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Geospatial Technologies for Crops and Soils

Springer

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Foreword

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The ever-growing world population will lead to enormous pressure on land resources to produce food for 10 billion people in 2050. However, to meet the future challenges of feeding the world population, there is a need for a continuous assessment and prioritized intervention to halt the declining trends in crop productivity, minimizing the rate of land degradation, reducing the environmental damage, and enhancing farm income through a sustainable resource development plan. The adoption of Geospatial Technologies encompassing techniques and tools related to Remote Sensing (RS), Geographic Information System (GIS), Global Positioning System (GPS), advanced data processing, Information Technology (IT)-driven outreach, and web-services might play the much-needed role of a fulcrum to increase future agricultural productivity. Geospatial technologies can pave way for significant improvements in efficiency of input-use, resulting in cost savings on inputs and precious resources. Geospatial tools can be used for soil profiling, satellite imagery, and mapping results to assess nutrient deficiencies in site-specific location and fine tune products (i.e., area-specific fertilizer mixtures for crops), which can help promote judicious and balanced use of fertilizers rather than blanket applications that can lead to several environmental issues .The goal is to develop agricultural resources management options for advancing global food security, adapting and mitigating climate change, and promoting "Sustainable Development Goals" of the United Nations.

Therefore, this book is timely and highly pertinent because it addresses the applications of geospatial technologies for crops and soils. It also provides information about cost-effective measures, easy-to-understand interpretation, and the documentation needed to formulate sustainable action plans to achieve effective resource management at global, national, regional, and farm level. The information collated in this book is based on joint efforts of many scientists, professors, experts, and researchers. It is a reflection of long years of professional experience of the authors in reviewing, analyzing, and synthesizing the vast and dynamic field of expertise and innovations. The authors have focused on many case studies that review a variety of modern tools and techniques for data collection, storage, analysis, update, integration, interpretation, and representation for informed decision making. Specifically, the book highlights availability and use of various spatial, temporal, and spectral data to formulate sustainable resources development plans and associated challenges. The authors have explored and examined numerous advances such as those related to precision farming, crop monitoring, crop production, soil moisture, soil quality, land degradation, digital soil mapping, agricultural land use, etc.

Above all, authors have highlighted the use of proximal sensing, unmanned aerial vehicle (UAV), and various modelling approaches to assessing crops and soils. They have also described the applications of GIS which is considered one of the important tools for decision making in a problem-solving environment dealing with geo-information. They have elucidated that such technologies can monitor the overall prospect of agriculture through its capabilities to provide decision support scenarios. Hence, the book is a major contribution to the field of crop and soil science by highlighting the importance of applied research. Finally, the contributors have prepared the volume encompassing latest developments in the field of geospatial technologies. This book is a pertinent reference material for policymakers, researchers, students, and practitioners in soil science, agronomy, ecology, and management of natural resources with specific focus on some global issues such as food and nutritional security, adaptation and mitigation of climate change, soil quality, biodiversity, and the action plan for advancing the “Sustainable Development Goals” of the United Nations.

Sincerely,

Distinguished University Professor of Soil Science, SENR; Director, Carbon Management and Sequestration Center, The Ohio State University, Columbus, OH, USA

Rattan Lal

May 11, 2020

Preface

Human civilization has started facing an unprecedented situation towards the sustainable use of natural resources for the ever-increasing population. The situation is further complicated by the changes in temperature and rainfall patterns, increasing extreme weather events, altered pest and disease profiles, and rapid degradation of land and soil quality. So there is a need to introduce the latest technologies in agriculture to enhance its production and also help policymakers make informed decisions. Geospatial technologies and tools which includes Remote sensing (RS), Geographical Information System (GIS), Global Positioning System (GPS), mobile and web applications, etc., would provide unique capabilities to analyze multi-scale multi-temporal datasets and generate decision supports to sustainable development, food, nutritional environmental, and economic security. Satellite RS images of an optical, microwave, thermal, and hyperspectral domain could provide a unique instrument allowing a regular and synoptic coverage of crop and soil resources at a continental or regional level. Hence, it proved to be a powerful tool to assess crop and soil properties in varying spatial and temporal scales with cost-effectiveness.

This book is a compilation of the development in the field of geo-spatial technologies towards monitoring and assessment of crops and soils. The focus has been given on the crop monitoring, crop growth and yield simulation modeling, crop yield estimation, crop production estimation, retrieval of crop biophysical and biochemical parameters, precision agriculture, etc. Moreover, soil moisture estimation, land degradation assessment, soil quality assessment, digital soil mapping, hyperspectral, and microwave remote sensing for crops and soils assessment have also been discussed in detail. Further, special emphasis is provided to integrate multi-dimensional, multi-temporal, multi-scale data, and its analytics towards informed decision making. The objective of this book is to document the applications of space-based technologies for crops and soil assessment for sustainable development of agriculture.

In general, this book is suitable for agronomists, soil scientists, environmentalists, researchers, policymakers, and students who wish to simultaneously enhance the production and profitability of land resources. Moreover, the editors have provided a road map to achieve sustainable crops and soil management using geo-spatial technologies. All chapters are well-illustrated with case studies, figures, appropriately placed data tables and photographs, and supported with extensive and most recent references.

