



Geospatial techniques for crop mapping and monitoring: A remote sensing perspective

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Abstract

This review paper examines the application of remote sensing techniques for crop area estimation and monitoring with special emphasis on rice cultivation. The study compiles research results from multiple national and international studies that used multi-temporal satellite imagery, such as Landsat, MODIS, and IRS datasets, and GIS-based analytical techniques. A wide range of classification techniques, including supervised classification, unsupervised classification (ISODATA), object-based image analysis (OBIA), and spectral index analysis like NDVI and NDSI, have been widely used in crop mapping and land use/land cover change detection. Previous studies have demonstrated that, in addition to attaining high accuracy in crop identification and acreage estimation, satellite-based techniques can offer significant insights into crop phenology, stress conditions, and spatial distribution patterns. The investigation emphasises planning. Additionally, remote sensing methods offer an effective framework for identifying shifts in cropping patterns and evaluating the effects of paddy cultivation on the environment, including greenhouse gas emissions. Overall, the study highlights the significance of geospatial technologies in contemporary agricultural monitoring systems and offers a thorough overview of techniques and applications for estimating crop area, especially in agricultural landscapes like Haryana that are dominated by rice.

Keywords: Remote Sensing, Crop Area Estimation, Rice Cultivation, Satellite Imagery, GIS Techniques, Land Use/Land Cover (LULC)

Introduction

Haryana plays a critical role in India's food security as a major contributor of food-grains to the Central Pool. Basmati rice makes up more than 60% of the state's total export volume, making it a leader in agricultural exports as well. The area under paddy cultivation increased to 15.59 lakh hectares in 2019–20 from 14.47 lakh hectares the year before, according to Haryana's Economic Survey 2020^[17]–21. On the other hand, the area planted to wheat, another staple crop, decreased slightly from 25.53 lakh hectares in 2018–19 to 25.34 lakh hectares in 2019–20. (Government of Haryana, 2021)

The growth of paddy farming is important for both the food supply and the environment, especially with regard to methane emissions. Flooded rice fields are a significant source of atmospheric methane, according to recent scientific research. Fields are submerged during the cultivation process, which stops the soil's oxygen supply. Similar to natural wetlands, this fosters anaerobic fermentation of soil organic matter. Diffusion, ebullition, and transport through the rice plants themselves release methane, the main by-product of this process, into the atmosphere. According to estimates from around the world, rice paddies produce between 20 and 100 trigrams of methane annually, or roughly 6–29 percent of all anthropogenic emissions (Neue, n.d.).

Remote sensing is a great way to collect data over large areas with high revisit frequency on a regional to global scale, and it can greatly help provide a timely and accurate picture of the agriculture sector. Current sensor satellites record data that can be used to evaluate two aspects of crop production: yield and acreage. Additionally, crop phenological information, stress conditions, and distribution can be identified. Among other things, the information

retrieved enables decision makers to obtain an objective and unbiased spatial picture over large area risk management and to better anticipate the effects of events.

Geographic Information Systems (GIS) have become a potent tool for managing and analyzing vast amounts of spatial-temporal data and information, as well as for producing information products like maps and textual and tabular reports for land use decisions. In order to address land-related issues at the regional level, FAO has been creating GIS in connection with its agro-ecological zoning and related models in recent years (Sarkar A, 2008)^[11]. The development of GIS-based tools and packages for land resource planning has advanced significantly in recent years, both on a large (local) and small. GIS technology is very useful for automated logical integration of bio-climate, terrain and soil resource information, which are required for land use planning in a region. Generation of spatial database from point database using geo-statistical techniques is an important part of GIS application which aids in the integrated analysis. The system is capable of containing all data required to solve resource management problems. Topographic maps, land resource map and contour maps having physiographic, geographic and bio-climate information forms primary input of GIS for land use planning. GIS is a vital tool to analyse a multi-layered database. Its capabilities to process various data in spatial domain make the planning process easier. A GIS-based decision support system creates opportunities as an invaluable tool for all aspects of the land use planning process. (Sarkar A, 2008)^[11]

The present study summarizes the remote sensing application in area estimation of paddy and identifies the shifting agriculture of rice crop in the Haryana state.

