An Investigation of Reliability on Remote Sensing and GIS Data as an Aid to Urban Development Plan: A Case Study on Bhopal

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Abstract

This study investigates the four criterias - namely scale of GIS map, remote sensing and GIS integration, level of classification and accuracy of classification with respect to visual assessment, for reliability of remote sensing and GIS in Urban Development Plan. The study proposes a fusion of LISS IV and Cartosat - 1 for enhanced visual classification and gives some suggestions for better land use map generation using remote sensing and GIS data for Urban Development Plan, preparation.

1. INTRODUCTION

Urban and rural developments are key to the growing economy of India. Proper urban development is necessary to boost industry sector, to provide standard urban livelihood, and to prevent urban extension, which generally envelops nearby rural and sub-urban areas. Rural development, which concerns with land and agriculture, is essential to boost agriculture based rural economy and to provide basic amenities for rural livelihood because agriculture still employs country's major population. In order to prevent the capture of rural development land from rapid urbanization, a well studied and sustainable urban development is imminent. Urban development is carried out using urban development plan. Proper urban development plan is the requirement of every growing city to handle its growing demand of land, transportation facilities, to check urban sprawl and for environmental management. This study has its focus on urban development plan.

2. URBAN DEVELOPMENT PLAN

Urban Development Plans (UDP), City Development Plans (CDP) and master plan are all related to each other. The difference lies in plan formulating bodies and focus. Urban Development Plan is generally revised every 10 years. This requires a long term analysis and modelling such that the current development should bear fruit in future. UrbanDevelopment Plan needs geographic information of the area. The information consists of topography, land use, cadastral map, soil type, transport networks, vegetation, water supply reach, flood hazard, suitable for structures, residence, industry commerce, agriculture, ecological

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conservation and many more (NUIS, 2006; UDPFI, 1996) . These information consist of both spatial attributes and associated non-spatial attributes. It also constitutes a bulk of geographic information which should be properly stored, managed and analyzed for fruitful results. The best way to analyze them is with maps of various scales of information. Conventional methods utilize old topographic maps and have extensive survey requirements, which don't incorporate changes in the growing city (Uttawar, 2001). In India too, traditional methods were employed requiring paper based Survey of India (SOI) maps and ground surveys, having drawback of viewing map at a fixed scale only. Today's digital map have brought a relief such that map can be viewed at all scales above its preparation scale and resolution. More about scale and resolution will be discussed in subsequent chapters.

2.1 Suitability of Remote Sensing and GIS in Urban Development Plans

GIS offers map representation but it requires map preparation. Traditionally, maps are prepared using extensive land surveys. However, this method is expensive and time consuming due to dynamics of urban city. Further, developing country like India faces unplanned changes more than planned changes (Tiwari, 2002). Remote sensing imagery offers a great relief by providing a detailed overview of the area. High spatial resolution remote sensing data has great potential for map creation after geo-referencing (Chidambaram, 2002). The details on the remotely sensed image helps in creation of land use map, urban sprawl map, transport network map, cadastral map, etc; hence, integration of remote sensing and GIS is critical in urban development plan (Mesey, 2008; Perera and Shantha, 1995).

Remote Sensing image might seem helpful but before relying on it, its suitability analysis for urban development program (UDP) should be carried out. There are several crucial points which need to be studied for suitability analysis (Mesey, 2008; Tiwari, 2002). The most important four points are as follows:

- Scale of GIS map generation;
- Remote sensing and GIS integration for example geometric correction, ortho rectification, registration, etc;
- Level of Land use Land cover (LULC) Classification achievable with respect to resolution of remote sensing data; and
- Accuracy of map generated from remote sensing.

The reliability will be validated using the guidelines used for urban planning (NUIS, 2006; UDPFI, 1996).

Maps for UDP of Bhopal for the year 2005 were created using Survey of India (SOI) topographic sheets and traditional survey. The proposed LU map of Bhopal

UDP plan 2005 was verified using the LU map developed in the year 2005 by IRS P6 LISS IV data, 2004. UDP of 2021 utilizes LU map prepared from remote sensing data as mentioned above. UDP includes analysis of a lot of maps but this study is focused on LU map mainly. Details will be discussed in the next section. The Remote Sensing Satellite is now available with very high spatial resolution such that even cars and individual buildings can be isolated. This has increased its capability for visual classification for land use purposes. However, even visual classification is restricted based on the spatial resolution. Level IV LU classification map is used for Bhopal UDP 2021. The spatial resolution of LISS IV image is 5.8m which is appropriate up to Level III classification and 1:10,000 scale of GIS map (Gupta & Jain, 2005). Thus, a better spatial resolution map is required for correctly identifying Level IV classification.

