Bridging gaps: Open Source geospatial technology as a public participatory tool for landscape assessment

Nita Shashidharan[1, 2,*] and Goldin Quadros[3, 4]

1. Environmental Science Department, Institute of Science, Madame Cama Road, Mumbai.
2. GreenLine, Don Bosco Provincial House, Matunga, Mumbai, 400019.
3. WWF-India, Maharashtra State Office, Godrej and Boyce Compound, Lalbaugh,Parel, Mumbai.
4. Wetland Ecology Division, Salim Ali Centre for Ornithology and Natural History. Anaikatti Post, Coimbatore 641108. Tamil Nadu.

*For correspondence. (E-mail: nita.shashidharan@gmail.com)

Abstract : Geospatial tools assist in landscape assessment and open source geospatial tools could enable participation of a wider community beyond trained professionals. In this study a public domain model for landscape assessment was designed and executed to document the landscape at a small scale in the Sanjay Gandhi National Park (SGNP). Further, landscape changes in and around the SGNP were monitored at a larger scale using the GLOBE protocol. The SGNP faces management challenges due to the changing land use and land cover patterns (LULC) within and adjacent the park boundaries. For the large scale LULC change detectigon, Landsat imagery from 2000 and 2010, and Google Earth were used. The result show increase of urban land along the park's boundaries and some parts within the national park. It also highlights the pressure of anthropogenic activities on the fringes of the park. Over the same time period, vegetation also shows an increase. This increase could be a false positive because of seasonal variationdue to difference in imagery months. The results of both the small scale and large scale landscape assessments demonstrate that the internet, open source public participatory landscape assessment method, though not without limitations, can be effective in landscape assessment.

Keywords: open source; geospatial; public; participation; landscape

Introduction

Land use and land cover change assessments are important for monitoring and evaluating the health of the environment. Changes in land use and land cover impact various ecosystem goods and services including impacts on biodiversity worldwide (Sala et al., 2000), soil degradation (Trimble and Crosson, 2000), climate (Sagan, Toon, and Pollack, 1979), ability of biological systems to support human needs (Vitousek, Mooney, Lubchenco, and Melillo, 1997)and also, to an extent, determining the vulnerability(Kasperson and Kasperson, 1995) of places and people to climatic, economic, or sociopolitical disturbance (Lambin, Geist, and Lepers, 2003). Anthropogenic changes and vegetation succession are recognized factors causing LULC change scenarios (Bray, Ellis, Armijo-Canto, and Beck, 2004; Flamm and Turner, 1994; García-Frapolli, Ayala-Orozco, Bonilla-Moheno, Espadas-Manrique, and Ramos-Fernández, 2007, Goetz et al., 2003; Nagendra and Utkarsh, 2003).

Remote sensing and geographic information system (GIS) are considered to be effective tools for LULC change analysis (Mas, 1999; Sarma et al., 2008) with their potential for timely and cost effective assessment of natural resources. Both the techniques have been used extensively for generating valuable information on forest cover, vegetation type and landscape changes. Also, open source GIS, remotely sensed imagery and virtual globes like Google Earth (GE) with GIS-like capabilities that are freely available have reduced the financial challenges that were a limitation for such studies especially to monitor tropics (Dorais and Cardille, 2011; Ploton et al., 2012).

GE has found numerous applications, including climate change (Sun et al., 2012), weather forecasting (Travis &Valliappa,2006), natural disasters (Nourbakhsh et al., 2006; Parks, 2009) and many more. Dorais and Cardille (2011) utilized the high resolution GE database to understand deforestation in Borneo, whereas (Ploton et al. 2012) discussed the potential of free GE canopy images for forest monitoring and tests the advantages of GE imagery compared to that of commercial IKONOS. The GE Outreach (a Google initiative) has documented how nonprofits are taking advantage of GE's presence in engaging with the public to document causes including wildlife, forest, and land use (Butler, 2009; Mishra, 2012; Tracking, 2012).

The prospect of public participation in using geospatial technology depends on if the public find the tools and techniques simple and can possibly use them independently. For LULC monitoring this means designing and promoting models, platforms and protocols that are user-friendly.

