High resolution remote sensing, GPS and GIS in soil resource mapping and characterization- A Review

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ABSTRACT

Timely and reliable information on soils with respect to their nature, extent, spatial distribution is very crucial for optimal utilization of available natural resources on a sustained basis. The technological advances in the field of remote sensing, Global Positioning System (GPS) and Geographic Information System (GIS) have augmented the efficiency of soil survey. The management of resources on sustainable basis emphasis the overall development of the region without diminishing the environment. The integrated use of advanced computer technologies with database can be used to assist decision makers for future plans. Yet, so far most of the studies have been performed on a small scale and only few on regional or larger map scale. Although progress has been made from earlier, current methods and techniques still bear potential to further explore the full range of spectral, spatial and temporal of high resolution satellites in soil resource mapping and characterization. Precisely, the present article, aims to review the status on the applications of high resolution remote sensing data like IRS-P6 LISS IV, PAN, Cartosat-I, IKONOS, GPS and GIS in soil resource inventory and characterization at large scale for the micro level agricultural planning.

Keywords: GIS, GPS, High resolution remote sensing, Soil resource mapping, Soil survey.

Soil is a valuable non-renewable resource, which provides essential support to ecosystems and exists throughout the World in diverse behavior and properties. Over exploitation of resources to meet the basic amenities has not only depleted the finite land resources but also degraded their quality. The global demand for raw materials, industrial inputs and energy has been the main drivers of the depletion and degradation of resources (Cronin, 2009). Soil is the base for every production system and knowledge on their properties, extent and spatial distribution is extremely important. Therefore, it is imperative to maintain soil resources to sustain the ecosystem (Beckett and Webster 1971, Gessler 1996). In this context, characterization and mapping of different types of soils and their interpretation attains greater importance. Accurate baseline information and methods to evaluate the quantity and quality of resources is a prerequisite for mapping and characterization of soils (Laake 2000). Soil survey provides an accurate and scientific inventory of different soils, their kind and nature, and extent of distribution so that one can make prediction about their characteristics and potentialities (Mandal and Sharma 2005). It also provides classification of soils and other properties in an area and geo-encoding such comprehensive information enhances the knowledge on natural resources for their proper planning and management. The traditional methods of gathering information are expensive and time consuming due to large number of observations. However, advances in computer and information technology have introduced new group of tools, methods, instruments and systems. Rapid developments in new technologies such as remote sensing (RS), GPS and GIS provide new approaches to meet the demand of resource planning and successfully used in studying the various aspects of soils in spatial and temporal domain (Shrestha 2006, Yeung and Lo 2002).

The field of remote sensing and GIS has become exciting and glamorous with rapidly expanding opportunities (Patra 2011). It has been recognized as a valuable tool for land resource inventory at local, regional and global scales. Remote sensing and photogrammetric techniques provide spatially explicit, digital data representations of the earth’s surface that can be combined with digitized paper maps in GIS to allow efficient characterization and analysis of vast amounts of data. Satellite remote sensing, in conjunction with GIS, has proved to be an extremely useful tool for natural resource management. Karla et al. (2010) stated that integration of remote sensing within a GIS database can...
Spatial resolution refers to the size of the smallest object that can be detected in an image. The basic unit in an image is called a pixel. One-meter spatial resolution means each pixel image represents an area of one square meter. The smaller an area represented by one pixel, the higher the resolution of the image (Dhinwa et al. 2010).

Various high resolution satellites and their spatial resolutions are shown in Table 1. With the successful launch of IKONOS, Cartosat I, II, WorldView and Quickbird satellites, very high resolution imagery is within reach of users. The approach commonly taken in studying the feasibility of using imaging devices for soil mapping has been the acquisition and analysis of imagery, or other remotely sensed data over a specific area, which can be supplemented by limited ground reference data. The goal of the present study is to review the various applications of high resolution remote sensing in conjunction with GPS and GIS in land resource management it includes soil resource inventory, mapping and its characterization.