2.2 Image Fusion

This study proposes a digital image processing technique which would modify the image such that the LU map up to level IV classification (NUIS, 2006) with better accuracy can be obtained. The specified technique is image fusion, which enhances the spatial resolution of the image. The next paragraph gives a brief introduction of trends and methods used to achieve image fusion.

With the advent of Remote Sensing, high spatial, spectral and temporal remote sensing satellite images are nowadays acting as a good source of geospatial information. One of the major thrust of digital image processing is on extraction of various information from the high resolution imageries. Image fusion is one of the techniques which aim to extract high spectral and spatial information from two distinct images and coalesce them into single image. In order to maintain signal to noise ratio in an image and the sensor design complexity, an image with high spatial and high spectral properties cannot be produced (Zhang, 2004). Such types of images are used for better mapping, visual interpretation, classification, change detection and many GIS based application. However, the problem is to find out the appropriate method for image fusion which can be used for LU map generation. In order to solve this problem, this work investigates seven fusion techniques namely, Brovey transform, IHS (intensity hue saturation), HPF (high pass filter), PCA transform (principle component analysis, UNB pan sharpening, wavelet transform, multiplicative fusion, available in commercial software. The assessment of effectiveness of the fusion techniques can be compared. Quality assessment can be done by visual interpretation and the quantity assessment can be done by measuring certain parameters like mean bias, standard deviation, average gradient, correlation coefficient, Q4 quality index information entropy and many more (Zhang, 2008). Image fusion can be performed on two images of same sensor as well as of different sensors. The initial parameters of two satellites while acquiring the images are different.

This effect can be reduced little by using images of same sensor (Couloigner et. al., 1998) like the images acquired by IKONOS, SPOT and Quickbird. Further, level I LU classification (NUIS, 2006) is used to evaluate the effectiveness of the fused image.

2.3 Study Objectives

UDP has specific norms and guidelines to be followed and is explained in details in the study area section. Bhopal as study area has several specific topics to be discussed like administrative boundary, population dynamics, geography, topography, weather, wind direction and speed etc. The objectives behind this study are:

- To investigate the extent of reliability of GIS and remote sensing data for LU map generation used in UDP with case study of Bhopal UDP, of year 2005 and 2021; and
- To propose a suitable fusion technique for enhancement of spatial resolution

Quantitative and qualitative assessment of fused image: This work is based on analysis of urban master plan or UDP. The study area is selected as Bhopal due to urban development its history and familiarity of the place by author. The analysis includes base map preparation, reliability and validation. It also identifies the shortcomings of master plan of Bhopal, used as case study, and suggests a technology to improve the base map preparation specially land use and land cover maps.

3. THE RELIABILITY ON REMOTE SENSING AND GIS FOR MASTER PLAN

The reliability of Remote Sensing (RS) and GIS can be validated by ensuring efficient RS and GIS integration, selecting appropriate spatial resolution of RS satellite data for map preparation, proper scale for GIS analysis, following the design standard in terms of required land use and land cover analysis, accuracy assessment of visually generated map. The scale of map to be used for a particular purpose in a project is determined as to what topographical features and what plan elements (details) are required to be shown with a certain degree of clarity on one or more sheets. Master Plan (CDP) maps are required to be prepared at larger scales, 1:20,000 or 1:10,000 (for Metros and large cities), and 1:5,000 for others (NUIS, 2006, UDPFI, 1996).

