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Geospatial Approaches to Assessing Soil Degradation and Crop Productivity

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Abstract: *Soil degradation poses a major threat to agricultural productivity and global food security. Geospatial technologies, including remote sensing, Geographic Information Systems (GIS), geostatistical modeling, and Unmanned Aerial Vehicles (UAVs), provide powerful tools to monitor, assess, and manage soil and crop dynamics at multiple spatial and temporal scales. This paper reviews the role of geospatial approaches in evaluating soil degradation specifically soil erosion, salinization, and nutrient loss and their impacts on crop productivity. Techniques such as the Revised Universal Soil Loss Equation (RUSLE), digital soil mapping (DSM), and vegetation indices (NDVI and EVI) enable precise assessment of soil quality, crop health, and yield prediction. Furthermore, integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning with geospatial data enhances precision agriculture by enabling real-time monitoring, resource optimization, and evidence-based decision-making. While these technologies hold strong potential for promoting sustainable agriculture, challenges such as high initial costs, large data management, and technical expertise requirements remain. Future directions emphasize the integration of multi-source geospatial data with AI-driven analytics to develop sustainable land management strategies, improve soil health, and optimize crop productivity under changing climatic conditions. This review highlights that geospatial technologies are indispensable for achieving sustainable agricultural practices and ensuring long-term food security.*

1. Introduction

Geospatial approaches are necessary for assessing soil degradation and crop productivity. They can improve assessments by spatializing data in a useful and effective way. Advanced technology such as remote sensing, GIS, and geostatistical models offers numerous advantages for agriculture and land management (Niel & Mcvicar, 2004). Geospatial technologies play an important role in mapping soil degradation and crop productivity over a wide area. One of the applications of remote sensing techniques is being able to identify the type of crop, measure the area under various crops and assess the yield variation at the regional level It is important for analyzing the effect of soil degradation, such as erosion, on agricultural productivity (Pierce & Lal, 2017)

An important aspect of geospatial technology is the evaluation of soil erosion and its impacts on crop agitations. The model is based on the Revised Universal Soil Loss Equation (RUSLE), in combination with land use and vegetation will assist in identifying erosion hot spots and the severity of land degradation. Integrated initiatives of this kind will generate the requisite data for evidence-based policy making and land management practices (Workie & Teku, 2025; Jan et al., 2025). People use geospatial information to manage their resources efficiently. It helps them put things like water, fertilizer and pesticides in the right place. This is important because it saves resources and reduces environmental degradation, especially in water using systems such as irrigated rice (Niel & Mcvicar, 2004). Furthermore, farmers may utilize geospatial mapping of soil properties to make improved decisions about crop options and nutrient management, leading to greater crop productivity and sustainability (Hadeed et al., 2024).