Hyderabad, Telangana, India — Tarik Mitran
Varanasi, Uttar Pradesh, India — Ram Swaroop Meena
Hyderabad, Telangana, India — Abhishek Chakraborty

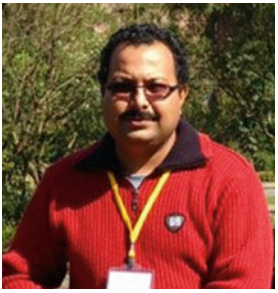
Contents

About the Editors

Tarik Mitran is a Soil Scientist working in Soil and Land Resources Assessment Division, National Remote Sensing Centre, Indian Space Research Organisation (ISRO), Hyderabad, India. He completed his Ph.D. in Agricultural Chemistry and Soil Science in 2012 at Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India, with Prestigious "Maulana Azad National Fellowship" funded by University Grant Commission, India. In 2017, he completed his postdoctoral research on "Soil Carbon Modeling Using Geospatial Techniques" under Prof. Rattan Lal, World Food Prize 2020 Laureate, Distinguished Scientist and Director of Carbon Management and Sequestration Centre (CMASC), The Ohio State University (OSU), USA. Dr. Mitran has published 25 articles in reputed peer-reviewed journals, 8 book chapters, 15 conference papers as well as number of technical bulletins, popular articles, and scientific reports. He has been awarded prestigious "INDO-US Post-doctoral Fellowship" in 2016 by Science and Engineering Research Board (SERB) and Indo-U.S. Science and Technology Forum (IUSSTF), Department of Science and Technology (DST), India. Dr. Mitran has also received "Certificate of Recognition" from Office of International Affairs, OSU, USA; "Junior Scientist of the Year 2017" by IFEE and Confederation of Indian Universities (CIU), New Delhi; "Clean Environment Education and Promotion Award" by International Benevolent Research Foundation (IBRF), Kolkata; and Best Poster Presentation Award twice by Indian Society of Soil Science, New Delhi. He has qualified National

Eligibility Test (NET) in Soil Science twice, conducted by Indian Council of Agricultural Research (ICAR). Dr. Mitran has also received University Merit Scholarship, Junior/Senior Research Fellowship during his studies. He is actively involved as a Principle Investigator/ Co-Principle Investigator in various National, Operational, as well as technology development projects at National Remote Sensing Centre, ISRO, India. His current areas of research is soil carbon assessment, soil CO_2 efflux assessment and its role in climate change, soil fertility and spatial mapping, predictive soil mapping, hyperspectral remote sensing of soils, land degradation assessment using remote sensing, soil erosion modelling, land use and land cover assessment using remote sensing, etc. Dr. Mitran is also acting as a reviewer for various peer-reviewed international journals and is member of scientific societies.

Ram Swaroop Meena is working as an Assistant Professor in the Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi (UP). Dr. Meena has secured first division in all the classes with triple NET, Junior Research Fellowship (JRF), and Senior Research Fellowship (SRF) from the Indian Council of Agricultural Research (ICAR) and RGNF Award from the University Grants Commission (UGC), Government of India. Dr. Meena has been awarded Raman Research Fellowship by the Ministry of Human Resource Development (MHRD), GOI. He has completed his postdoctoral research on soil carbon sequestration under Prof. Rattan Lal, World Food Prize 2020 Laureate, Distinguished Scientist and Director of Carbon Management and Sequestration Centre (CMASC), The Ohio State University, USA. Dr. Meena is working on soil sustainability, crop productivity, and resources use efficiency under the current climatic era. Dr. Meena has supervised 20 postgraduate and 5 Ph.D. students, and he has 10 years of research and teaching experience at the undergraduate/postgraduate/Ph.D. level. He is working on the three externally funded running projects from DST, MHRD, and ICAR (GOI) and involved in many academic and administrative activities going on at the institute/university level. Dr. Meena has published more than 110 research and review papers in peer-reviewed reputed journals up to 7.2 impact factor with H-index 38. He has published 4 books at the national level and another 12 books at the international level and contributed to 15 book chapters at national and 35 at international levels. Dr. Meena has worked as an expert in the National Council of Educational Research and Training (NCERT), MHRD, GOI, to develop the two books for school education at XI and XII standards. Dr. Meena has been awarded several awards, namely, Young Scientist, Young Faculty, Global Research, Excellence in Research, Honorable Faculty Award, etc. Dr. Meena is a member of 9 reputed national and international societies and is working as a general secretary, editor, and member of the editorial board in 12 national and international peer-reviewed reputed journals and has attended several national and international conferences in the country and abroad. Dr. Meena is contributing to the agricultural extension activities on farmers' level as associate coordinator in trainings, meetings, workshops, and farmers' fair.



Abhishek Chakraborty is working as a Senior Scientist at the National Remote Sensing Centre (NRSC), Indian Space Research Organisation, Hyderabad, India. He has completed his B.Sc. (Hon) in Agriculture at Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India, and obtained his M.Sc. and Ph.D. degrees from the Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi. Dr. Chakraborty has more than 15 years' experience in the applications of geospatial technologies in agriculture. He has been working under several projects of national importance funded by DST, ISRO, Central/State Ministries, etc. He is responsible for establishing a network of eddy covariance flux towers over different agro-ecosystems to study the dynamics of carbon/moisture fluxes. Dr. Chakraborty has developed a geo-portal (BHUVAN -JAIVOORJA) to assess spatial distribution of biomass potential from crop residues over India to facilitate site suitability of biofuel/biomass power plants. He played a significant role in National Agricultural Drought Monitoring and Assessment System of India and developed two new indices for detection of early season drought.