4. DESIGN STANDARDS

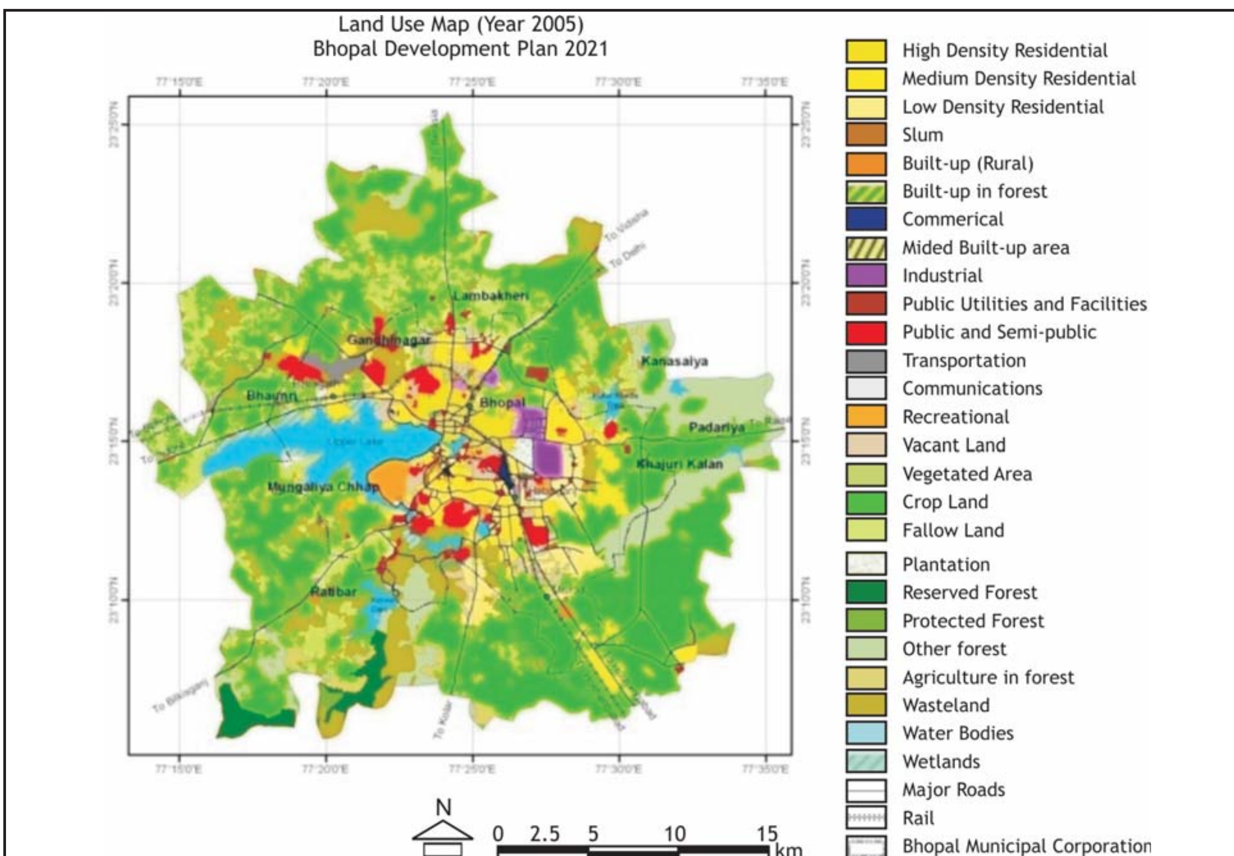
Detailed design parameters for USIS have been evolved within NUIS framework. The spatial framework, to be adopted for the two different levels of USIS - Master Plan (1:10000) and Zonal Plan / Detailed Town Planning Schemes (1:2000) scales, is given in Table-1.

Table 1 Design Standards

Parameter (All Values at 3s)	1:10000	1:2000
A) Image Standards		
Generic / Standard Resolution	• 5M XS or better	• 0.2m
IRS Image Resolution recommended	• 5.8 multi spectral • Aerial B/W	• 2.5 m (P+Mx)
NSF	State	Local
Projection for Image output	UTM	UTM
Datum for image products	WGS 84	WGS 84
Image Frames (geometrically corrected, important for seamlessness)	3'x3'	36"x36"
Image Position (Planimetric corrected, important for seamlessness)	5	0.5 (0.25mm of scale)
Band-to-Band Registration for XS data (0.25 pixel) in m	~1.5	~0.1