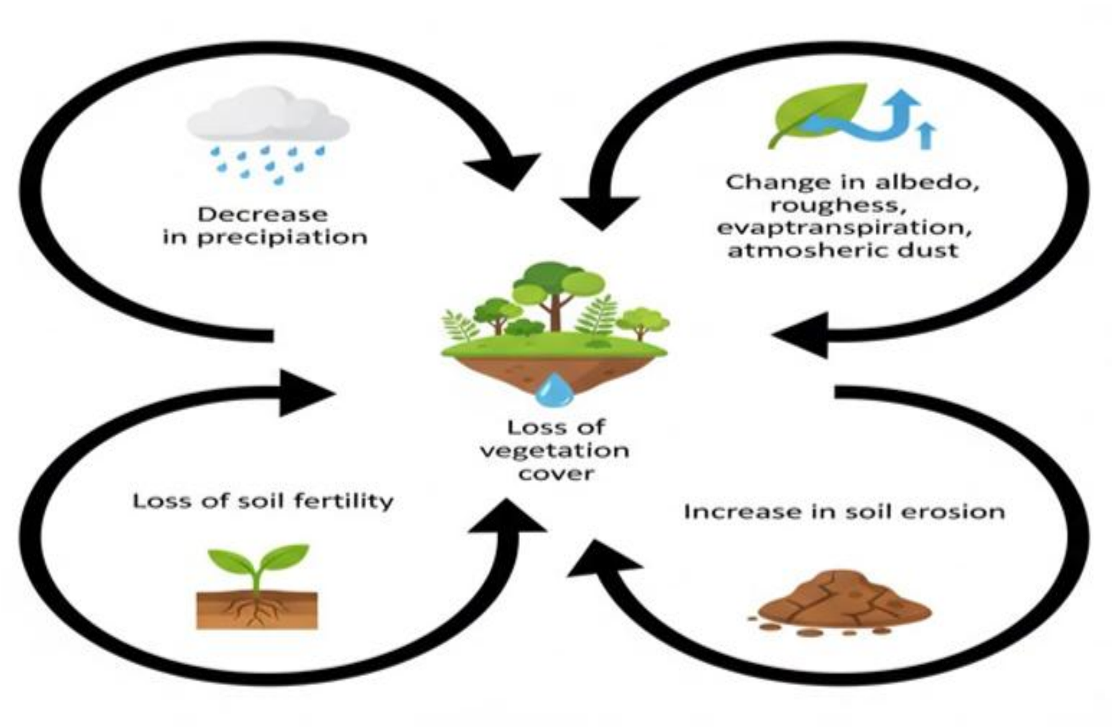
Geospatial technologies help assess soil quality, which is important for sustainable agriculture and soil conservation. Geospatial approaches combine multivariate analysis and geostatistical approaches to enhance precision agriculture and spatial assessment of soil properties. Soil degradation, crop productivity, and zoning are some of the inputs in geospatial approach these have the potential to promote sustainable agriculture. A mixture of remote sensing, IoT, and AI is installation of geospatial tools to yield results on soil health monitoring and they play a significant role in increasing crop yield. These technologies are used to visualize agricultural ecosystems in detail. This is important for precision agriculture (Sanad et al., 2024).

The advancement of Unmanned Aerial Vehicles (UAVs) and IoT sensors along with geospatial analysis will enable better monitoring and management of farm practices. By helping to identify the variability of the field, it ensures efficiency of input use. According to the IoT-Assisted Smart Agriculture Framework or IoT-SFF Projections, these systems significantly enhance the accuracy ratios and crop yield while minimizing the production cost (Zhao et al., 2023). Integrating multiscale geospatial analysis can allow for comprehensive monitoring crop’s growth, soil condition and hydrological dynamics. Through the use of remote sensing data in conjunction with digital soil mapping, crop health, soil nutrients and water quality can be better understood. This approach supports sustainable agricultural management through research that provides spatial and temporal details (Akanbi et al 2024)

Geospatial technology can help enhance agriculture across the world to improve food security. It uses satellites and drones to remotely sense soils and crops, allowing efficient mapping of the condition of soils and crops for better yield and sustainable farming practices. Sustainable development goals are further ensured with the help of technologies that conserve biodiversity and manage land better. By applying the IoT and AI to soil health monitoring systems like the WESIS of Western Greece, optimization through data analysis in real time takes place. Such systems manage soil interventions in a data-driven manner, which enhances the efficiency and productivity of soil resources, as a result of which crop yields increase (Kalantzopoulos et al., 2024; Jan et al., 2025). Using these technologies is an effective way to ensure sustainable crop production. Geospatial tools facilitate accuracy monitoring of essential crop parameters, allowing better yields with efficient utilization of resources to meet growing global food demand while promoting sustainability in agriculture (Sonal et al., 2024).

2. Soil Degradation

Soil degradation is a major environmental problem impacting agricultural productivity, ecosystems, and biodiversity. Soil erosion, salinization, nutrient loss are three main types of soil degradation. Each type has its characteristics and impact. The interconnected processes of



soil degradation often reinforce each other, creating a feedback loop that accelerates land deterioration, as illustrated in Fig. 2.1.

Figure.2.1: Interconnected processes of Soil Degradation

2.1 Soil Erosion.

Soil erosion happens when the top layer of soil is washed away by water, wind or ice. If soil erosion continues it worsens and leads to serious consequences. Erosion takes away soil nutrients and the organic matter plants need to grow properly. Soil erosion is one of the main causes of land degradation around the world. Various studies show how bad soil erosion can get. In Thailand, in the Pa Deng sub-district, soil erosion risk has been taking place due to changes in land use. In addition, land cover changes caused great importance for the understanding of the soil erosion intensities in the Maritsa Basin of Europe. The deterioration of land due to erosion can contribute to water quality problems. The management of these problems is often required (Issaka & Ashraf, 2017).