S.No.	Title of the Paper	Data Used	Methods	Highlights	Author & Year
1	LU/LC Change Analysis in Haridwar Region	Landsat imagery (1996–2017), Ground survey, GPS, Literature	Supervised classification, Ground validation	Significant decline in orchards converted to urban and agricultural land; demonstrates effectiveness of RS in monitoring temporal LU/LC change	Kumar <i>et al.</i> , 2020
2	Monitoring spatio-temporal dynamics of urban and peri-urban landscape using remote sensing and GIS – A case study from Central India	Historical maps (1936), Landsat data (2010)	Object-Based Image Analysis (OBIA), GIS	Major urban expansion and land cover transformation; useful for sustainable urban planning	Kar <i>et al.</i> , 2018 ^[1]
3	Study on rice crop distribution vis-a-vis climatic suitable zones in Haryana using geo-informatics	Landsat & MODIS (Kharif 2015–2016), Ground truth data	Unsupervised ISODATA classification	90% accuracy; 5% annual increase in rice area; cultivation expanded into marginal zones	Kumar <i>et al.</i> , 2018 ^[1]
4	Wheat production forecast using remote sensing and agromet variables in Haryana state	IMD meteorological data, IRS LISS-I, II & III	Supervised classification, Spectral indices analysis	Established relationship between temperature and wheat yield; crop discrimination using RS	Verma <i>et al.</i> , 2003 ^[3]
6	Unsupervised classification techniques for assessing soil properties and crop yield variability using satellite spectral data	Satellite spectral data, Soil & crop data	Spectral clustering, Management zone delineation	Demonstrated reliability of RS for soil property & yield variability mapping	Calvo <i>et al.</i> , 2014 ^[6]
7	Agricultural area diversification planning using remote sensing and GIS techniques with IRS-P6 AWiFS and RADARSAT data	IRS P6-AWiFS, RADARSAT Scan SAR	GIS-based crop rotation mapping	Developed crop diversification plan using RS and agro-physical parameters	Choudhury <i>et al.</i> , 2013 ^[7]
8	Crop-shelter classification using high-resolution multispectral satellite imagery and spectral indices. Remote Sensing Applications in Agriculture	High-resolution multispectral imagery	Per-pixel classification, Spectral indices	Improved classification accuracy compared to RGB imagery	Arcidiacono & Porto, 2012 ^[4]
9	Soil suitability assessment using remote sensing and GIS based on FAO land evaluation criteria	RS data, Field survey, Laboratory analysis	FAO land evaluation, ArcGIS mapping	Prepared soil suitability maps for groundnut, paddy & finger millet	Sathish & Niranjana, 2010 ^[10]
10	Application of remote sensing and GIS for land resource planning and crop coverage identification	Digital satellite imagery	GIS integration, Automated classification	Emphasized GIS for land resource planning & decision-making	Omkar <i>et al.</i> , 2008 ^[9]
11	Application of remote sensing and GIS techniques for sustainable land resource planning and management	Digital imagery, GIS database	Computerized mapping, GIS modeling	Highlighted integration of RS & GIS for sustainable land planning	Somvanshi <i>et al.</i> , 2018 ^[15]
12	Application of remote sensing for mapping salt-affected soils in Kaji Playa Lake region, South-Khorasan, Iran	Landsat ETM+, Soil samples (31 samples)	NDSI, EC analysis, Image classification	Identified salinity zones using reflectance values	Mahdi Saghafi, 2017 ^[8]
13	Mapping and change detection of land use/land cover in Nathusari Chopta block of Sirsa district, Haryana using IRS satellite data and GIS techniques	IRS satellite data (2007–2010)	Visual interpretation, ArcGIS tools	Decrease in agricultural land; increase in wasteland area	Singh <i>et al.</i> , 2015 ^[14]
15	Integrated land and water resource planning for Chevella watershed using remote sensing and GIS techniques	IRS LISS III, IRS PAN imagery	GIS-based hydrogeomorphology mapping	Developed integrated land & water conservation plan	Saxena <i>et al.</i> , 2008 ^[12]
16	Mapping and documentation of wastelands using geomatics techniques in Mysore district, India	SOI toposheets, IRS-1D PAN+LISS III, Google Earth	GIS analysis, Ground Truth Check	Identified degraded land categories for reclamation planning	Basavarajappa <i>et al.</i> , 2015 ^[5]
17	Land use monitoring and resource mapping using remote sensing and supervised classification techniques in Shivpuri region, India	Satellite imagery (1:15,000 scale)	Supervised classification, Accuracy assessment	Improved land resource monitoring through controlled classification	Tomar, 2012 ^[16]

