# A MULTI-SCALE, OBJECT-BASED IMAGE ANALYSIS APPROACH IN ASSESSING BIODIVERSITY FOR NEPAL AND NEW ZEALAND SITES.

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**KEY WORDS:** Object based image analysis, biodiversity, Nepal, New Zealand, NDVI

**ABSTRACT:** The relationship between remote sensing and biodiversity is well recognised due to the spatial component inherent in the landscape. The landscape phenomena exist and interact in multiple scales. The interaction in multiple scales occurs within the scale and across the scales. To address the issue of this interaction, we develop a framework in multi-scale environment from remotely sensed data of diverse geographical territories (Nepal and New Zealand) by extracting the meaningful image objects, analysing such image objects and relating these image objects to landscape objects. In relating the image objects to landscape objects, we apply thematic, topological and geometric indices such as the Normalised Difference Vegetation Index (NDVI), the Grey Level Co-occurrence Matrix (GLCM), shape index, area, density and asymmetry for image objects. These indices and the developed framework are tested for pertinent scale (the most appropriate scale for analysis) issues using statistical measure of association – Relative Interquartile Range (RIQR). The test result shows that the pertinent scale can be achieved and it is dependent on interpreter's objective, heterogeneity / homogeneity of the landscape. This methodology shows that pertinent scale issue is promising in the study of biodiversity and associated landscape phenomena.

## 1. INTRODUCTION

The relationship between remote sensing and biodiversity is well recognised due to the spatial component inherent in the landscape. Hierarchy theory and spatial heterogeneity are the key in studying the landscape (Blaschke, 2010; Groom, 2006; Hay, 2003; Marceau, 1994). Hierarchical theory integrated with patch dynamics led to new perspectives in spatial and temporal dynamics with explicit linkage between scale and heterogeneity (Wu, 1995). The idea of nested hierarchies of patch mosaics is a significant element of hierarchical patch dynamics which can be characterised by the objects concept. In this concept, we consider that objects are formed by merging contiguous homogeneous pixels in multiple scales. The nested objects thus formed reflect our cognition to the real world. The spatial objects formed in the real world interact in vertical as well as in horizontal manner. These interactions can be visualised with the analysis of object characteristics across and within the scales using object based image analysis (OBIA). The image objects can be linked to the landscape objects using their spatial attributes. As attributes, we include patch area, number of pixels in forming a patch (density), shape index of individual patch, asymmetry index of individual patch, Normalised Difference Vegetation Index (NDVI) and Grey Level Co-occurrence Matrix (GLCM) of each patch. The computation and statistical visualisation of these attributes help us to determine the most appropriate analysis scale (pertinent scale) for biological diversity. In this study, our primary objective is to present an object based methodology to characterise the landscape structure by interpreting the thematic, topologic as well as geometric attributes for pertinent scale and linking them to the biological diversity. In developing this methodology, we use Landsat images from Nepal and New Zealand. The logic behind in choosing these two sites is that both of these are biodiversity hotspots of the world (Myers, 2000). In section 2 we present the data, study area and methodology. Section 3 shows the results obtained from this research and in section 4 we discuss research findings and conclude with the proposed future research.

## 2. DATA, STUDY AREA AND METHODOLOGY

### 2.1 Data

A Landsat 7 Enhanced Thematic Mapper (ETM) image of December 2001 is acquired for the New Zealand site - Christchurch city and surroundings. The imagery is having 0 % cloud cover and is from high vegetation growth season. Similarly, another ETM image of May 2011 is acquired for the Nepalese site - Kathmandu city and surroundings. The image is acquired from United States Geological Survey (USGS, 2011). The spatial resolution of the satellite image is 25 m for the New Zealand site and 30 m for the Nepalese site.

**2.2 Study Area**

The New Zealand study site - Christchurch city and its surroundings- consists of 37.2 Km x 19.2 Km (Fig. 1(a)). Christchurch is situated on the east coast of the South Island of New Zealand in the South Pacific Ocean. The altitude ranges from 0m (sea level) to highest elevation 920m. The unique characteristic of the study site – the Christchurch city- is that about one third of the flora is dry-land species found in no other urban environment (Given, 2000). The city's flora and fauna are widely recognised for biodiversity richness (Given, 2000). The study area consists of the sites of outstanding biodiversity value. For example, the Ricarrton bush is heavily dominated by introduced species such as oaks (*Quercus lanata, Q. semecarpifolia*), limes, willows, poplars, Tasmanian blue gum, pines (radiate and maritime) and macrocarpa (Christchurch City Council, 2008). Geologically, the city is located at the coast of the Canterbury Plains adjacent to an extinct volcanic complex forming Banks Peninsula (Brown, 1995). In this setting, the landscape of study site has diverse flora and fauna including city, hills, ocean, flat areas and steep slopes.