2.2 Salinization.

Soil salinity is the build-up of the water-soluble salts in the soil, where the concentration gets to such levels that it has a negative impact on the agricultural production of the land. Salinization usually occurs on dry regions with irrigation. When water from irrigation evaporates, the salt starts getting deposited. Salinization damages the soil's structure and makes the soil less permeable and more toxic to plants. Management of salinization can be done using proper irrigation, suitable salt-tolerant crops, along with soil amendments that can help reduce salinity problem (Akanbi et al 2024).

2.3 Nutrient Loss.

Soil nutrient loss is when nutrients like nitrogen, phosphorus and potassium are lost from the soil. When too much cropping takes place with too little replenishment, and soil erosion and leaching happen, a depletion occurs. This is often the case in intensive farming areas. The soil is being more and more depleted. As a result of this, use of higher dosages of fertilizers is getting necessary. This will lead to other forms of environmental damage due to run-offs, water pollution, etc. Nutrient loss can be minimized by working with nature’s processes through crop rotation and cover cropping as also using organic fertilizers (Alebachew et al., 2025; Jan et al., 2025).

To prevent this soil degradation, integrated land management practices should be adopted that take care of soil health and agricultural productivity. Technological advancements like remote sensing and Geographic Information System (GIS) have become important tools in monitoring and managing soil degradation as reported in studies published in diverse regions (Barbosa et al., 2024; Maurya et al., 2024). The Revised Universal Soil Loss Equation (RUSLE) techniques have been effective in modelling soil erosion; however, the significance and impacts of soil degradation on the environment remain an ongoing issue (Haseeb et al., 2023). The productivity of crops is adversely affected by soil degradation. Soil organic carbon (soc) degradation is one of the important effects that contribute significantly to soil health. Studies with long durations show that yield drops when SOC is reduced due to continuous cropping, which may still have 2% and above SOC (Rubio et al., 2021). Moreover, the degradation of land in Horqin Sandy Land is causing an alteration of soil organic matter (SOM) and microbial properties, resulting in a significant drop in maize yield. Microbial properties, especially fungi, have been identified as important yield components whose contribution exceeds that of SOM composition (Gao et al., 2024).

In Central Myanmar, soil erosion has caused land degradation. Crop yields of important crops like rice and sesame are multiplied several times lower in highly degraded locations than low degraded areas. The reduction in yield is worsened by the higher costs of cultivation and less cultivable land. Soil erosion also affects soil quality and productivity in Sub-Saharan Africa, reducing crop yields. We can address these challenges using several management practices like a sawah ecotechnology that focuses on the production of lowland rice (Obalum et al., 2012). Besides, accelerated soil erosion is a global issue, especially in the tropics and subtropics. It leads to losing the topsoil which is fertile, thus affecting productivity and quality of environment. Soil degradation will not be resolved by technological advances or additional inputs but merely masked by them (Lal, 2001). A change in international policies and expert action is required to tackle climate change issues effectively, and it would help if the farming community would respond positively, according to Jayaraman and Dalal (2022).

Soil degradation refers to the decline in soil quality due to unfit practices, contamination of soil quality, pollution and many factors. Soil erosion caused by water and wind is a key factor affecting soil quality which ultimately hurts agriculture. Soil erosion by water is a problem in many places. For example, in the highlands of Ethiopia and Nepal, just to name a few, rainfall runoff combined with poor agricultural practices (Chalise et al., 2019). As a result, in Ethiopia, this process contributes to high agricultural economic losses in addition to soil nutrient depletion, which threatens food security and causes economic hardship (Bekele, 2019).