Dr. Chakraborty has also assessed long-term changes/shift in the weather patterns vis-a-vis crop phenology using time series satellite and weather data. He is recipient of ISSS gold medal for best doctoral thesis and four best paper awards in conferences. Dr. Chakraborty has co-guided two M. Tech. students and presently guiding a Ph.D. student. He has published more than 30 research papers in peer-reviewed reputed journals and conferences and more than 50 scientific reports. Dr. Chakraborty is life member of two national scientific societies. Presently, he is heading Agroecosystem and Modelling Division of NRSC.

Chapter 1
Geospatial Technologies for Crops and Soils: An Overview

Tarik Mitran, Ram Swaroop Meena, and Abhishek Chakraborty

Contents

Abstract Natural resource monitoring and assessment is a vital step to formulate a sustainable development plan. The introduction of various modern geospatial techniques and tools like Remote Sensing (RS), Geographic Information System (GIS), Global Positioning System (GPS), and information technology (IT) have provided

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powerful approaches of surveying, identifying, classifying, mapping, monitoring, and characterization of the composition, extent, and distribution of various natural resources. Geospatial techniques deal with the acquirement, storage, processing, production, presentation, and dissemination of geoinformation. The information obtained from RS, GPS, and through conventional methods could be used effectively to create database in GIS platform for various spatial and temporal analysis related to sustainable management of land resource and formulate environment-friendly action plans. Major applications of geospatial technologies related to crops and soils are crop inventory and monitoring, crop production estimates and forecasting, crop growth simulation modeling, crop yield estimation, precision agriculture, soil mapping, land degradation assessment, soil erosion assessment, soil quality assessment, digital soil mapping, digital terrain modeling, soil-landscape modeling, land use/land cover mapping, agricultural land use planning, etc., which have a far-reaching impact on mapping, monitoring, and management of crop and land resources on sustainable basis. Geospatial approaches have made inroads across different sectors both in private and public domain in various countries across the world. Selected tools can help to restore the soil health, stop exploitation of the natural resources, reduce energy consumption, carbon and water footprints, and improve the productivity and sustainability under changing climate. Geospatial technologies for crops and soils a novel tool for the food, nutritional, environmental, and economic security for the future generations under limited natural resources. This book will be helpful for the producers, researchers, teachers, and policymakers to deal with the future alarming issues.

Keywords Agriculture · Geospatial · Geographic Information System · Information Technology · Remote Sensing

Abbreviations

AI	Artificial Intelligence
ALOS	Advance Land Observing Satellite
APEX	Airborne PRISM Experiment
AVIRIS	Airborne Visible Infrared Imaging Spectrometer
CA	Conservation Agriculture
CNSA	China National Space Administration
CSA	Climate-Smart Agriculture
DESIS	DLR Earth Sensing Imaging Spectrometer
DGPS	Differential Global Positioning System
EM	Electromagnetic
ENVISAT	Environmental Satellite
ESA	European Space Agency
EWT	Equivalent Water Thickness

FAO	Food and Agricultural Organization
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GHGs	Greenhouse Gasses
GIS	Geographical Information System
GPS	Global Positioning System
HSI	Hyperspectral Imager
ISRO	Indian Space Research Organization
IT	Information Technology
JAXA	Japan Aerospace Exploration Agency
LAI	Leaf Area Index
LANDSAT	Land Satellite
MODIS	Moderate-resolution Imaging Spectrometer
MRS	Microwave Remote Sensing
NASA	National Aeronautics and Space Administration
NAVSTAR	Navigation System with Time and Ranging
NDRI	Normalized Difference Red Edge Index
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
PA	Precision Agriculture
PALSAR	Phased Array Type L-band Synthetic Aperture Radar
PF	Precision Farming
RDVI	Renormalized Difference Vegetation Index
RISAT	Radar Imaging Satellite
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SAVI	Soil Adjusted Vegetation Index
SIF	Sun Induced Fluorescence
SPAD	Soil Plant Analysis Development
SPOT	Système Pour l'Observation de la Terre
SWIR	Shortwave Infrared Region
TIR	Thermal Infrared
TM	Thematic Mapper
TRS	Thermal Remote Sensing
UAV	Unmanned Aerial Vehicles
UN	United Nation
USGS	United States Geological Survey
VRT	Variable Rate Technology

1.1 Introduction

For about 2.5 million years, human species fed themselves by hunting animals and gathering plants. Human ecological footprint was minimal. Nearly about 10,000 years ago, human started controlling and manipulating few animals and plants species for their benefit. This leads to development of agrarian society with concept of advance food security. It translated into population explosion and more tilling for the extra food. Since then humans have been facing this cyclic phenomenon and surprisingly surviving it. But in the present scenario, horizontal expansion of agricultural activities is limited. Hence, our sole effort has been directed toward vertical expansion under limited resources.