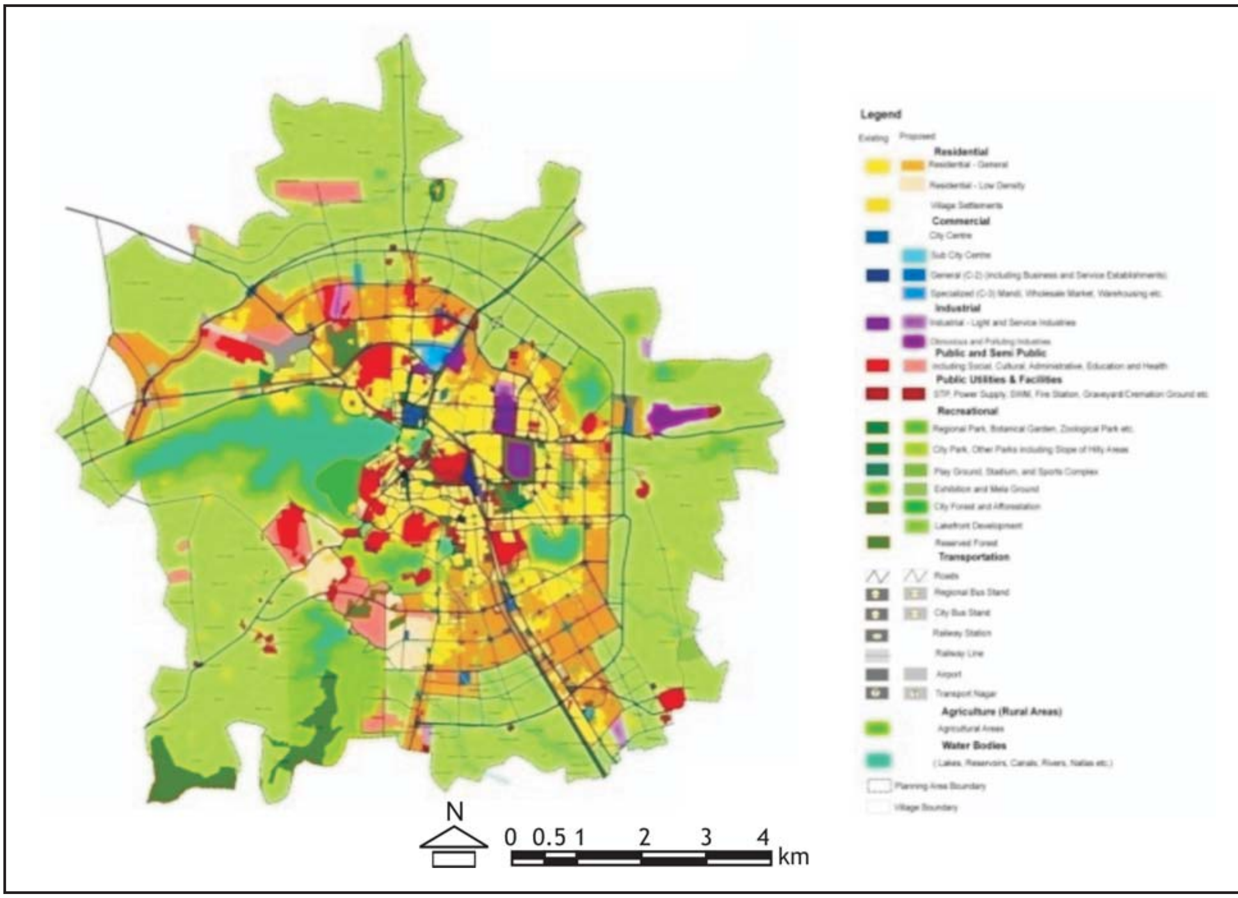
Source: NUIS, 2006, DTCP, Government of India

Fig. 1 Land Use Government of Bhopal of year 2005



Source: Bhopal Development 2021 (Draft), Directorate of Town and Country Planning, M.P.

Fig. 2 Proposed Land Use Map of Bhopal-2021



Source: Bhopal Development 2021 (Draft), Directorate of Town & Country Planning, M.P.

The classification for proposed LU map for Bhopal master plan 2021 is of Level IV which is shown in Fig. 1, while Fig. 2 shows the current LU map for the year

Level of classification of LU map is given in Table 2. The level of classification for UDP is found out by the legend of the LU maps of year 2005 and 2021 as shown in Fig 1 and 2. The classes and sub classes of the map depends on the utility of that map.