Deforestation also greatly contributes to soil erosion. In some regions, deforestation is driven by the need for agriculture and fuelwood. It tends to increase soil erosion and flood risks. An example is the Pacific Islands and some parts of China (De La Paix et al., 2011). In the areas where land is being cleared for agriculture, inappropriate agricultural practices are resulting in a deterioration of soil physical properties and nutrient loss. This threatens food security and the areas (Wairiu, 2016). Our farming practices are making soil degradation even worse. Examples of such practices include perennial tillage, growing only one crop, inappropriate use of water, fertilizers and herbicides. Soil health is reduced with such practices increase soil salinity, organic matter loss and compaction (Karlen & Rice, 2015). Overgrazing, urbanization, mining and construction are other manmade activities that damage soil structure and decrease its potential for supporting vegetation as well as agricultural activities (Karlen & Rice, 2015). Climate change like increase in rainfall intensity and occurrence of droughts together contribute to land degradation (Chalise et al., 2019). This happens through escalation of erosion and reduction of vegetation cover (Megerssa and Bekere 2019). These types of soil degradation occur more frequently in dry and semi-dry areas (Gong et al., 2022; Jan et al., 2025). That said, soil degradation can be improved using improved land management processes. This includes advanced agricultural practices, afforestation, reforestation as well as policies to protect environment impact which can take into account human and environment soil protection parameters (Wang, 2004).

Table 1: Soil Degradation Types and Their Impacts

Degradation Type	Description	Causes	Impacts on Crop Productivity	Management Strategies	Ref.

Soil Erosion	Loss of topsoil due to water, wind, or ice	Deforestation, poor agricultural practices, heavy rainfall	Reduces soil nutrients and organic matter, lowering crop yields (e.g., rice and sesame in Myanmar)	Use of RUSLE, conservation tillage, afforestation	Tun et al., 2015;
Salinization	Accumulation of water-soluble salts in soil	Irrigation in dry regions, evaporation	Decreases soil permeability, toxic to plants	Proper irrigation, salt-tolerant crops, soil amendments	Issaka & Ashraf, 2017
Nutrient Loss	Depletion of essential nutrients (e.g., nitrogen, phosphorus)	Intensive farming, erosion, leaching	Increases fertilizer dependency, causes environmental damage via runoff	Crop rotation, cover cropping, organic fertilizers	Workie & Teku, 2025