In this paper, we present the landscape assessment of the Sanjay Gandhi National Park at a small scale for a pilot site in the park using a public domain model and further, we investigate the park's landscape changes at a larger scale. First, we design the model and demonstrate its use for identifying specic aspects of land for interested individuals to monitor and document changes in their immediate landscape. Second, we monitor the park using the established Global Learning and Observation to Benefit the Environment (GLOBE) change detection protocol and document the landscape changes at a larger scale.

Materials and Methods

Study Area

The study was conducted in Sanjay Gandhi National Park which is located partly in Mumbai and partly in Thane district (19°8' N 72°53'' E to 19°21''N 72°58'' E) in Maharashtra, India and is spread over 103.09 sq. km. The mean annual temperature is 27 °C and the mean annual rainfall of about 2600mm, concentrates itself from middle of June to end of September. The park area is rich in biodiversity and encompasses a varietyof forest types including southern moist deciduous forest, tropical moist deciduous mixed forest, pockets of semi-evergreen forest, western tropical hill forest and mangrove scrub forest (Paranjpye, 1997). Increase in population and industrialization on the park's fringes has resulted in pressure on forests causing alteration in the forest's extent, structure, composition and wildlife habitat conditions (Jadhav, 1995; Paranjpye, 1997; Ze´rah, 2007). Also, Illegal encroachment of the forest land is a serious problem faced by the SGNP.

Google Earth Land Resource Monitoring Model: A Public Domain Model

Google Earth (GE), a free, virtual globe, provides the capability of integrating satellite imagery, aerial photography, and digital map data into a three-dimensional interactive virtual image of the world. A GE user would be able to recognize land cover types, disturbance events and additional features from imagery observations. This makes GE a potential tool for landscape assessment. Its potential applications beyond image visualization, its user friendly interface, high resolution (<2.5 m for some locations) and free distribution were the reasons for choosing it for the current model.

To design the model for landscape assessment at a small scale the factors considered include possible simple and user friendly steps, efficiency, cost-effectiveness and potential users. The potential users include public and non-governmental organizations. The conceptual model was formulated after extensive relevant literature survey on GE applications and open source softwares. The model (Fig. 4) was than verified on the pilot site in the SGNPand calibrated accordingly.

The GE imagery of 25 January, 2010 of the SGNP was used for the initial GE survey (Fig. 1). For the initial GE image survey, this imagery was surveyed based on spectral characteristics and ancillary data including prior field knowledge and available literature. This authenticated the visual accuracy of the GE image. Next, the pilot site was selected and several landscape features were marked based on visual cues (Fig. 2). These features were to be identified on field during ground truthing when the field data was documented and verified. The ground truthing was conducted along the pilot site using Garmin GPS; which can be substituted by mobile GPS by the public. Further steps, include data transfer to GE (Fig. 3), this transferred data along with the image under scrutiny is interpreted by the user. The individual can then share the data using GE or advanced users can carry out the more technical steps using open source data conversion tools and QGIS independently or in collaboration with scientists or experts to monitor or document more details of the landscape.

Figure 1. Initial Google Earth Survey (Step 1)