Result and discussion

The reviewed studies collectively demonstrate the extensive application of Remote Sensing (RS) and Geographic Information System (GIS) techniques in land use/land cover (LU/LC) mapping, agricultural monitoring, soil assessment, wasteland identification, and sustainable land resource planning. A prominent characteristic across the literature is the use of multi-temporal satellite datasets such as Landsat, MODIS, IRS (LISS-I, II, III), AWiFS, RADARSAT, and

ETM+, which enable temporal analysis of environmental and agricultural changes. Studies such as Kumar *et al.* (2020) and Kar *et al.* (2018)^[1] highlight the effectiveness of long-term satellite imagery in detecting urban expansion and landscape transformation, while Kumar *et al.* (2018) and Verma *et al.* (2003)^[1, 3] emphasize crop acreage estimation and yield assessment through spectral indices and classification algorithms. The integration of ground truth verification, GPS surveys, soil sampling, and meteorological

datasets strengthens the accuracy and reliability of satellite-based interpretations.

The study shows a shift from traditional visual interpretation methods to sophisticated digital image processing techniques like spectral clustering, NDVI-based vegetation health assessment, Object-Based Image Analysis (OBIA), supervised and unsupervised classification (e.g., ISODATA clustering), and GIS-based spatial modeling. A growing emphasis on suitability analysis and micro-level planning (1:10,000 scale mapping) is demonstrated by the use of FAO land evaluation frameworks (Sathish & Niranjana, 2010)^[10] and Land Resource Inventory (LRI) approaches (S.K. Singh, 2016). The ability of RS to identify dynamic environmental degradation processes is further demonstrated by multi-temporal analysis for monitoring degraded lands and salinity mapping (Mahdi Saghafi, 2017^[8]; Venkataratnam, 1996). Furthermore, database creation, geoportal development, watershed planning, and decision-support systems for sustainable agriculture are supported by the integration of GIS with remote sensing data.

From a thematic perspective, the studies reveal three major research orientations: (1) Urban and peri-urban expansion analysis, (2) Agricultural crop mapping and productivity assessment, and (3) Land degradation and reclamation studies. Urban-focused research underscores the rapid conversion of agricultural and orchard lands into built-up areas, raising concerns regarding sustainable urban development. Agricultural studies highlight the increasing cultivation of crops like rice in marginally suitable zones, which has implications for groundwater depletion and resource sustainability. Land degradation and wasteland mapping studies provide critical baseline data for reclamation, conservation planning, and ecological restoration.

Overall, these characteristics indicate that RS and GIS technologies have evolved into cost-effective, time-efficient, and scientifically robust tools for spatial planning and resource management. However, the review also suggests the need for higher-resolution datasets, integration of machine learning techniques, climate-linked modeling, and socio-economic data incorporation for more comprehensive and policy-relevant research outcomes. For research purposes, this body of literature provides a strong methodological foundation, diverse case studies, and a clear direction toward sustainable land use planning supported by geospatial technologies.

Conclusion

In conclusion, the advancement and integration of remote sensing and GIS technologies provide a strong scientific framework for accurate crop area estimation and continuous monitoring of agricultural systems. Their application not only improves agricultural assessment and resource planning but also contributes to sustainable land management and long-term environmental conservation.

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