GIS and its applications: A GIS has been defined as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough 1986). It is based on four software functions: inputs, storage, manipulation and output of spatial information (Cowen 1987) and designed to accept large volume of spatially distributed data from a variety of sources. The information derived from satellite data and topographical maps could be stored in GIS as a database. GIS enables effective and efficient manipulation of spatial and non-spatial data for scientific mapping and characterization of soils for the benefit of local people (Star et al. 1997). The use of GIS software can help to eliminate data integration problems caused by different geographic units related to various data sets. GIS include both manual and computer based information systems (Dickinson and Calkins 1988). Mainly, we rely on the ability to analyze and extract information from images by using a variety of computer available research tools and then express these findings with images. In short, the primary goal of GIS is to take raw data and transform it, via overlay or other analytical operations, into new information which can support decision-making processes.

In recent years, the application of GIS has increased many folds in various fields. The introduction of GIS promoted interdisciplinary studies, both within the natural, environmental, social and economic sciences. Its applications have expanded rapidly in parallel with advances in remote sensing and provides infrastructure for the examination of complex spatial problems in new and exciting ways (Asadi et al. 2012). GIS proved to be an effective tool in handling...
TABLE 1: High resolution (<20 m) satellite sensors and their characteristics.

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Operation period</th>
<th>Spatial resolution (meters)</th>
<th>Swath (kms)</th>
<th>Actual Revisit (in days)</th>
<th>Scene Coverage (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS IC</td>
<td>1995</td>
<td>5.8</td>
<td>70</td>
<td>24</td>
<td>4900</td>
</tr>
<tr>
<td>SPOT-2</td>
<td>1990</td>
<td>10/20</td>
<td>60</td>
<td>26</td>
<td>3600</td>
</tr>
<tr>
<td>SPOT-4</td>
<td>1998</td>
<td>10/20</td>
<td>60</td>
<td>26</td>
<td>3600</td>
</tr>
<tr>
<td>Terra</td>
<td>1999</td>
<td>15 (VNIR)</td>
<td>60</td>
<td>16</td>
<td>3600</td>
</tr>
<tr>
<td>IKONOS-2</td>
<td>1999</td>
<td>1 (PAN)</td>
<td>11.3</td>
<td>3</td>
<td>121</td>
</tr>
<tr>
<td>Quickbird-2</td>
<td>1999</td>
<td>0.6 (PAN)</td>
<td>16.5</td>
<td>3</td>
<td>400</td>
</tr>
<tr>
<td>SPOT-5</td>
<td>2002</td>
<td>2.5/5/10/20</td>
<td>60</td>
<td>26</td>
<td>3600</td>
</tr>
<tr>
<td>OrbView-3</td>
<td>2003</td>
<td>1.0(PAN)</td>
<td>8</td>
<td>&lt;3</td>
<td>64</td>
</tr>
<tr>
<td>Cartosat-1</td>
<td>2005</td>
<td>2.5</td>
<td>30</td>
<td>5</td>
<td>756</td>
</tr>
<tr>
<td>KOMPSAT-2</td>
<td>2006</td>
<td>1.0(PAN)</td>
<td>15</td>
<td>3</td>
<td>225</td>
</tr>
<tr>
<td>Cartosat-2</td>
<td>2007</td>
<td>0.8</td>
<td>9.6</td>
<td>4</td>
<td>92</td>
</tr>
<tr>
<td>GeoEye-1</td>
<td>2008</td>
<td>0.41(PAN)</td>
<td>15.2</td>
<td>&lt;3</td>
<td>225</td>
</tr>
<tr>
<td>WorlsView-2</td>
<td>2009</td>
<td>0.46(PAN)</td>
<td>16.4</td>
<td>4</td>
<td>230</td>
</tr>
<tr>
<td>RESOURCESAT-2</td>
<td>2011</td>
<td>5.8</td>
<td>23.9</td>
<td>24</td>
<td>560</td>
</tr>
</tbody>
</table>


High resolution remote sensing and GIS in terrain characterization: Traditionally, landform mapping was done by visual interpreting aerial photographs (Dent and Young, 1981). The advent of remote sensing technology has paved the way to gather information about the earth’s resources more accurately (Karale et al. 1988). A wide variety of satellite data is available for the preparation of resource maps at different scales. The huge datasets in the core of GIS provide an excellent means of spatial data analysis and interpretation. The analysis of morphometric parameters of terrain helps to assess and evaluate erosion risk, soil and water conservation strategies, watershed characterization and other environmental parameters (Reddy et al. 2004). The qualitative drainage morphometric estimation helps to understand the relationship among the different aspects of the drainage parameters and land resources distribution. Such parameters have been studied earlier using conventional methods (Strahler 1964). Many researchers consider the topographic variation as a base for depicting the soil variability. It demands all round knowledge of geomorphology supported by field survey experience (McBratney et al. 2000, Velmurugan and Carlos 2009). Satellite data with toposheets are used for characterizing physiographic variation in terms of slope, aspects and land cover for delineating the soil boundary (Speight 1990).