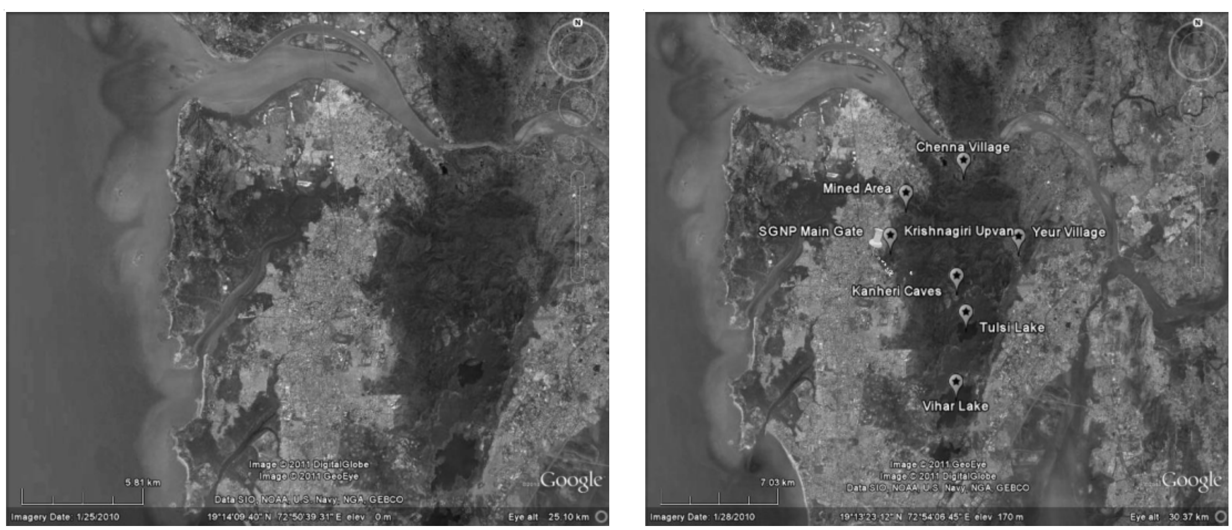


Figure 2. GE showing marked landscape features on the sample study area in the SGNP (Model: Step 1)

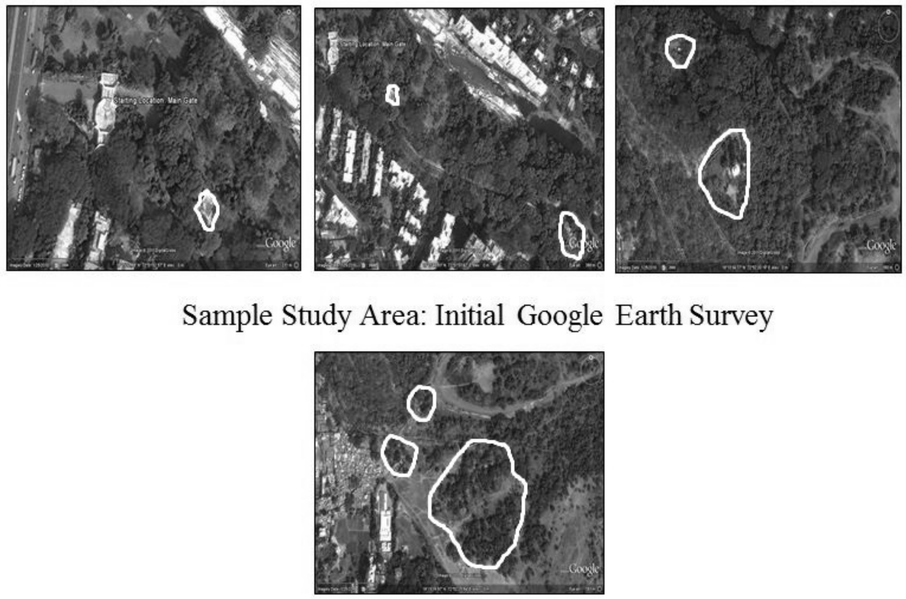
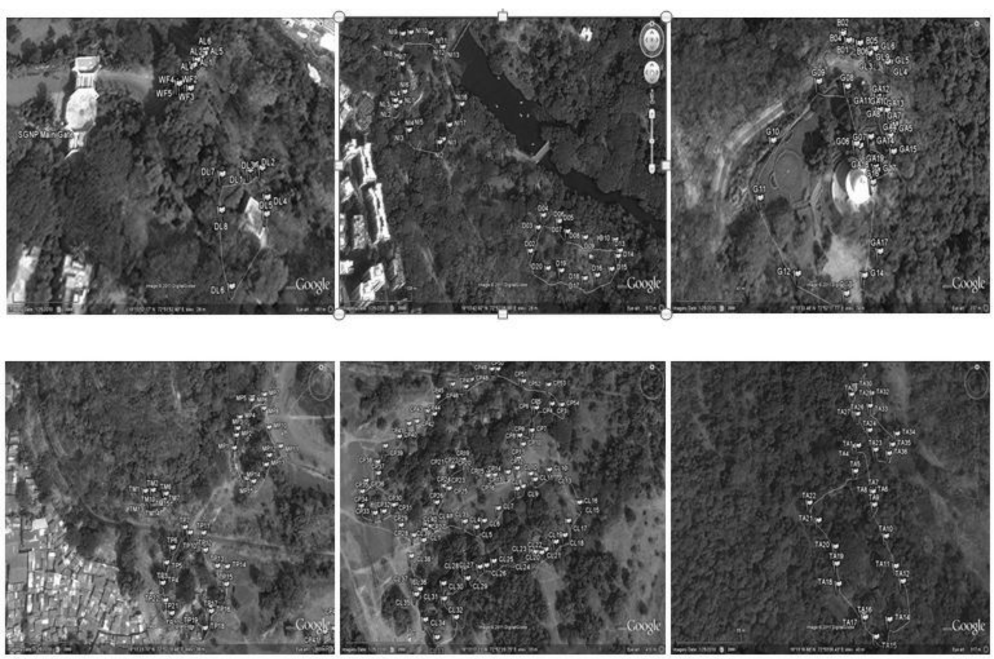