The latest United Nations (UN) projections reveal that the world population will rise from 6.8 billion to 9.1 billion in 2050, which leads to an increase in demand for agricultural produces by 60% (Alexandratos and Bruinsma 2012). Other constraints like fragmented land holdings, land degradation, deterioration of soil health, the declining trend of the total crop productivity, as well as global climatic variations have posed serious threats in agricultural growth and development. However, to meet up with the future challenges to feed the 9 billion people of the world, there is a need to halt the declining trend of the total crop productivity, minimizing the rate of degradation of natural resources, and enhancing farm incomes through sustainable resources development plan. The adoption of newly emerged technology and tools like remote sensing (RS), geographic information System (GIS), global positioning system (GPS) and information technology (IT) might play a major role to enhance agricultural productivity in the future (Hakkim et al. 2016) through continuous monitoring and assessment of the natural resources. The gamut of all these technologies and tools, termed as geospatial technology, is a rapidly growing and changing field that assists the user in the collection, storage, analysis, interpretation, and dissemination of spatial data. It is a cost-effective approach which includes acquisition of real-time satellite images through RS, data analysis and management through GIS, location services and geo-referencing through GPS, and web services and outreach through IT. The advances in RS generate data for detailed inventory, mapping, and monitoring of crop, land, and water resources on a large scale (Gerhards et al. 2019). Satellite RS coupled with GIS and mobile app–based positional information has emerged as an efficient tool for the sustainable development in agriculture sector by optimizing input resources, minimizing the cost of production, and risk of biotic/abiotic in nature. Such technologies have the capabilities to provide "Decision Support Scenarios" which could be vital for monitoring the overall health of the agricultural sector and facilitate informed decision-making. Some of the major applications of geospatial technologies related to agriculture are crop inventory and monitoring (Schmedtmann and Campagnolo 2015; Ghazaryan et al. 2018; Heupel et al. 2018), crop growth simulation modeling, crop yield estimation (Huang et al. 2019; Ban et al. 2019; Phung et al. 2020), PA (Friedl 2018; Neupane and Guo 2019), soil mapping (Manchanda et al. 2002; Mulder et al. 2011), assessment of soil erosion (Woldemariam et al. 2018; Meena et al. 2018;

Zabihi et al. 2019); assessment of soil quality (Paz-Kagan et al. 2014, 2015), digital soil mapping (Ma et al. 2019; Wadoux et al. 2019), water management for irrigated agriculture (Taghvaeian et al. 2018; Tazekrit et al. 2018; Ojo and Ilunga 2018), agricultural land use planning (Ambika et al. 2016; Useya et al. 2019; Pareeth et al. 2019), etc. The medium and coarse resolution RS datasets can provide a regular and synoptic coverage of crop and soil resources at a continental or regional level. Whereas the fine-resolution satellite data helps in micro-level or farm-level agricultural activities such as water resources mapping, drainage pattern, management of fertilizers, pesticides, variable rate technology, crop insurance, crop damage assessment, etc. RS data of optical, microwave, thermal, and hyperspectral domain has proved to be a powerful tool to assess crop and soil properties in varying spatial and temporal scales. Several researchers (Mulla 2013; Pareeth et al. 2019; Rotairo et al. 2019; Phung et al. 2020) have shown the usefulness of RS technology to get spatially and temporally variable information for agriculture. A large number of satellite RS data are available nowadays to the researcher for natural resources management such as Moderate-Resolution Imaging Spectrometer (MODIS), Land Satellite (Landsat), Sentinel, Resourcesat-2, Cartosat-1, Cartosat-2, Planet, and QuickBird, etc. The number of satellite missions by various space agencies like National Aeronautics and Space Adminstration (NASA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), China National Space Administration (CNSA), Indian Space Research Organization (ISRO), etc., dedicated to RS, has increased space resources sgnificantly over the past decades and will further increase over the coming decades and beyond. Nowadays several countries from the Asia-Pacific, South Asia, North America, and Europe are creating an Agricultural Market Information System which utilizes geospatial tools to fuse basic socioeconomic and crop statistics for the overall management of agriculture produce and demand–supply chain. In nutshell, geospatial technology has become part and parcel of agriculture management system. The technology has proven its potential and effectiveness, and also provides scope of future development.

1.2 Current Challenges in Agriculture: Global Perspective

Agriculture, in generic sense, is harvesting of sunlight toward conversion of carbon dioxide and water into carbohydrate/sugar. This basic translation is modulated by prevailing weather, pests and diseases, soil, and plant resources. Often agriculture is livelihood, not a profitable business, particularly in the third world countries. Hence, agriculture is done sub-optimally with limited resources in majority of the global arable land. This caters the biggest challenges as well as the opportunities of agriculture.