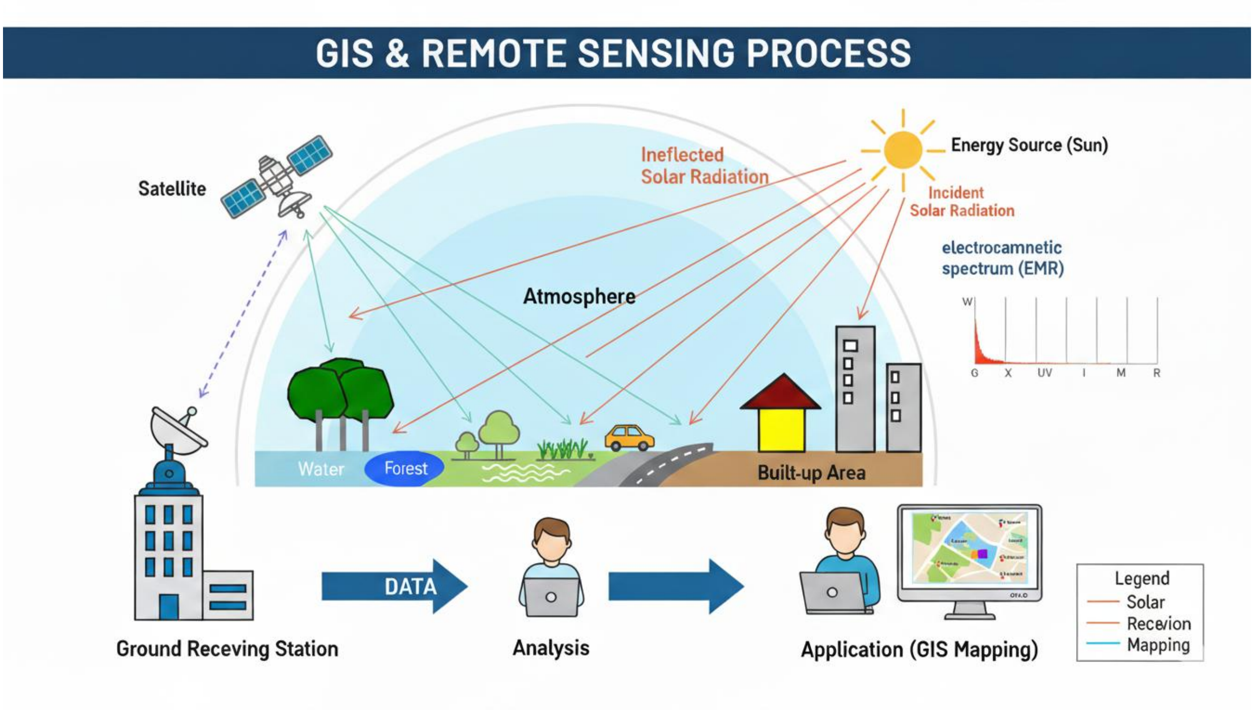
3. Geospatial Approaches

Remote sensing and GIS, UAVs together offer a considerable potential for assessment of soil degradation. Each has its own specific capability for monitoring soils but combined will allow accomplish a lot more. The figure 4.1. illustrates how remote sensing, UAV, and ancillary geospatial data are integrated within GIS platforms to assess soil erosion risk. By applying models such as RUSLE, erosion hotspots can be identified and used to guide conservation planning, targeted management, and monitoring strategies. Linking this workflow to the discussion of soil erosion highlights how geospatial approaches provide a systematic framework for addressing land degradation and supporting sustainable land-use management.

4.1 Remote Sensing and Geographic Information System (GIS)

Remote sensing is important for monitoring soil degradation through collected data that can access soil erosion risk, vegetation cover, land use and more. The Revised Universal Soil Loss Equation (RUSLE) in conjunction with remote sensing data generates a prediction of annual soil loss. This method uses satellite imagery to quickly achieve land use categories for determining soil erosion probability zones (Li et al., 2023). In addition, GIS-enabled RUSLE is a model for analyzing and mapping the potential hazards for soil erosion, which could help in formulating soil conservation strategies (Abdelsamie et al., 2022). As an example, in District Chakwal of Pakistan, such integrated methodologies have been adopted to successful identification and classification of the areas based on level of erosion that could be useful in conservation planning (Li et al., 2023).

Figure 4.1 GIS and Remote sensing process



4.2 UAVs in Soil Degradation Monitoring.

UAVs or Unmanned Aerial Vehicles can be used for monitoring and tracking of the environment with greater detail than the usual way. Drones are especially beneficial as they can fly at low altitudes to collect high-resolution images flexibly and in a rapid manner (Huang et al., 2017). UAVs are highly accurate in calculating soil features, such as sinkholes and gully heads, for soil degradation. A comparison with satellite data, such as Sentinel-2 or SPOT-6, shows a strong correlation. Thus, UAVs are useful for detailed topographic analysis for soil loss (Kariminejad et al., 2023).

Digital soil mapping develops soil spatial information systems using models to anticipate the spatial and temporal variation of soil classes and soil properties. This technique uses the observation of soil, knowledge, and associated environmental variables, which allows the elaboration of soil maps (Auzzas et al., 2024). The DSM, after all these years of research, has advanced in critical areas, such as the production of soil covariates, soil data sampling, numerical model development and evaluation, and representation of digital soil maps (Lagacherie, 2008).

Soil observations can also be integrated with other spectroscopically inferred data using Vís-NIR and MIR (mid-infrared) spectroscopy via DSM. By employing this method, the maps can more accurately capture soil spatial variation without incurring high costs for fieldwork expenses or laboratory analysis (Chen et al., 2023; Jan et al., 2025). Moreover, DSM practices establish relationships of variables through the use of other auxiliary ones such as topographic wetness indexes, geomorphological maps, elevation, and satellite imagery (Taghizadeh-Mehrjardi et al., 2014). The figure 4.1. illustrates how remote sensing, UAV, and ancillary geospatial data are integrated within GIS platforms to assess soil erosion risk. By applying models such as RUSLE, erosion hotspots can be identified and used to guide conservation planning, targeted management, and monitoring strategies. Linking this workflow to the discussion of soil erosion highlights how geospatial approaches provide a systematic framework for addressing land degradation and supporting sustainable land-use management.