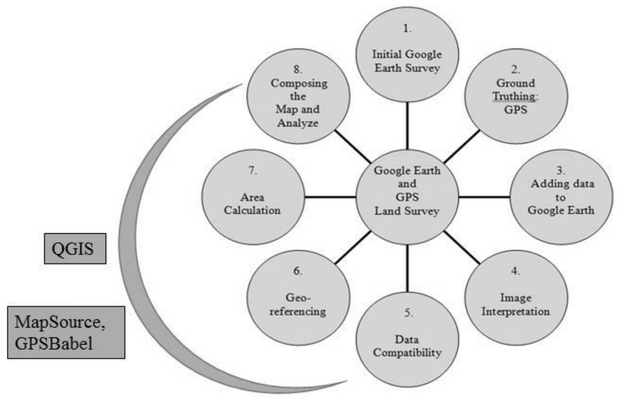
Figure 3. GE showing data obtained from ground truthing of the survey area (Model: Step 2-4)



Landscape changedetection at a larger scale

The freely available remotely sensed cloud-free satellite data obtained from the United States Geological Survey were used in the Landscape change detection study for the SGNP: Landsat-5 TM of 23 November, 2000 and Landsat-7 ETM+ of October 26, 2010. Since the obtained images have the same source and were available as orthorectified images with sufficient product processing, for the current use no further processing was required.The Global Learning and Observations to Benefit the Environment (GLOBE) program's land cover change detection protocol(GLOBE at the University of New Hampshire, n.d.,Finarelli 1998; Becker et al. 1998) was then run on the acquired Landsat images of the SGNP for the whole area using the open source Multispec software. Google Earth was used for ancillary data when required.

Figure 4. The public domain model including the model components; enclosed within the arc are steps required for advanced processing.



Results

Google Earth Land Resource Monitoring Model: A Public Domain Model

The designed model (Fig 4) was tested. Steps 1 to 4 are user friendly and can be easily executed to document land resource. Steps 5 to 8 require some technical assistance with data conversion and Quantum GIS processing and map composition.All the areas marked in the initial survey to be checked for their presence/ absence could be traced on the study site. Also, additional features along the survey route that were marked in field could be traced on GE. Minor blank brown patches in GE were identified during ground truthing to denote areas of land use for instance, Deer Park. Due to dense vegetation a tribal settlement could not be clearly identified on GE but easily marked by ground truthing.

Steps 5- 8 were executed and represented as a map for sharing of information (Fig.5).Smaller polygons could not bemeasured.The measurements of larger polygons are given in Table 1.

Figure 5. Map showing the assessed landscape features and their area

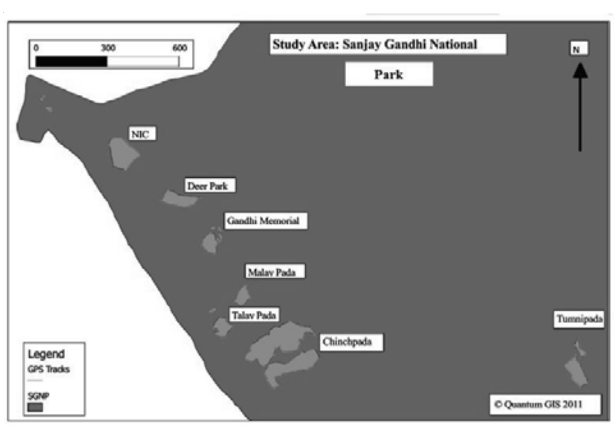


Table 1. Landscape features assessed and their determined area

Sl.No	Name of the landscape feature	Area measurement (in km^2)
1	Nature Information Centre	0.0116
2	Deer Park	0.00542
3	Gandhi Memorial	0.00382
4	Malay Pada	0.00342
5	TalayPada	0.00414
6	Chinchpada	0.0355
7	Tumnipada	0.00683