Feeding 9 billion of human population by 2050 is the target set by FAO (Alexandratos and Bruinsma 2012). It requires increase of agricultural produce by 60% from present status. The target is really challenging and further complicated by the changing global climatic pattern (Meena et al. 2018a). The world scientific community has reached to a broad consensus that the concentration of atmospheric greenhouse gases, mainly carbon dioxide, has been increasing unprecedently, and more so in the last few decades. This resulted in significant warming of global climate as evident from rise in global average air and ocean temperature, widespread melting of snow and ice, and rise in global average sea level. Studies across the globe have reported these changes over European region (Hasanean 2001; Domonkos and Tar 2003; Feidas et al. 2004), China (Liu et al. 2004), Japan and Korean peninsula (Chung and Yoon 2000; Yue and Hashino 2003), Malaysia (Tangang et al. 2007), Alaska (Stafford et al. 2000), and India (Revadekar et al. 2012; Chakraborty et al. 2017; Chakraborty et al. 2018). The warming pattern has also caused change in rainfall pattern, increase in extreme weather events, altered pest and disease profiles along with the crop phenology, and rapid degradation of land and soil quality (Cleland et al. 2007; Das et al. 2013; Chakraborty et al. 2014). The phenomena of the changing climatic and ecosystem condition have been found to be global in nature, though they do exhibit considerable spatial and temporal variability at local level.

To meet the demands of higher production, overexploitation of land may lead to land degradation. At present 33% of arable land suffers from various kinds of degradation processes. It is a global threat which leads to reduction in area and productivity of 13.4 billion ha of global cultivable land (Reddy 2003). Agricultural production is deleteriously affected due to inappropriate land care strategies in maximum portions of the world (Lambin and Meyfroidt 2011; Lambin et al. 2013). Sometimes direct impact of land degradation may appear in rapid desertification of semi-arid and arid region, frequent and intense drought occurrence, and loss of productive topsoil and biodiversity (Gibbs et al. 2010; Lambin and Meyfroidt 2011; Meena et al. 2020). Besides land degradation, volatile weather and extreme events would change the growing seasons; limit the availability of water; allow weeds, pests, and disease to thrive; and reduce crop productivity drastically. Apart from all the above-mentioned issues, some of the biggest problems facing the agricultural sector in developing and under-developed countries are low yield, fragmented land holdings, poor infrastructure, low use of appropriate and best farming techniques, a decline in soil fertility etc., which are leading contributors to low agricultural productivity. Hence, countries need to prioritize agriculture and growing food with more sustainable methods.

1.3 Importance of Geospatial Technologies

To meet up with the future challenges to feed the 9 billion people of the world, there is a need to continue investing in appropriate technologies to arrest the declining trend of the total crop productivity, minimizing the rate of degradation of natural resources, reducing environmental damage (including greenhouse gas emission), and enhancing farm incomes through a sustainable resources development plan. Over the few decades, the innovation in digital agricultural technologies such as precision farming (PF), crop monitoring and surveillance system, artificial intelligence (AI) in agricultural decision supports, IT-driven extensions are gaining more importance. The adoption of such newly emerged technology and tools into the entire agriculture value chain might play major role in increasing agricultural productivity in the future (Hakkim et al. 2016; Mitran et al. 2018a). These technologies help in continuous monitoring and assessment of the condition and availability of the agricultural resources and simultaneously transformed agriculture into a sustainable ecosystem. Further, it can also reduce the impact of agriculture on the global environment by optimizing the use of water, fertilizer, fossil fuel, and land for food production. The greenhouse gas emissions contributed by agriculture can also be mitigated through adopting climate-smart practices.

1.4 Geospatial Tools and Techniques

The modern geospatial technologies include RS, GIS, GPS, proximal sensing, mobile technology, etc., which can be used efficiently for agricultural resources management and precision farming. The overall idea and integration of such technologies are presented in Fig. 1.1.

1.4.1 Remote Sensing

RS is the "science of making inferences about material objects from measurements, made at distance, without coming into physical contact with the objects under study" (Lillesand et al. 2015). A RS system consists of a platform (satellite, rocket, balloon, etc.), where a sensor can be mounted to collect and or emit radiation/signal (Sabins 1997). RS can be "active" when a signal is emitted by a satellite and its reflection by the object is detected by the sensor and "passive" when the object is illuminated by sunlight and its reflection/emission is detected by the sensor (Ran et al. 2017a, b). RS imagery along with GIS to process, alter, manipulate, store, and retrieve can very effectively used for natural resource management. RS images can be obtained either from sensor in satellite platform or boarded on small aircraft as aerial photography (Mulla 2013). Aerial photography is the original form of RS and remains the most widely used method until recently. It has few advantages, that is, aerial images are generally of high resolution depending on the flight height (3–5 km). They are relatively immune to the cloudiness, and acquiring time of the image can be scheduled at will. Aerial photographs are different types such as black and white, high- or low-altitude photographs, vertical/oblique, infrared, multi-spectral, etc. The selection of aerial photographs depends on the purpose of the study. These photographs are very useful in small areas for micro-level investigation. Vertical aerial photographs are mostly used in land use planning, cartography, specifically in photogrammetric surveys, to generate topographic maps (Twiss et al. 2001). Oblique