The Nepalese study site - Kathmandu city and Shivapuri National Park - is important for its cultural, religious heritage and its proximity to the capital city of Nepal, Kathmandu. The study site covers the area of 28.8 Km x 27.8 Km (Figure 1 (b)). The Park covers an area of 144 km2 and the altitude ranges from 1366 m to 2732 m asl. At present, the park consists of 2122 flowering plants with 16 endemic plants (Shakya, 1997; Shrestha,1996) including 19 mammals species and 151 bird species. The land use pattern of the Shivapuri area shows that subtropical and temperate vegetation types are prominent. At higher elevations, mixed temperate forest of oak (*Quercus lanata*, *Q. semecarpifolia*) and Rhododendron (*Rhododendron arboretum*) are predominant. Geologically, the park area lies in the inner Himalaya region. The main soil types are loamy sand on the northern sides to sandy loam on the southern slopes. The study site has diverse characteristics including part of the highly populated heterogeneous Kathmandu valley and a protected national park area having homogeneous vegetation along with steep hills.

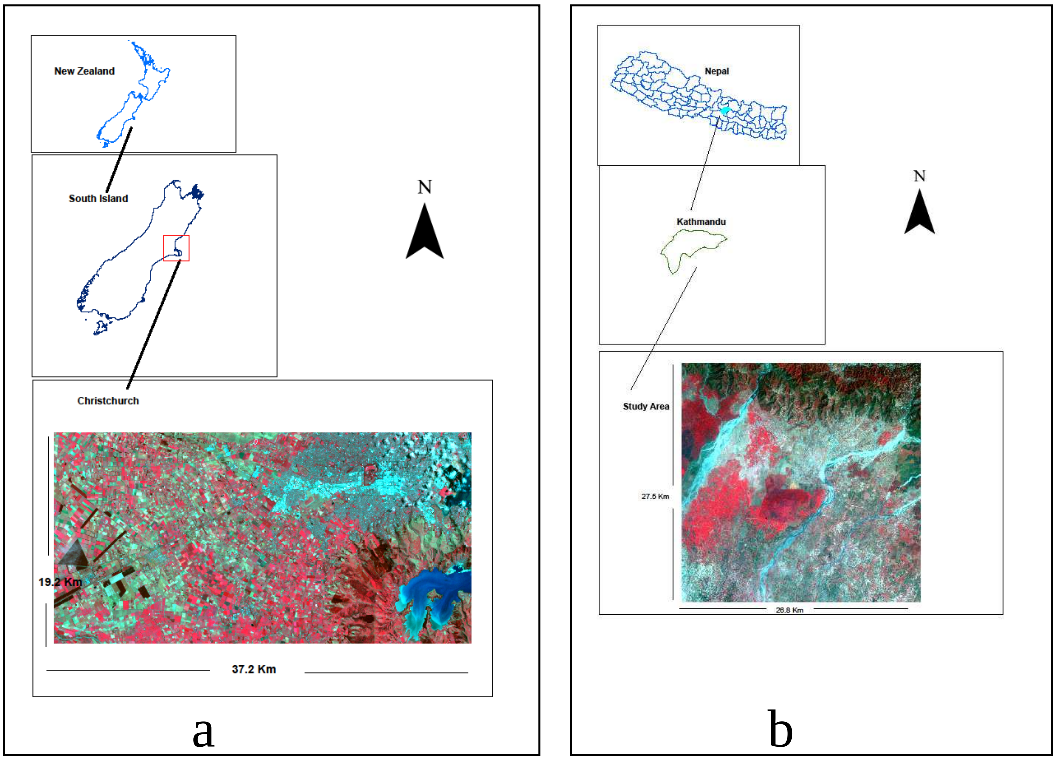


**Figure 1**: False colour composite (band 4, band 3 and band 2) of Land sat imagery (a) Christchurch city, South Island New Zealand (b) Part of Kathmandu valley and Shivapuri National Park, Nepal.