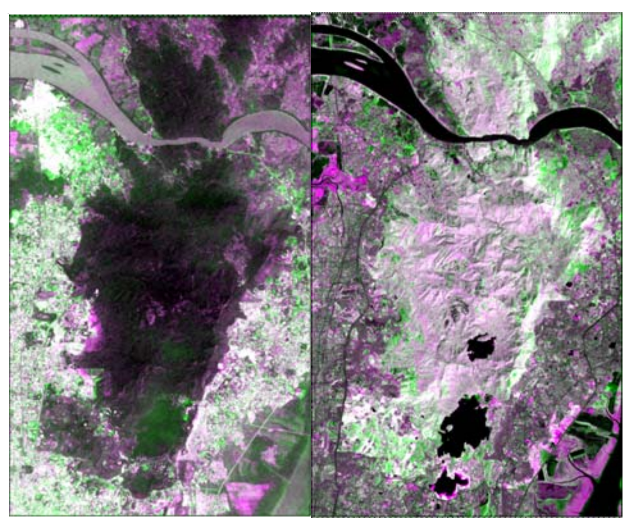
Of these, Malaypada, Talaypada, Chinchpada and Tumnipada are tribal settlements while others are land use by the forest department. In terms of area (Table 1), Chinchpada is the largest tribal settlement with an area of 35500 m^2 while the Nature Information Centre covering an area of 11600 m^2 is the largest land use by the forest department in the pilot site.

Landscape change detection at a larger scale

Landscape change detection was carried out for the SGNP with the satellite images of Landsat-5 TM of November, 2000 and Landsat-7 ETM+ of October 26, 2010. The change detection for urban areas and vegetation change can be seen in the Fig. 5.

Figure 6. Change detection for:

A) Urban Areas B) Vegetation



Change detection for urban areas (Fig 6A): The green areas represent an increase in reflectance in Channel 1 (Blue Visible Band) in 2010 image compared to that of 2000. This strong visible reflectance is often associated with exposed urban development, rocks, bare ground. It was inferred that these dense green areas have undergone an increase. Verification using GE confirmed these to be the change areas of increased urban development in the national park.

Change detection for vegetation (Fig 6B):

The green areas represent an increase in reflectance in Channel 4 (Near Infrared) in 2010 compared to 2000. This strong visible reflectance is associated here with exposed vegetation, it is inferred that these green areas have undergone an increase. Verification using GE confirmed these to be areas showing increase in vegetation.

Discussion and Conclusion

The GE land resource monitoring model for landscape assessment at a small scale was designed and effectively implemented on the pilot site in the SGNP. The result of the application of the model for the park highlights the effective use of GE and users ground-based and image-based observations for identifying specific landscape features by interested individuals to monitor and document landscape changes in their vicinity. Such a combined use of imagery, individual land observations and further image interpretation aid in understanding the local land use of the concerned area. There are limitations to the use of GE; GE does not have the same level of high resolution and cloud free imagery for every location. This makes it essential to do the initial GE survey described in the model before using GE imagery 'as is' to note landscape features.

The use of virtual globes for landscapes is also emphasized by Sheppard and Cizek, (2009) who states the benefits of the virtual globe to include accessibility, interactivity and engagement in landscape visualization and that this technology has the potential application for participatory GIS but its limitations should be acknowledged.

Further, the landscape change detection conducted at a larger scale highlights the need for greater protection of the park's fringes. The results show an increase of urban land along the park's boundaries and some parts within the national park for the change detection of 2000 and 2010. It also highlights the pressure of anthropogenic activities on the fringes of the park. Our findings are in support of Jadhav (1995) who indicates increase in population and industrialization on the park's fringes to be causing pressure on the park and showcases the encroachments areas in the SGNP. Further, this is also in accord with Tiwari (2007) who presents points of encroachment areas in the park; many of which are along the fringes.

Over the same time period, the park's vegetation also shows an increase in the LULC change detection but is not entirely due to true increase in vegetation growth, this is because the imageries are of two different months: October, 2010 and Novemeber, 2000.This accounts for seasonal variation in terms of change detection. To conclude about the actual vegetation increase in the national park; same month image would give correct estimates.

Our study shows that open source geospatial technology can contribute significantly towards enhancing public participation in landscape monitoring and demonstrates that the internet, open source public participatory landscape assessment method, though not without limitations, can be effective in landscape assessment.

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