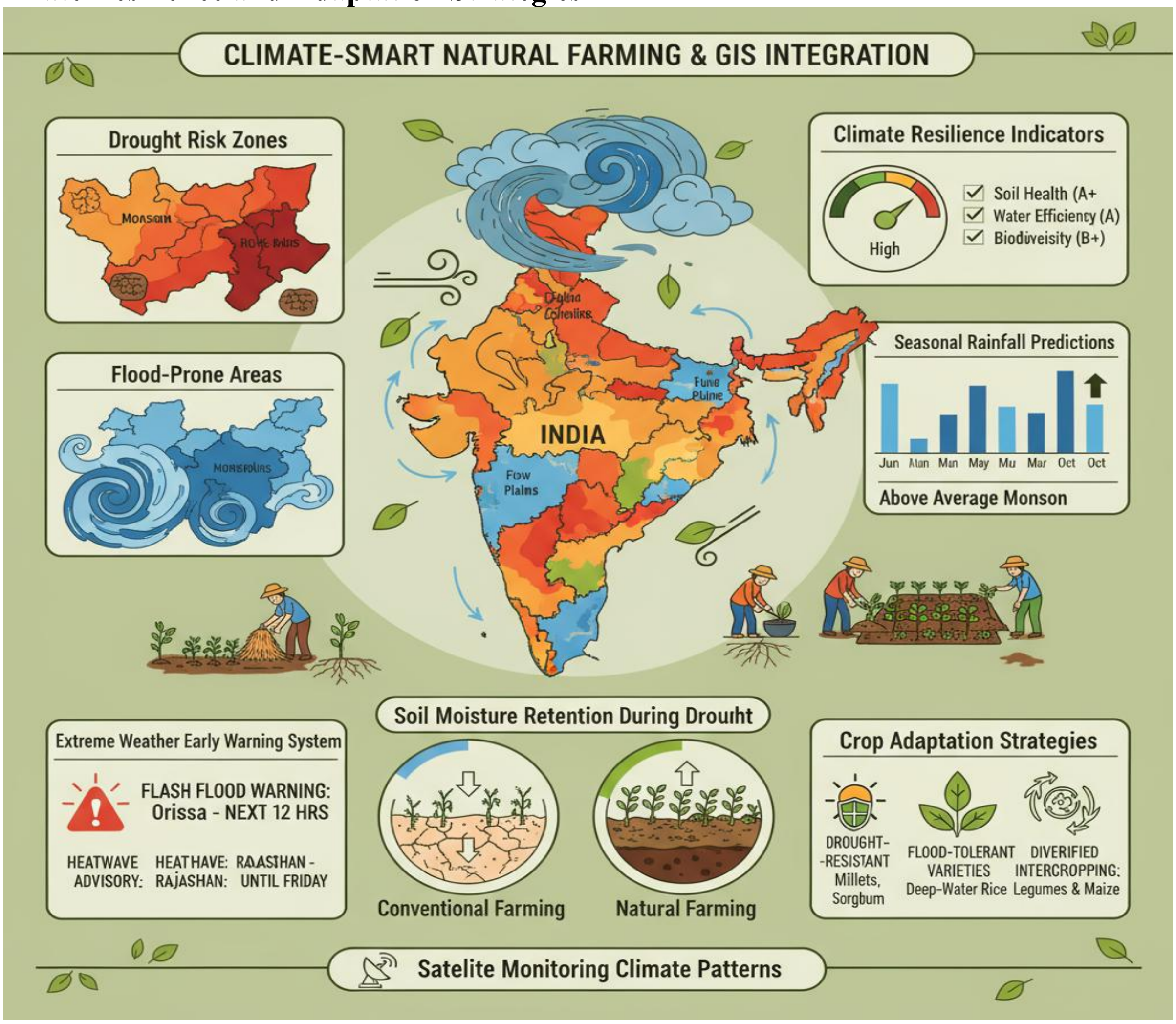

Figure 10: GIS synthetic infrastructure with climate measurements in the development of resilience in natural farming.

Climate information services that are provided on GIS platforms are essential instruments of resilience construction in natural agricultural systems. Climate models combined with agricultural GIS systems can support long-term planning with respect to crop choice and adaptation planning, forecasting seasonally to assist in operations planning, early warning of extreme weather events to protect crops and infrastructure, and risk of drought and flood assessment to aid mitigation planning.