High resolution satellite data provides reliable source of information to delineate and generate comprehensive and detailed inventory of geographic units in an area (Mukerjee 1982). The detailed analysis of landforms is an important aspect of any environmental or resource analysis and planning (Blarzcsynski 1997, Reddy et al. 2001). Reddy and Maji (2003) reported the analysis of IRS-ID LISS-III data in conjunction with distinct lithological units, drainage pattern and contour information improves the capability in delineation and characterization of geomorphological units. The analysis of landform-soil relationship, in association with drainage and elevation properties can be effective to understand spatial patterns of soil attributes in similar geological and climatic terrain conditions (Bell et al. 1994, Wilson and Gallant 2000, Hengl and Reuter 2008, Reddy et al. 1999). Soil-landform units are expected to be relatively homogeneous in terms of the main factors including parent material to identify dominant soil-geomorphic processes. Hammer et al. (1995) reported the use of DEMs with GIS to investigate the precision and accuracy of computer generated...
slope class maps for soil survey and land use planning. Terrain attributes derived from digital elevation models and satellite imagery has been used to aid the delineation of soil boundaries (McBratney et al. 2003). Reddy et al. 2012 demonstrated that the utility of high resolution satellite data and GIS technologies supplemented with ground truth is found to be the most efficient and effective way in terrain characterization and soil resource inventory in a toposequence and established soil-landform relationship to characterize the landform and soil properties.

**High resolution remote sensing and GIS in Soil resource mapping and characterization:** Soil is the most important natural resource, which should be managed effectively, efficiently and optimally for sustainable agricultural production. Soil mapping may be defined as the spatial demarcation of soil types (Abuzar and Ryan 2001). The kind and distribution of different soils and their problems and potentials in a micro level can be assessed by using high resolution satellite data. Technological advances during the last few decades have created a tremendous potential for improvement in the way that soil maps are produced (McKenzie et al. 2000, Boonyanuphap et al. 2004, Hopkins 1977).

The spatial database facilitates the authorities in planning and also assists in understanding the effect of developmental activities undertaken by incorporating the data derived from the repetitive coverage of the satellite. Liengsakul et al. (1993) estimated about 60-80 % time is saved using satellite imagery for soil mapping, compared to manual methods. Several researchers have suggested that large scale soil resource mapping using satellite data IRS-P6 LISS III by Velmurugan and Carlos (2009), IRS P-6 LISS-IV (Reddy et al. 2012, Hiese et al. 2011) whereas Walia et al. (2010) reported PAN merged satellite data for soil resource inventory which provide detailed information of the study area. The potential application of high resolution satellite imagery has stimulated much interest among researchers to characterize soil (Pareta and Pareta 2012). In recent years, satellite imagery has gained a broad base of application in preparing soil maps as well as mapping individual soil-related features on the ground (Singh and Dwivedi, 1986, Lee et al. 1988, Zidat et al. 2003, Dobos et al. 2000). Many authors have reported that the satellite remote sensing and GIS are proven as promising tools in soil resource mapping with visual interpretation of remotely sensed data (Srivastava and Saxena 2004, Reddy et al. 2008). In a study carried out by Ramakrishnan and Guruswamy (2009), it was observed that if soil information is available in GIS then many professionals could assess the information for developmental purposes, effective agricultural research and in advisory programs. Advances in these technologies have created a tremendous potential, for improvement in the way the soil maps are produced (Scull et al. 2003). Therefore, mapping and characterization of soils in specific region will provide farmers and land use planners with a means to easily assess the nature of land and divide it into meaningful management zones.