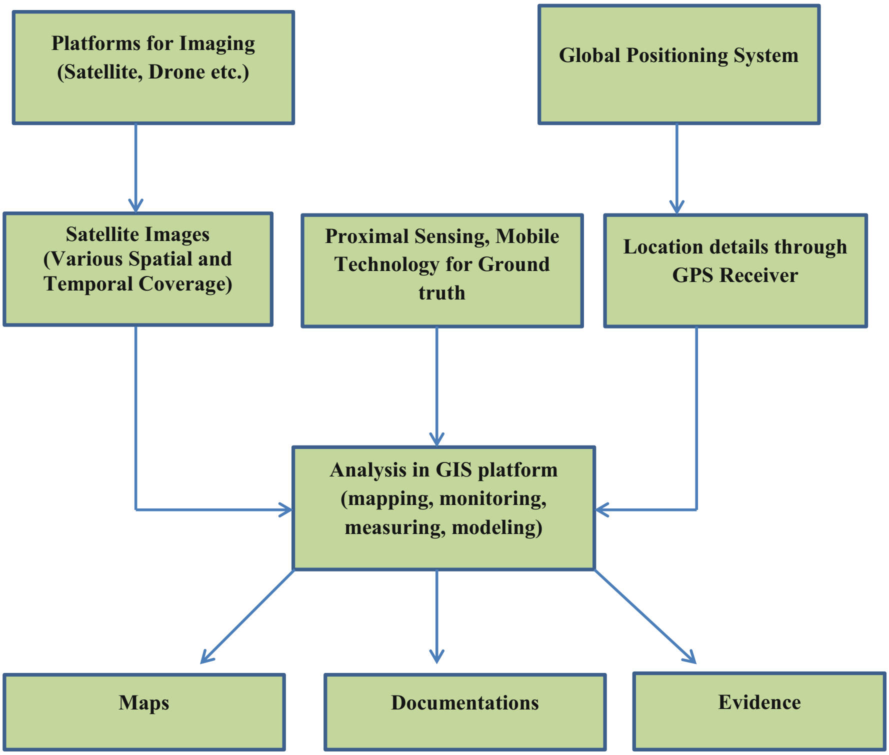

Fig. 1.1 A schematic diagram on geospatial technologies

aerial photography is useful for environmental studies (Stewart et al. 2014). The satellite RS for systematic natural resources management began with the launch of the Earth Resources Technology Satellite (ERTS-1) by the USA in 1972, later renamed as LANDSAT. Remote sensors, such as on-board radiometers or spectro-radiometers allows the observation of large areas of the Earth surface (synoptic capability) at different wavelengths (optical, infrared, thermal, etc.) of the electro-magnetic (EM) radiation (multispectral capability) and at a frequent time interval (multi-temporal capability). Optical RS deals with collecting radiation reflected and emitted from the object under study within the EM spectrum of visible (0.4 μm), near-infrared (NIR) and thermal infrared (TIR, 15 μm). Landsat, Sentinel-2, Resourcesat, Quickbird, and SPOT satellites are the well-known multispectral satellite sensors. Optical RS is one of the suitable technologies for the analysis, surveying, mapping, and monitoring of soils and crops. However, using optical RS datasets for mapping have several limitations. Instrument calibration, atmospheric correction, and cloud screening for data especially during the monsoon period are major limitations for optical RS. However, the introduction of microwave remote sensing (MRS) overcame few issues such as monitoring the Earth's surface, irrespective of day/night and even in cloudy weather conditions which make it more effective and useful (Navalgund et al. 2007). The main advantages of MRS are its ability to penetrate the clouds, rain, vegetation, and even very dry soil surfaces. EM waves having frequencies between 109 and 1012 Hz are generally considered as microwaves. Radar is an active MRS system in which the terrain is illuminated using EM energy and the scattered energy returning from the terrain (known as radar return or backscatter) is detected and recorded as images. Examples of radar RS instruments include Synthetic Aperture Radar (SAR), scatterometers, altimeters, and radar sounders. MRS technology is been widely used for crop monitoring during the rainy season, soil moisture estimation, and land cover analysis. Sentinel-1, Radarsat-1&2, Radar Imaging Satellite (RISAT-1), Environmental Satellite (ENVISAT), Advance Land Observing Satellite–Phased Array type L-band Synthetic Aperture Radar (ALOS-PALSAR) are the well-known satellite sensors that use microwave sensors. Nowadays hyperspectral remote sensing is gaining more importance because of choice for more bands (>200 bands) as compared to multispectral imagery (between 3 and 10 bands). Hyperspectral imaging sensors measures surface reflectance with a given spatial resolution, covering an area instead of a single point (Gerighausen et al. 2012) and providing spectral information at high spatial density (Franceschini et al. 2015). Hyperspectral datasets have a greater potential to detect differences among land and water features. For example, multispectral imagery can be used to map cropped areas, while hyperspectral imagery can be used to map crop type too. The growing demand for large-scale investigations related to natural resources management and environmental issues has required the development of air- and spaceborne imaging spectroscopy. Currently, airborne hyperspectral sensors predominate over spaceborne imaging spectroscopy (Transon et al. 2018). Airborne sensors such as Airborne Visible Infrared Imaging Spectrometer (AVIRIS), DLR Earth Sensing Imaging Spectrometer (DESIS), and Airborne PRISM Experiment (APEX) have excellent potential for imaging spectroscopy (Rast and Painter 2019). Airborne hyperspectral data has been widely used for crops and soil assessment such as discrimination of crop type, retrieval of crop biophysical parameters, determination of soil mineral content, organic matter, nitrogen, salinity status, iron oxide content, and carbonate by using diagnostic absorption features of hyperspectral bands. Upcoming spaceborne sensors with high revisit time (from 3 to 5 days), higher spatial resolution, from several countries, are planned for launch in the coming years.