Natural farming techniques, such as enriching organic soil matter, mulching, and diversified structures of crops, develop soil resiliency to climate extremes. With the help of GIS-DSS, vulnerable areas to climate change can be identified, with suitable natural farming intervention being advised, and climate-smart agricultural landscapes can be produced.

Table 4: Government Initiatives Supporting GIS-enabled Natural Farming

Initiative	Budget/Scope	GIS Component	Impact

Digital Agriculture Mission	₹2,817 crore (2024)	AgriStack, Krishi DSS, Soil Profile Maps	142 million hectares of coverage
Krishi Mapper Portal	Part of Digital Agriculture Mission	Real-time crop monitoring, soil mapping	Nationwide implementation
PKVY & BPKP	Ongoing scheme	Cluster identification, monitoring	Natural farming promotion
Namo Drone Didi	₹500 crore (2024-25)	Drone-based precision agriculture	15,000 women SHGs
e-NAM Platform	Ongoing digital marketplace	Market location mapping, logistics	1.7 crore farmers connected
Soil Health Card	Digital soil health management	GIS-based nutrient mapping	Digital soil profiles

Source: Ministry of Agriculture and Farmers Welfare, Government of India, 2024

8. CONCLUSION

GIS-enabled Decision Support Systems would be an effective means of marketing and expanding natural farming activities in the heterogeneous Indian farms. Spatial technology can be combined with traditional ecological knowledge to generate synergies, which are applicable in solving contemporary challenges in sustainable agriculture. The growing trend of organic farming in India, which presently occupies an area of 7.3 million hectares and a production of 3.6 million MT per year, shows that the trend of chemical-free farming is gaining momentum. GIS-DSS solutions, such as the Krishi Mapper portal, which is based on the Digital Agriculture Mission, ₹ 2,817 crore of support, can offer the necessary infrastructure in this change.

The implemented systems in Sikkim, Madhya Pradesh, Maharashtra, and Karnataka are successful examples that show that natural farming on a large scale can be realized using technology. Such case studies demonstrate that the key success factors are good institutional support, sufficient financial resources, thorough training programs, the proper utilization of spatial technologies in planning and monitoring, and the unity with the market systems. Nevertheless, there are still major challenges, especially the digital divide that concerns rural communities, low digital literacy rates in the farming community, insufficient rural infrastructure, and high start-up costs in the adoption of technology and transition to natural farming.

GIS-DSS is a promising prospect in natural farming due to some positive developments. The large-scale investment in digital infrastructure and rise in smartphone access to the rural population (425 million users), the rise of agricultural technology startups and innovation systems, the adoption of advanced technologies such as AI and machine learning and the use of drone technology, and greater attention to sustainable agriculture by policy-makers all point to an enabling environment. The presence of public-private collaboration, capacity development, such as Krishi Sakhis and climate resiliency needs, adds to the relevance of GIS-based natural farming systems.

Going forward, priority activities ought to encompass making rural spaces more connected to the broadband and the digital world, designing interfaces in vernacular languages and voice-based GIS, developing comprehensive farmer and training programs on both natural and digital farming, improving the quality of data, standardization, cross-site compatibility, contributing to the research on bridging GIS-DSS with traditional ecological knowledge, a developing supportive policy infrastructure and institutional coordination systems, and ensuring equitable access to the technology across socioeconomic lines and geographical locations.

The integration of GIS technology with natural agricultural practices is a way to fulfill several sustainable development objectives: the assurance of food security and the preservation of environmental resources, the improvement of farmer livelihoods due to lower input costs and higher prices, the development of climate resilience in agricultural infrastructures, and the availability of traditional knowledge as digital data and information delivery. The only thing it needs is a long-term dedication on the part of the government, research institutions, the business sector, and the farming communities to overcome the current obstacles and leverage the transformative potential of GIS-enabled decision support of natural farming.

The agricultural transformation process in India proves that technology and tradition are not opposites to each other. GIS-DSS is the analytical rigor and precision demanded by modern agriculture, whereas natural farming practice offers sustainability and resilience of centuries of indigenous wisdom. When these methods are combined through proper policies and investments, it will be possible to have a more sustainable system of agriculture that can meet the needs of the growing population of India and, at the same time, protect the natural resources of the country as well as those of future generations.

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