5. INVESTIGATION OF SCALE OF MASTER PLAN / UDP (LU MAP)

The scale of map is found by measuring the distance on the map represented as scale of the ground. As per the Indian norms (NUIS, 2006), the scale of the master plan of metro and large cities should be 1:10,000. Bhopal being considered under the large cities of India, the base map and LU map of UDP Bhopal is created using IRS P6 LISS IV MS data which follows the norm. As per the legend of master plan of year 2005 and 2021, the classification level IV is applied. However, at this scale some details are omitted for example transportation

Table 2 Land Use Classification of LU Map 2021

Level I	Level II	Level III	Level IV
Built up	UrbanBuilt up	Residential	Residential-generalResidential low densityVillage Settlement
		Commercial	City CentreGeneralMandi, whole sale market etc
		Industrial	Light and service industryPolluted industry
		Public and semi public	STD, power supply, grave yard etc
		Recreational	Regional park, zoological parkCity parkStadium, play ground, sport complexLake frontMela ground
		Transportation	RoadsRegional bus standRailway stationAirportTransport Nagar
		Agriculture	
		Water body	

area has been fixed with commercial area near bus stand and railway station as shown below in Fig 3. It had been shown that Cartosat-1 itself is sufficient for 1:10,000 scale map (Radha et al., 2009). Hence, the major question is at which all the maps are prepared. If scale is 1:10,000, then images have improper resolution and if higher scale then NUIS and UDPFI guidelines are violated.

6. GIS AND REMOTE SENSING INTEGRATION

It constitutes of geometric correction and orthorectification of remote sensing image and image geo-registration. The received data was already geometrically corrected. Ortho rectification is not possible because of the lack of stereo pair of remote sensing data. Thus, it only refers to image geo-registration. Image registration can be relative registration or absolute registration. In this study, relative registration is used. The panchromatic band of Cartosat-1 was already geo-registered. So, it is treated as reference image for LISS IV bands which are registered with an accuracy of 0.2 pixel, which is below the design standard of 0.5 pixel, NUIS, 2006. Image geo registration is a critical step before any map generation using remote sensing data. A small error in registration might propagate to large changes in overall area of land use. Bhopal UDP does not mention about the

Fig. 3 Class Transport Mixed with Commercial Area

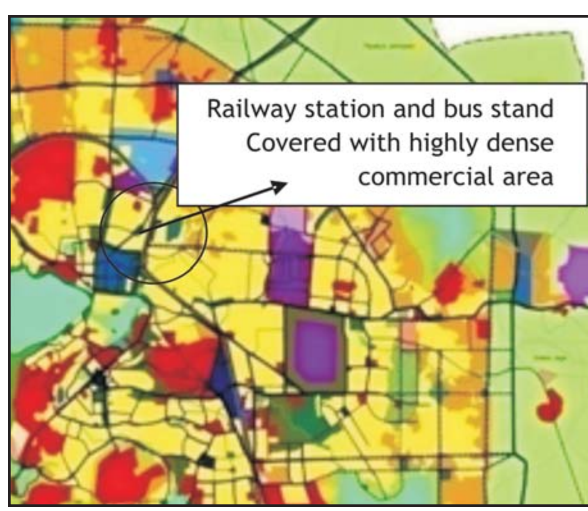


Table 3 Level of Classification of Master Plan 2005 of Bhopal

Class	Sub classes	Level of classification (NUIS standards)
Transportation	-	III
Commercial		III
Recreational		III
Forest	Reserved forest Protective forest Another forest	II
Water body		I
Wet land		I
Agriculture	Crop land Fallow land Plantation	II
Waste land		I
Communication		III
Vacant land		III
Vegetated area		III
Public and semi public		III
Industrial		III
Built up	Built up rural Built up in forest	II
Mixed built up		III
Public Utility and facility		III
Residential	High density Medium density — slums Low density	IV and level V classification for

registration error in the UDP report. The proposed modification of fusion follows the norms hence can be utilized for LU map generation.

7. INVESTIGATION OF LEVEL OF CLASSIFICATION AS PER NUIS NORMS

In LU map of 2005, the legend of LU map shows that up to level IV classification has been carried out for class residential only. Rest of the classes and their classification level has been given in Table 3. Yet few slum areas have been identified but considering the scale of map, their proper boundary delineation is crucial. Slums are level V classification. Hence, it is almost impossible to visualize the boundary using LISS IV data set. The similar is the case with residential which is further subdivided into high, medium and low density residential as level IV classification. Apart from these classes, all the other classes are at maximum up to level III classification which is possible to identify using LISS IV data (Gupta & Jain, 2005).