Besides hyperspectral RS, thermal remote sensing (TRS) is also gaining importance for natural resources and environmental studies. Thermal infrared radiation refers to EM waves with a wavelength of between 3 and 20 μm. Most of the TRS applications make use of 3–5 and 8–14 μm ranges. The major difference between the near infrared and thermal infrared is that NIR is the reflected energy where thermal infrared is emitted energy. The principle of TRS in agriculture is based on the emission of radiation responding to the temperature of the leaf and canopy. However, the emission of radiation varies with air temperature and the rate of evapotranspiration (Maes and Steppe 2012; Gerhards et al. 2019). TRS is widely used for the detection of plant responses to environmental and water stresses (Gago et al. 2015; Ramoelo et al. 2015; Khanal et al. 2017; Huang et al. 2018).

RS technology has a great potential to acquire high spatial, spectral, and temporal resolution data as input for PA (Gerhards et al. 2019). The advances in RS technology generate data for detailed inventory, mapping, and monitoring of crop, land, and water resources on large scale (Gerhards et al. 2019). A RS data user should be aware of various data products and their use in respective domains in order to choose a dataset. A variety of remote sensing satellite datasets with their specifications is distributed through different websites from manufacturers, satellite operators, data providers, and is presented in Table 1.1.

1.4.2 Proximal Sensing

Besides remote sensing, proximal sensing is also getting attention in agriculture especially in precession farming. To overcome the constraints of satellite-based remote sensing, modern world is emphasizing on the use of proximal sensing techniques in PA to assess the growth and stress of crops. In proximal sensing, the platforms are mostly handheld, tractor based, stationary installation, and robotics managed, etc., and the sensors are in close contact to the object. The types of sensors used in this case can be simple RGB or gray-level imaging, multispectral, hyperspectral imaging, or IR-thermography (Rossel and Behrens 2010; Mulla 2013). Apart from reflectance, transmittance, and absorption, plant leaves can also emit energy by fluorescence (Apostol et al. 2003) or thermal emission (Cohen et al. 2005). Sensors have significant uses in the field of agriculture, especially in the field of plant monitoring. The information collected through the proximal and remote sensors is always tied to efficient data analysis approaches such as advance machine learning, data mining, spectral soil, and vegetation indices–based algorithms, identification of specific wavelength and feature, etc. The proximal RS is able to provide information on both biotic and abiotic stresses such as nutrient deficiency, pests, and diseases, etc. A number of proximal sensors such as Soil Plant Analysis Development (SPAD) meter (Schepers et al. 1992), green seeker (Raun et al. 2002), crop spec (Reusch et al. 2010), H-sensor artificial intelligence (Partel et al. 2019), etc. have been developed for crop assessment. Besides crop sensors, proximal soil sensors are also getting more attention in precision farming. Proximal soil sensors allow inexpensive and rapid collection of quantitative, precise, high-resolution data, which can be used to better understand soil temporal and spatial variability. Rossel et al. (2011) provided description of proximal soil sensing techniques used and the soil properties that can be measured by these technologies. The characterization of the temporal and spatial variation of soil at field and landscape level using point-based observation is time-consuming, expensive, and impractical. The remotely sensed satellite images, as well as aerial photos, can provide excellent spatial coverage; however, the measurement is, indirect, involves large uncertainties and typically limited to the surface to surface soil (5–6 cm), hence not appropriate to measure spatial and temporal variability at farm level. Such limitations make the proximal soils sensing increasingly popular by filling the data gap between the lower

Table 1.1 The list of major satellite data available for agricultural and land resources assessment

Satellite data	Spatial resolution	Temporal resolution (days)	Spectral coverage	Date range of acquisition	Provider/ developer	Uses	Source
Landsat 7 ETM+	15, 30, 60 m	16	Band 1: 450–515 nm (30 m), Band 2: 525–605 nm (30 m), Band 3: 630–690 nm (30 m), Band 4: 750–900 nm (30 m), Band 5: 1550–1750 nm (30 m), Band 6: 1040–1250 nm (60 m), Band 7: 2090–2350 nm (30 m), Band 8: 520–900 nm (15 m)	Since April 15, 1999	NASA/USGS	Vegetation types, crop classification, crop stress, crop water use, crop residue, land surface phenology, biomass content, water resources assessment, land use and land cover, land degradation, soil map, etc.	https://www.usgs.gov/land-resources/nli/landsat
ASTER	15–90 m	4–16	Band 1: 520–600 nm (15 m), Band 2: 630–690 nm (15 m), Band 3: 760–860 nm (15 m), Band 4: 760–860 nm (15 m), Band 5: 1600–1700 nm (30 m), Band 6: 2145–2185 nm (30 m), Band 7: 2185–2225 nm (30 m), Band 8: 2235–2285 nm (30 m),	Since December 18, 1999	NASA, USA Government of Japan	Vegetation, ecosystem dynamics, crop stress, change detection, Earth science, land cover analysis, etc.	https://asterweb.jpl.nasa.gov/eos.asp

(continued)

Table 1.1 (continued)