**2.3 Methodology**

The remote sensing image analysis was performed in Object Based Image Analysis (OBIA) software ([www.ecognition.com](www.ecognition.com)) – eCognition (Trimble, 2010). This allowed us to implement expert knowledge, to generate homogeneous objects through a local optimization procedure, and to create a hierarchical framework of decomposable image objects (Benz, 2004; Hall, 2004). Many works have demonstrated its usefulness in landscape habitat mapping (Mathieu, 2007; Lathrop, 2006). Vegetation patch visualisation is performed in ESRI ArcGIS / ArcInfo (http://www.esri.com/software/arcgis/arcinfo/index.html) and numerical / statistical modelling of various biodiversity indices were performed in the statistical data language GNU R (http://www.r-project.org/). The optimum segmentation parameters were determined using a systematic trial and error approach validated by the visual inspection of the image objects. In this study, the colour criterion was assigned a weight of 0.9 and the shape received the remaining 0.1 (compactness 0.5 and smoothness 0.5) as these two are complementary. Five levels were generated in hierarchy namely for scale indexed by scale factors 20, 50, 100, 150 and 250 to extract the meaningful image objects, to analyse and to test for the pertinent scale issues. With such an approach, we have the meaningful image objects for both sites in an intrinsic scale at multiple levels (Table 1) that reflects our cognition to the real world. The image objects are numerous (4033 and 933) in the lower level (level 1), which corresponds to finer scale (20 scale), whereas in the highest level (level 5) that corresponds to coarser scale (scale 250), the image objects are few (15 and 10). The mean object size is small in the finer scale (17 and 73 ha) whereas it is a large area in coarse scale (4819 and 7265 ha) for the New Zealand and the Nepalese site respectively (Table 1).

**Table 1.** Multiple levels, scales and generated image objects for the New Zealand site and the Nepalese site.

| New Zealand site | | | | Nepalese site | | | |
|---|---|---|---|---|---|---|---|
| Level | Scale | Number of objects | Mean object size (ha) | Level | Scale | Number of objects | Mean object size (ha) |
| 5 | 250 | 15 | 4819 | 5 | 250 | 10 | 7265 |
| 4 | 150 | 56 | 1290 | 4 | 150 | 21 | 3459 |
| 3 | 100 | 118 | 612 | 3 | 100 | 39 | 1863 |
| 2 | 50 | 638 | 113 | 2 | 50 | 194 | 374 |
| 1 | 20 | 4033 | 17 | 1 | 20 | 993 | 73 |
| 0 | Pixels | --------- | ------ | 0 | Pixels | --------- | -------- |

A section of the study area is presented for hierarchical segmentation (Figure 2) for New Zealand's site. This shows how the features in the landscapes spatially aggregate across the scales in a hierarchy. We developed the models to test the extracted image objects of vegetation patches and visualised for statistical distribution. After visualisation, we have chosen three indices (NDVI, Shape index and GLCM entropy) in observing the "pertinent scale", by using a statistical measure of association, the Relative Interquartile Range (RIQR).

$$RIQR = \left\| \left[ \frac{Q_3 - Q_1}{Median} \right] \right\| \quad (1)$$

Where, $Q_3$ = 3rd quartile and $Q_1$ = 1st quartile

NDVI is strongly related to the extent of vegetation cover and is an indicator of both landscape heterogeneity (Kerr, 2003) and biological diversity (Gillespie, 2008; Oldeland, 2010). Similarly, the shape index describes the smoothness of an image object border. The smoother the border of an image object is, the lower its shape index (eCognition, 2010). If the border of the objects is smoother the biodiversity is lower due to the reduction of potential contacts between different types of landscapes. The GLCM is a tabulation of how often different combinations of pixel gray levels occur in a scene and is a measure of texture. For the vegetation / plant study, this index is an important one as the texture characteristic is prominent in describing the vegetation.