Hence, the availability of high spatial resolution remote sensing data is always desirable because of its enhanced capability of boundary delineation and object oriented classification (Blaschke, 2010). This arises a question that why high resolution data set (for example, IKONOS data, available since 2000, of spatial resolution 1m) or aerial photography have not been used for the preparation of LU map of year 2005. Further, aerial photography which is available for Bhopal of the year 2005 has not been utilized.

8. IMAGE FUSION TECHNIQUES

Three bands of multi spectral image were resampled to the radiometric resolution of Cartosat-1. The two registered images, Pan and resampled MS, underwent fusion by seven image fusion techniques using various image processing software. Here, seven fusion algorithm are applied namely, Brovey transform, intensity hue saturation (HIS), high pass filter (HPF), principle component analysis (PCA), PCI Pan Sharpening, wavelet transform and multiplicative fusion. Erdas Imagine 9.2 has been used for Brovey transform, multiplicative, HIS, HPF, Wavelet Transform and PCA. PCI Geomatica 10.1 has been used for PCI Pan sharpening. The fused image generated from the above mentioned techniques were resampled using nearest neighbour technique.

9. ASSESSMENT OF FUSION TECHNIQUES

Assessment of fusion techniques is done by using three parameters namely, mean bias, correlation coefficient and Q4 quality index. The fused image is resampled to the spatial resolution of original multi spectral image using nearest neighborhood as mentioned in Wald et. al.,(1997) for quality assessment. Analysis and conclusions are drawn from the results of classification and the quality indexes

10. CONCLUSIONS

This study has investigated four criteria for the suitability of Bhopal urban development plan. The scale of the map was not explicitly mentioned. However, this scale is not appropriate for detailed level V classification. Since accuracy of registration is not mentioned in Bhopal UDP, it is assumed that they would have followed the norms.

In order to generate a better Land Use map, a high spatial resolution remote sensing data is required. Aerial photography can generate map of scale up to 1:5,000. However, scale of 1:10,000 is suitable for Bhopal UDP which can be generated using only Cartosat 1 data (Radhadevi et. al, 2009). This study proposed a fusion of Cartosat 1 and LISS IV MS which has enhanced spatial resolution of 2.5m as well as good spectral resolution to provide the necessary contrast for class boundary delineation.

The major problem of identifying the appropriate fusion technique of remote sensing data for land use mapping purposes has been tried to solve. In order to solve this problem, this work have incorporated seven fusion techniques and quantitatively evaluated their performance with respect to each other. It followed a logical framework of accuracy assessment at each lower step before moving into next higher step. Seven fusion techniques are applied followed by their quantitative assessment. Due to low spectral resolution of Cartosat-1 image, bad classification results are obtained and due to low spatial resolution of MS LISS IV image, some of the classes are not well classified. This prompted for image fusion.

Commercially available image processing software (ERDAS, IDRISI and PCI Geomatica) are used for image fusion namely, HPF, IHS, PCA, Wavelet, Brovey, Multiplicative and PCI Pan sharpening. Wavelet transform fusion technique is ranked the best based on quantitative assessment followed by Brovey and PCI Pan sharpening fusion techniques. Rest of the fusion techniques were unable to provide a satisfactory performance based on quantitative assessment.

Taking above aspects into consideration, the specifie recommendations drawns for Bhopal are:

- Maps of Scale of 1:10,000 should be generated for Bhopal UDP using the images generated from one of the finally concluded fusion technique, or aerial photography or other high resolution like Cartosat 2 or IKONOS or Quickbird. Up to Level III classification, map of scale 1:10,000 is suitable;
- For higher level of classification, a map with scale larger that 1:10,000 should be used. If possible, latest remote sensing data set should be used for generation of existing LU map for example the draft of Bhopal UDP 2021 released in September 2009 utilises existing LU map of year 2005; and
- Fusion technique should be tried out, if possible with images of same sensor for their better performance in geo-registration. This should minimise the error in GIS and remote sensing integration.

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