**High resolution remote sensing and GIS in pre-soil survey:** Remotely sensed data and imagery in the electromagnetic spectrum have proved to be highly valuable. Barnes and Eckl (1996) reported that high resolution (PAN and LISS III) satellite sensor data can be registered with cadastral maps with remarkable accuracy and the cadastral information in the form of maps and records can be updated. For village level planning, large scale soil maps are very useful because individual soil series and their phases can be delineated. A

### Table 2: Summary of different satellites used at micro level planning

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Resolution (meters)</th>
<th>Study Area</th>
<th>Purpose</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS-P6 LISS IV</td>
<td>5.8</td>
<td>Borgaon Manju watershed (Maharashtra)</td>
<td>Soil Resource Inventory</td>
<td>Reddy et al. (2012)</td>
</tr>
<tr>
<td>Resourcesat-1+</td>
<td>2.5</td>
<td>Mohammadabad village (Andhra Pradesh)</td>
<td>Soil fertility assessment</td>
<td>Wadodkar and Ravishakar (2011)</td>
</tr>
<tr>
<td>Cartosat-1</td>
<td></td>
<td>Experimental plot (Jalandhar)</td>
<td>Soil mapping</td>
<td>Raj and Koshal (2012)</td>
</tr>
<tr>
<td>IKONOS</td>
<td>1 (PAN) 4 (NIR)</td>
<td>Nawalparasi district (Nepal)</td>
<td>Precision Agriculture</td>
<td>Barala (2010)</td>
</tr>
<tr>
<td>WorldView-2</td>
<td>0.46 (PAN) 1.84 (NIR)</td>
<td>Bhopalpur village (Uttar Pradesh)</td>
<td>Village mapping</td>
<td>Praveen et al. (2010)</td>
</tr>
<tr>
<td>IKONOS</td>
<td>1 (PAN) 4 (NIR)</td>
<td>Sheo tehsil (Rajasthan)</td>
<td>Demarcation of watershed</td>
<td>Tomar and Singh (2012)</td>
</tr>
<tr>
<td>Cartosat-1</td>
<td>2.5</td>
<td>Bandu watershed (West Bengal)</td>
<td>Watershed prioritization</td>
<td>Das et al. (2012)</td>
</tr>
<tr>
<td>IRS-P6, LISS III, LISS IV</td>
<td>5.8</td>
<td>Pavagada taluk (Karnataka)</td>
<td>Resource management</td>
<td>Vittala et al. (2010)</td>
</tr>
<tr>
<td>PAN+LISS III</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
detailed landform map, derived from topographical sheets and satellite data analysis through visual interpretation, can be prepared and digitized to form a base map in soil survey. The interpretation is done initially with physiographic approach together with image characteristics. This physiographic-cum-photomorphic delineation are then transferred on a toposheet and taken in field for verification and developing the soil landscape relationship through study of soils in a particular area (Karale 1988). The detailed maps show spatial variations of the terrain features, which in turn, help in soil survey and mapping the soils and finalize the soil mapping units in the region. The computer aided techniques utilize the spectral variations for classification. It assists in identification of homogeneous areas, which can be used as a base for carrying out detailed field investigations. The surface features reflected on satellite image provide enough information to accurately delineate the boundaries, which is accomplished effectively through systematic interpretation of satellite imageries (Velmurugan and Carlos 2009). Before starting fieldwork, preliminary traverse of the surrounding areas, preferably the whole taluk in which the study area is located, is carried out with the help of satellite images or toposheet of the same scale (Natarajan et al. 2009).

Field observations based on conventional soil survey are tedious and time consuming. The remote sensing data in conjunction with ancillary data provide the best alternative, with a better delineation of soil mapping units. (Hora 2010) The advantage of using high resolution satellite data that it can cover the same area at regular intervals of time so that the changes over the area can be picked up for detailed investigations. Reddy and Maji (2003) reported that analysis of IRS-ID LISS-III data in conjunction with distinct lithological units, drainage pattern and contour information improves the capability in delineation and characterization of geomorphological units. Although, individual images often show tremendous amount of spatial detail, the use of multi-temporal remote sensing databases complemented with terrain information was found to be very essential for deriving reliable soil categorization (Dobos et al. 2000, McBratney et al. 2000).

**High resolution remote sensing and GPS during soil survey:** With increasing GPS capability and its integration with GIS, the ability to collect accurate spatial data for soil survey components has revolutionized the process of soil survey field data collection. Considerable production time is saved and the number of errors that result from processing and converting the hard copy maps to digital are reduced (Stombaugh et al. 2002). With the application of GPS position data into GIS, the surveyor is no longer burdened in order to locate the position on the map. GPS with high resolution data during the soil survey provides a wide array of uses as locating position which results in an accurate and detailed soil map, recording the location of profile description sites and locating boundaries of recently altered areas (Longley et al. 1999). It precisely locates soil sampling points within field and provides more detailed information about the variability of soils. Panhalkar (2011) used the advance navigation technique GPS for collecting the training site data and to field check classified datasets. The geographic coordinates link the field information to the corresponding area on the satellite image, which supports classification and interpretation. Together with further metadata, the latitude and longitude coordinates are saved and can be later assessed using image processing or GIS tools (Reddy et al. 2012).