4.3 Crop Productivity Assessment

NDVI is used because it is simple and effective and uses the difference in reflectance of the near-infrared (which vegetation reflects strongly) and red (which vegetation absorbs) bands. Higher NDVI values usually indicate good health of the crops and vegetation. Alternatively, a drop in NDVI values suggests that factors like drought or disease may have stressed the crops. (Samsuddin Sah et al., 2023) EVI was created to overcome some disadvantages of NDVI. One of them is the effect of the atmosphere on the NDVI values. Soil background noise is another disadvantage which is dealt with in EVI. Additionally, it has more features making it much more sensitive in high biomass regions. EVI has a correction factor for the consideration of such influences ensuring stability across a wider range of conditions. According to Wardlow and Egbert, 2010, EVI is useful for monitoring crops with high leaf area index and for heterogeneous background terrain (Erdanaev et al., 2022). NDVI and EVI are used to derive dynamic metrics for crop growth. For example, these indices assist in developing time-series models to capture the growth status of crops at different stages for yield modeling. Using NDVI and EVI growth metrics to calculate maximum value, integrated value over the growing season, or value at the critical growth stage has been successful in yield prediction and growth monitoring. A maximum predictive accuracy was achieved in soybean crop study according to (Shammi & Meng, 2020). They are incorporated into machine learning models for targeted agricultural interventions. Some examples of this would be cropland mapping, crop type detection and yield spatial variability. By integrating NDVI and EVI with other remote sensing data, the effectiveness of these models has increased, subsequently enhancing proper agricultural management at different spatial and temporal scales (Wijayanto et al., 2020). Table 1 provides a comparative overview of different geospatial technologies, including remote sensing, GIS, geostatistical modeling, and UAVs, in relation to their applications for soil degradation monitoring and crop productivity assessment.

Technology	Application	Key Features	Case Study	Ref.
Remote Sensing	Monitors soil erosion, vegetation cover, and land-use changes	Uses satellite imagery to predict annual soil loss via RUSLE	RUSLE model applied in District Chakwal, Pakistan, to identify erosion-prone areas	Li et al., 2023
GIS	Integrates multi-source data for spatial analysis of soil erosion	Enables mapping of erosion hazards and conservation planning	GIS-enabled RUSLE for soil erosion risk assessment in arid zones	Abdelsamie et al., 2022
UAVs	High-resolution imaging for detailed soil degradation monitoring	Captures topographic features like sinkholes and gully heads	UAVs used for soil loss estimation on the Loess Plateau, showing strong correlation with Sentinel-2 data	Kariminejad et al., 2023
Digital Soil Mapping (DSM)	Predicts soil properties using environmental	Combines soil observations with Vis-NIR and MIR	DSM with Random Forest Regression to	Auzzas et al., 2024;

variables and machine learning	spectroscopy for cost-effective mapping	predict soil nitrogen content	Chen et al., 2023

Table 2: Comparative overview of geospatial approaches for soil degradation and crop monitoring.

4. GIS Mapping with Remote Sensing

The employing geospatial techniques (like remote sensing and GIS), various soil property maps can be generated to aid in effective crop management. Sensors and satellites observe soil condition and variability in the growth and yield of crops. For example, mapping soil attributes and vegetation health using remote sensing data to ensure efficient application of inputs, such as fertilizer, water, and pesticide, are cited by Hadeed et al (2023) and Niel & Mcvicar (2004). The figure 5.1. demonstrates how different spatial data sources, such as street networks, buildings, and vegetation are integrated into GIS-based layers for comprehensive analysis. In the context of agriculture, such integration is critical for generating soil and crop maps, monitoring vegetation health, and supporting precision farming practices. By overlaying these datasets, GIS and remote sensing enable data-driven decision-making, efficient resource utilization, and sustainable land management strategies, as discussed in this section.

5.1 Precision Agriculture

Using geospatial tools, precision agriculture methods can improve to make better use of resources and enhance the crop yield. UAVs and geospatial analysis help with accurate weed control, fertilization, and field management in the crop growing process. The use of UAVs also helps in reducing the costs of production while improving the quality of the crop (Zhao et al., 2023).

5.2 Data Driven Decision Making

IoT and AI, along with geospatial data, can facilitate monitoring and adaptive management of soil health through real time data (Kalantzopoulos et al., 2024). The identification of field variability and optimization of farming practices will enhance soils and crops (; Shafi et al., 2023).

5.3 Yield Prediction and Optimization

The accuracy of forecasting crop yield can be greatly enhanced through geospatial data and machine learning. Knowing this accurate estimation of yield becomes essential in ensuring the resource utilization and risk management. The process of data collection at different levels of crop development through various geospatial techniques can forecast yield and help make better agricultural management decisions (Shafi et al., 2023).