Satellite data	Spatial resolution	Temporal resolution (days)	Spectral coverage	Date range of acquisition	Provider/ developer	Uses	Source
			Band 9: 2295–2365 nm (30 m), Band 10: 2360–2430 nm (30 m), Band 11: 8125–8475 nm (90 m), Band 12: 8475–8825 nm (90 m), Band 13: 8925–9275 nm (90 m), Band 14: 10250–10,950 nm (90 m), Band 15: 10950–11,650 nm (90 m)				
ASTER GDEM Version 3	30 m		Created by compiling VNIR images	Version 3: August 2019	METI, Govt. of JAPAN and NASA, USA	Elevation, slope, terrain analysis, topographic analysis, watershed management, land suitability, soil erosion, cartographic applications	https://asterweb.jpl.nasa.gov/eos.asp
MODIS	250 m (B1-B2) 500 m (B3-B7) 1000 m (B8-B36)	1–2	Band 1: 620–670 nm, Band 2: 841–876 nm Band 3: 459–479 nm; Band 4: 545–565 nm, Band 5:	Terra: December 18, 1999 Aqua: May 4, 2002	NASA	Land boundaries and properties, vegetation types, agricultural crop monitoring,	https://modis.gsfc.nasa.gov/

			1230–1250 nm, Band 6: 1628–1652 nm, Band 7: 2105–2155 nm, Band 8: 405–420 nm, Band 9: 438–448 nm, Band 10: 483–493 nm, Band 11: 526–536 nm, Band 12: 546–556 nm, Band 13: 662–672 nm, Band 14: 673–683 nm, B15: 743–753 nm, Band 16: 862–877 nm, Band 17: 890–920 nm, Band 18: 931–941 nm, Band 19: 915–965 nm, Band 20: 3660–3840 nm, Band 21: 3929–3989 nm, Band 22: 3.929–3.989 nm, Band 23: 4020–4080 nm, Band 24: 4433–4498 nm, Band 25: 4482–4549 nm, Band 26: 1360–1390 nm, Band 27: 6535–6895 nm, Band 28: 7175–7475 nm, Band 29: 8400–8700 nm, Band 30: 9580–9880 nm, Band			drought assessment, regional crop stress, vegetation phenology, crop residues, land use and land cover, long-term changes, primary productivity, ecosystem fluxes, Crop biophysical parameter, evapotranspiration, forest fire, global climate change, atmospheric correction, aerosol, ice and snow study, snow melt run-off, etc.	

(continued)

Table 1.1 (continued)

Satellite data	Spatial resolution	Temporal resolution (days)	Spectral coverage	Date range of acquisition	Provider/ developer	Uses	Source
			31: 10780–11,280 nm, Band 32: 11770–12,270 nm, Band 33: 13185–13,485 nm, Band 34: 13485–13,785 nm, Band 35: 13785–14,085 nm, Band 36: 14085–14,385 nm				
Landsat 8 OLI (B1-B9) TIRS (B10-B11)	15, 30, 60, 100 m	16	Band 1: 433–453 nm (30 m), Band 2: 450–515 nm (30 m), Band 3: 525–600 nm (30 m), Band 4: 630–680 nm (30 m), Band 5: 845–885 nm (30 m), Band 6: 1560–1660 nm (60 m), Band 7: 2100–2300 nm (30 m), Band 8: 500–680 nm (15 m), Band 9: 1360–1390 nm (30 m), Band 10: 1060–1120 nm (100 m) (IR), Band 11:	Since February 11, 2013	NASA/USGS	Vegetation types, crop classification, crop stress, crop water use, crop residue, land surface phenology, vegetation biomass content, water resources assessment, land use and land cover, land degradation, soil map, etc.	https://www.usgs.gov/land-resources/nli/landsat

			1150–1250 nm (100 m) (IR)				
ResourceSat	AWiFS: 56 m	AWiFS: 2–3; LISS-III: 12–13; LISS-IV:25–26	AWiFS: 56 m (ResourceSat 1, ResourceSat 2, 2A)	ResourceSat-1 October 17, 2003, ResourceSat-2 April 20, 2011, ResourceSat- 2A December 7, 2016,	ISRO	Crop monitoring, crop classification, drought monitoring, horticulture, water resource assessment, land use land cover, soil map, wasteland mapping, land degradation, etc.	https://www.isro.gov.in
	LISS-III:23.5 m		Band 2: 520–590 nm				
	LISS-IV:5.8 m		Band 3: 620–680 nm				
			Band 4: 770–860 nm				
			Band 5: 1,550–1700 nm				
			LISS-III:23.5 m (ResourceSat 1, ResourceSat 2, 2A)				
			Band 2: 520–590 nm				
			Band 3: 620–680 nm				
			Band 4: 770–860 nm				
			Band 5: 1,550–1700 nm				
			LISS-IV:5.8 m 1 (mono), 3 (MX) (ResourceSat 2, 2A)				
			Band 2: 520–590 nm				
			Band 3: 620–680 nm				
			Band 4: 770–860 nm				
Sentinel 2	10, 20 or 60 m	5	Band 1: 421–457 nm (60 m), Band 2: 439–535 nm (10 m), Band 3: 537–582 nm	Sentinel 2A: 2015.	ESA	Vegetation types, crop classification, crop stress, crop water use, crop	https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2
				Sentinel 2B in 2017.			

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