The GPS makes possible to record the in-field variability as geographically encoded data. It is possible to determine and record the correct position continuously (Shrestha 2006). The advantage of using GPS is to get more detailed information; therefore, a larger database is available for the user. Information collected from different satellite data and referenced with the help of GPS can be integrated to create management strategies (Liaghat and Balasundram 2010). The development and implementation of site-specific farming has been made possible by combining the GPS and GIS. These technologies enable the coupling of real-time data collection with accurate position information, leading to the efficient manipulation and analysis of large amounts of geospatial data (Barnes et al. 1998). The representative soil profiles were located with the help of hand held GPS and examined for various morphological properties as suggested in the USDA Soil Survey Manual (Soil Survey Division Staff 2000). The location details of profiles collected based on the GPS were transferred to GIS layer for the preparation of thematic maps.

**High resolution remote sensing and GIS in post-soil survey:** A soil mapping unit forms the backbone of the final soil database. With the development of computer technologies, the data generated through soil surveys can overcome much of the difficulties associated with paper-based data storage and processing. The rapid development and availability of powerful data acquisition systems and GIS have enormously helped in organizing the data generated and monitoring of the soil resources (Wright 1993). The digital soil database in GIS environment will better facilitate the availability and assess to spatial and attribute data of soils for all levels. The digital soil maps, geo-correlated in standard projection system allow the interpretation, overlaying with different thematic layers for numerous management
Soil suitability mapping: Soil suitability is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production (Ekanayake and Dayawansa 2003, Hanna et al. 2000). The emergence of high resolution satellite imagery and GIS-based terrain analysis has enhanced and broadened the opportunities for efficient and inexpensive soil suitability mapping approaches. This approach is focused on soil attributes, climate, landuse and topography assuming that these are continuously varying with space (Lagacherie and McBratney 2007). This information provides spatial information, which is easily represented and analyzed using GIS. Many authors generated soil suitability maps using Multi criteria evaluation, QuickBird (60cm) and LISS-IV data (Ceballos-Silva A and Lopez-Blanco J. 2003) whereas Mustafa et al. (2011) used IRS-P6 LISS III satellite data for land suitability mapping.

Soil and water conservation: Reliable and timely information on the natural resources is very much essential to formulate a comprehensive soil conservation and water harvesting measures for sustainable development (Renard et al. 1997). The soil and water resources are currently under tremendous pressure due to highly competing and often conflicting demands of an ever increasing population. Identification of problematic areas and quantitative estimation of soil loss rates with sufficient accuracy are of extreme importance for designing and implementing appropriate soil and water conservation practices (Shi et al. 2004). High resolution satellite data LISS III+PAN merged imagery was used and suggested vegetative barriers to prevent soil erosion and to preserve soil moisture. Similarly, checkdams and percolation tanks were suggested at different locations across stream and farm ponds, in the agricultural lands for the conservation of water (Saxena and Prasad 2008, Singh and Singh 2009, Sankar et al. 2012). Many researchers reported conservation measures viz. contour bunding, contour trenching, leveling of gullies etc. using LISS IV satellite data for conservation of resources at the parcel level (Chandrashekar and Govindappa 2009; Kumaraswami et al. 2011). Soil and water conservation requires scientific information as an essential input for selecting appropriate conservation measures and making them technically and economically effective. Tiwari (2004) suggested bio-engineering measures in high to very high risk of soil erosion area to conserve surface runoff and thus reducing soil loss for enhancing vegetation cover and improving soil productivity. It is necessary to have information pertaining to potentials and problems of the area and specific needs of the people to evolve local specific action plans for conservation of resources.