5. Integration and Applications

When soil data and crop information are combined, it enhances agricultural decision making such as precision farming, efficient resource utilization, crop yield improvement, etc. Geographic Information Systems are key to making this connection happen (Pandey & Pandey, 2023). By using GIS technology, the spatial information about the soil fertility, crop health, topography, etc., can be collected, stored, analyzed and visualized (Raihan, 2024). Thus, providing assistance in precision farming. GIS yields of fertilizer application reveal the crop yield benefits of overlaying different data layers to determine the relationship and patterns that influence fertilization, irrigation, and land management decisions (Raihan, 2024). By simulating and modelling any biological ecosystem, the integration can enhance sustainable soil management. This will help improve agricultural productivity and environmental conservation (Toromade & Chiekezie, 2024).

Geospatial approaches, including GIS and remote sensing, have various sustainable land management applications (Baja et al. 2002). Technologies offer better spatial analysis and real-time data which enhance efficiency, productivity and sustainability of agricultural practices (Nyeko, 2012). The precision agriculture assisted by GIS promotes variable rate application of fertilizers and pesticides, which enhances their use while minimizing the impact on the environment (Toromade & Chiekezie, 2024). What’s more, the GIS technologies help evidence-based decision making in sustainable agriculture by assessing crop yield, monitoring crop health, and managing agricultural inputs (Arulbalaji, 2019;). They can also be used to identify areas prone to stripping and for optimum allocation of land use for afforestation and agricultural expansion (Roba et al. 2025).

GIS and remote sensing can quantify land degradation, monitor land-use change and analyze the effect of land management practices on ecosystem services (Nath, 2023). Combining these technologies with field surveys and analytical methods could develop strategies for sustainable land management, such as soil and water conservation, and ecological maintaining land use for agriculture (Workie & Teku, 2025).

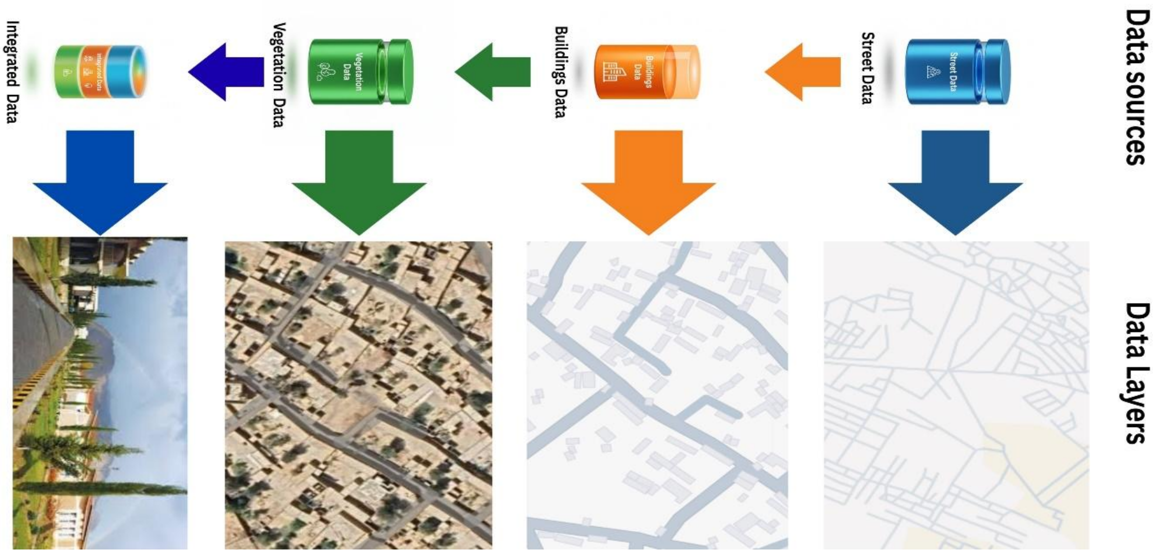


Fig. 5.1: Integration of Multi Source Geospatial Data Layers for Agricultural Decision Making

6. Challenges & Future Directions

Using geospatial tools with soil and crops has several limitations, even though these are helpful in precision agriculture. These digital means do not fit very well in the operations of precision agriculture (Ashique et al., 2024). An example of this problem is that traditional digital soil mapping frameworks are mostly grid-based. However, precision agriculture relies on operational units (Dong et al., 2018). Using this kind of technology will also require handling large, complex data, which may complicate management, ownership, and privacy issues (Gupta & Kumar Pal, 2025).

The initial cost of adopting AI and advanced geospatial technologies can be prohibitive, as it involves investing in infrastructure and acquiring the technical know-how (Ritambara et al., 2024). Also, reliable results need high-quality data and interpretable models. However, it is tough to maintain this consistency because agricultural environments are variable. Also, the data involved is massive (Roy et al., 2025).

Technologies like AI and precision ag can help solve some of these problems in farming. Machine learning and deep learning driven artificial intelligence provides improved modeling and data processing abilities (Rane et al., 2024). As a result, more accurate predictions and effective solutions can be developed to some complex agricultural problems such as pest and disease detection, precise irrigation and optimizing the use of resources (Roy et al., 2025). The improved mapping of soil nutrients using high-resolution remote sensing images and artificial intelligence technologies can significantly contribute to the efficient and precision agriculture (Dong et al., 2018).

AI models can monitor data and make decisions in real-time which helps farmers respond quickly to changing conditions and optimize input use, such as water and fertilizers as well as pesticides, according to the requirements of each crop or field (Ritambara et al., 2024). With the integration of precision agriculture with IoT, AI, and the ability to monitor various parameters, informed decisions can be made, and resources can be used optimally (K S et al. 2024).

7. Conclusion

Soil degradation remains one of the most pressing challenges for global agriculture, directly threatening crop productivity, food security, and environmental stability. Geospatial technologies particularly remote sensing, GIS, UAVs, and digital soil mapping—offer powerful solutions for monitoring, assessing, and managing soil degradation and its impacts on crop yields. These tools not only enable the detection of soil erosion, salinization, and nutrient loss but also provide valuable insights into vegetation health, soil fertility, and yield potential. By offering spatial and temporal data at multiple scales, geospatial approaches support evidence-based decisions that can improve agricultural sustainability. Remote sensing and GIS have proven highly effective for mapping land-use changes, estimating soil erosion through models such as RUSLE, and detecting nutrient deficiencies. UAVs complement satellite data by providing high-resolution imagery for localized degradation features, such as gully erosion and sinkholes. Digital soil mapping enhances predictive understanding of soil properties and variability, reducing reliance on costly and time-consuming fieldwork. Together, these technologies provide a comprehensive framework for monitoring soil health and crop productivity under diverse agro-ecological conditions. The integration of vegetation indices such as NDVI and EVI with geospatial analysis has advanced crop productivity assessment, enabling continuous monitoring of growth stages, stress conditions, and yield prediction. When combined with machine learning and AI-driven models, these tools provide highly accurate forecasts and resource optimization strategies. Moreover, IoT-based smart sensors enhance real-time field data collection, which, when linked with geospatial analytics, allows farmers to respond quickly to dynamic environmental conditions. Despite these advancements, challenges remain in the widespread adoption of geospatial technologies. High costs, technical expertise requirements, and the complexity of managing large datasets limit their application, especially in resource-constrained regions. Additionally, conventional frameworks such as grid-based DSM may not fully align with the operational needs of precision agriculture. Overcoming these barriers will require investments in capacity building, affordable technology access, and the development of user-friendly platforms to make geospatial tools more accessible to farmers and policymakers. Future directions point toward greater integration of multi-source data, AI, and IoT to enhance predictive capabilities and decision-making. Real-time monitoring systems powered by UAVs and satellite imagery can facilitate early detection of soil degradation, while AI-driven analytics will improve nutrient mapping, pest detection, irrigation management, and resource allocation. Such innovations will be essential for tackling the dual challenges of climate change and global food security. Geospatial approaches, therefore, provide indispensable tools for combating soil degradation and optimizing crop productivity. By bridging spatial science with agricultural management, they enable more precise, efficient, and sustainable practices. While barriers of cost and technical expertise remain, the potential benefits far outweigh these limitations. With continued advancements in AI, IoT, and machine learning, geospatial technologies will play a transformative role in promoting sustainable agriculture, conserving soil resources, and ensuring long-term food security.

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