Utility of soil database derived from high resolution data: Geo-spatial technology is an integrated approach that plays a significant role for sustainable development and management of watersheds (Khan et al. 2001, Gosain and Rao 2004). It has become an indispensable scientific tool for mapping and monitoring of natural resources and used for characterization and prioritization of watershed for planning. Watershed characterization models operate at various scale and intended to be used as decision support tools. They provide information and prioritize areas on the landscape for restoration, protection, conservation and development. Local governments can make use of this information as a base for land use regulations. The basin morphometric characteristics of the various basins have been studied by many scientists using RS and GIS methods (Biswas et al. 1999, Agarwal 1998). As evident from Table 2, PAN merged with LISS III, LISS IV data have been used widely for characterization and prioritization of watershed as reported by Shanwad et al. (2012), Vittala et al. (2010), Das et al. (2012) and Singh, (2009). Although there have been successful utilization of Cartosat-1 stereo data for the construction of Digital Elevation Model, which can be used for demarcation, mapping, characterization and various other applications (Pareta and Pareta, 2012, Kumar et al. 2008, Sharma et al. 2010, Mohamed and Murthy 2008). Table. 2 shows the summary of different satellites used at micro level planning.

Soil suitability mapping: Soil suitability is a prerequisite to achieve optimum utilization of the available land applications (Burroug and McDonnel 1998). A point theme is created in GIS with each point representing an observation point. Spatial variations of soil characteristics can be easily shown in GIS environment through Point marking on the basis of overall homogeneity of soil characteristics.


Geo-spatial technology is an integrated approach that plays a significant role for sustainable development and management of watersheds (Khan et al. 2001, Gosain and Rao 2004). It has become an indispensable scientific tool for mapping and monitoring of natural resources and used for characterization and prioritization of watershed for planning. Watershed characterization models operate at various scale and intended to be used as decision support tools. They provide information and prioritize areas on the landscape for restoration, protection, conservation and development. Local governments can make use of this information as a base for land use regulations. The basin morphometric characteristics of the various basins have been studied by many scientists using RS and GIS methods (Biswas et al. 1999, Agarwal 1998). As evident from Table 2, PAN merged with LISS III, LISS IV data have been used widely for characterization and prioritization of watershed as reported by Shanwad et al. (2012), Vittala et al. (2010), Das et al. (2012) and Singh, (2009). Although there have been successful utilization of Cartosat-1 stereo data for the construction of Digital Elevation Model, which can be used for demarcation, mapping, characterization and various other applications (Pareta and Pareta, 2012, Kumar et al. 2008, Sharma et al. 2010, Mohamed and Murthy 2008). Table. 2 shows the summary of different satellites used at micro level planning.
**Future Perspective:** The developments in high resolution sensors technology and their applications in conjunction with GPS and GIS have immense potential in providing timely, reliable and cost-effective information on soils and their characteristics. There are a wide variety of sensors operating in the optical and microwave regions and providing varied spatial, spectral and temporal resolutions which could be utilized for varying intensity of soil mapping. Although these technologies have been recognized as a potentially effective and cost-efficient technology, they are not yet routinely used in soil surveys. Our knowledge of how to apply advances in remote sensing to soil resource mapping and characterization is still incomplete (Ben-Dor et al. 2008). Using more coherent data sets with exhaustive coverage would also improve the identification of threats to soil quality which will be helpful in soil mapping and its characterization. The future of soil survey lies in using GIS to model spatial soil variation from more easily mapped environmental variables and should focus on the integrated use of remote sensing methods for spatial segmentation, as well as measurements and spatial prediction of soil properties to achieve complete area coverage. There is a need to correlate the soil resource inventories with the socio-economic conditions in the study area for better planning and management.

**CONCLUSION**

Emerging technologies like high resolution satellite data can be utilized successfully for deriving the spatial and temporal agricultural information at micro level. Organizing the satellite derived spatial data and ground observations and non-spatial attribute data, in a remote sensing, GPS and GIS environment, would be highly desirable to facilitate the sustainable development of the specific region. The advent of high resolution satellite data in recent years has considerably contributed for better management of resources, as it gives mere real time information and repetitive basis which is important for monitoring. The resources particularly soil and land needs not only protection and reclamation but also a scientific basis for the management on a sustainable manner so that the changes proposed to meet the needs of development are brought without diminishing the potential for their future use. Depending on the suitability of agro-ecological areas for alternative uses based on the detailed information, optimum way can be suggested taking into account the socio-economic conditions of the farming community and political will. The review on application of high resolution remote sensing data in conjunction with GPS and GIS shows that soil resource mapping and their characterization is cost and time effective for their efficient management and use on sustainable basis.

**REFERENCES**