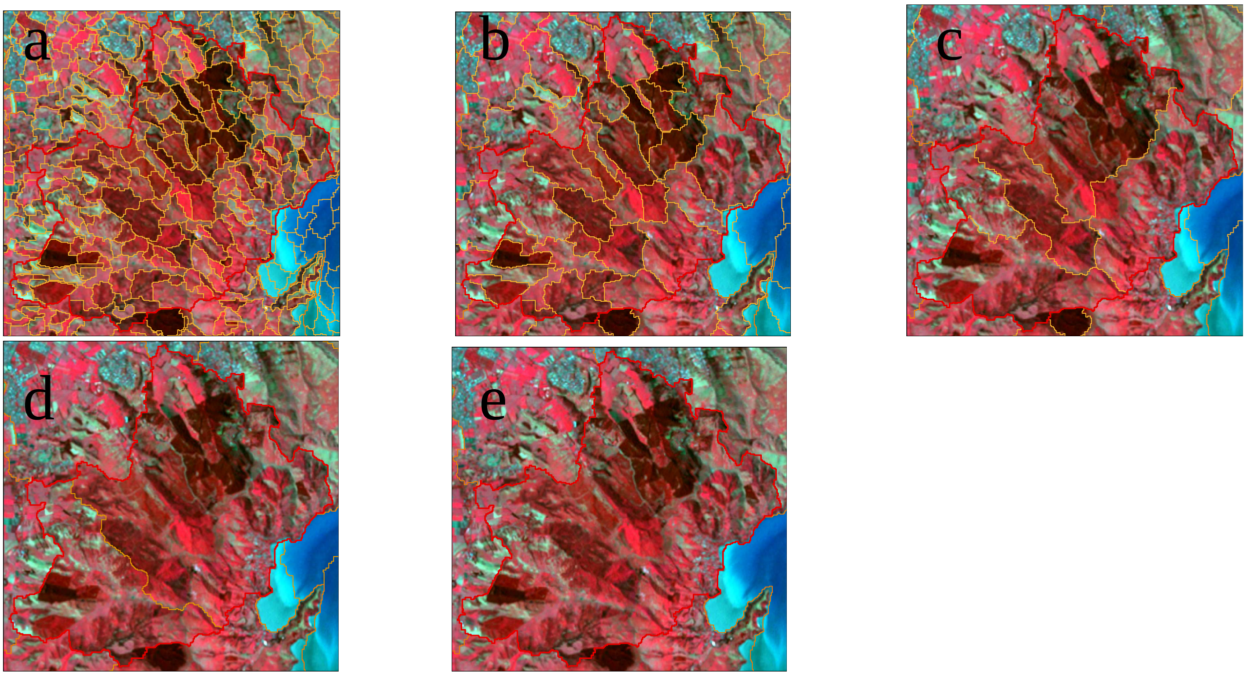


**Figure 2:** A section of the study area showing the spatial aggregation across five scales a) level 1 at 20 scale, b) level 2 at 50 scale, c) level 3 at 100 scale, d) level 4 at 150 scale and e) level 5 at 250 scale for a representative patch from New Zealand site.

## 3. RESULTS

### 3.1 Statistical Visualisation of Patch Attributes

Among the indices, we have observed their relationship in terms of correlation coefficient and statistical distribution (Figure 3). All the indices presented are independent variables. We want to observe whether there is a strong relationship (described by collinearity) among the variables in order to select the most relevant ones. As an example, in the New Zealand case, the results show that asymmetry and shape index have a correlation coefficient of 0.5, so we should only keep one of them. Further, we considered the ecological and statistical significance of each index for both sites. From the ecological perspective, shape index has a more significant impact than asymmetry.

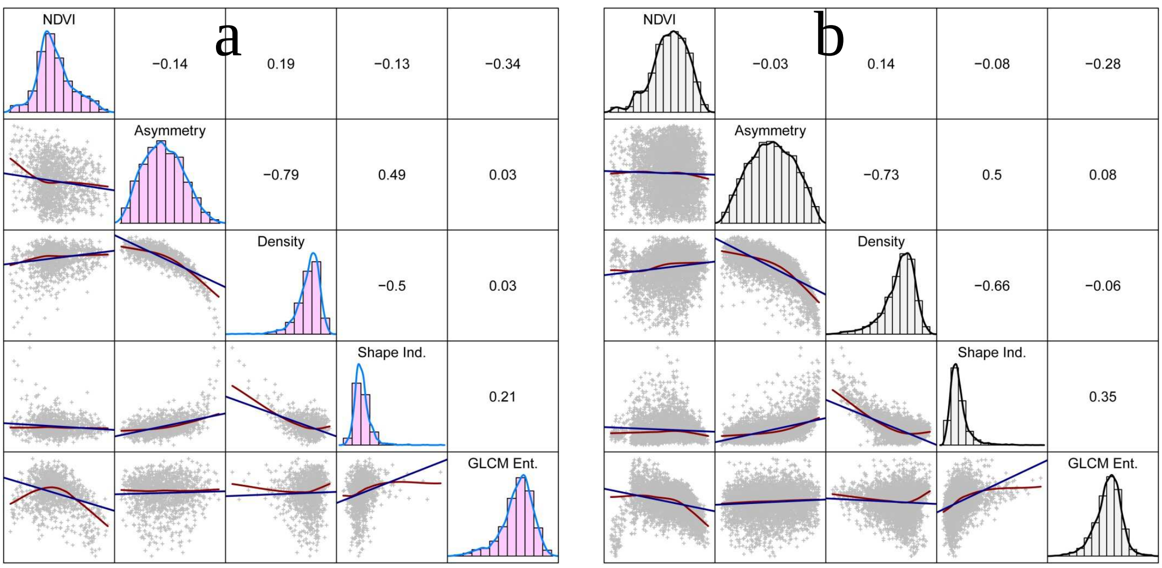


**Figure 3** Statistical distribution and correlation coefficient visualisation to ascertain the association between the attributes of patches (a) New Zealand site (b) Nepalese site.

### 3.2 Visualisation of Statistical Variability of Selected Indices

In our study, we have applied equation 1 on the set of objects characterised by the different indices to ascertain the pertinent scale of the objects. We assume that the pertinent scale would be the one for which the variability of most of the indices is maximum. The notion is that with the maximum variability of the indices we can have more ecological information of the landscape and hence biological diversity.

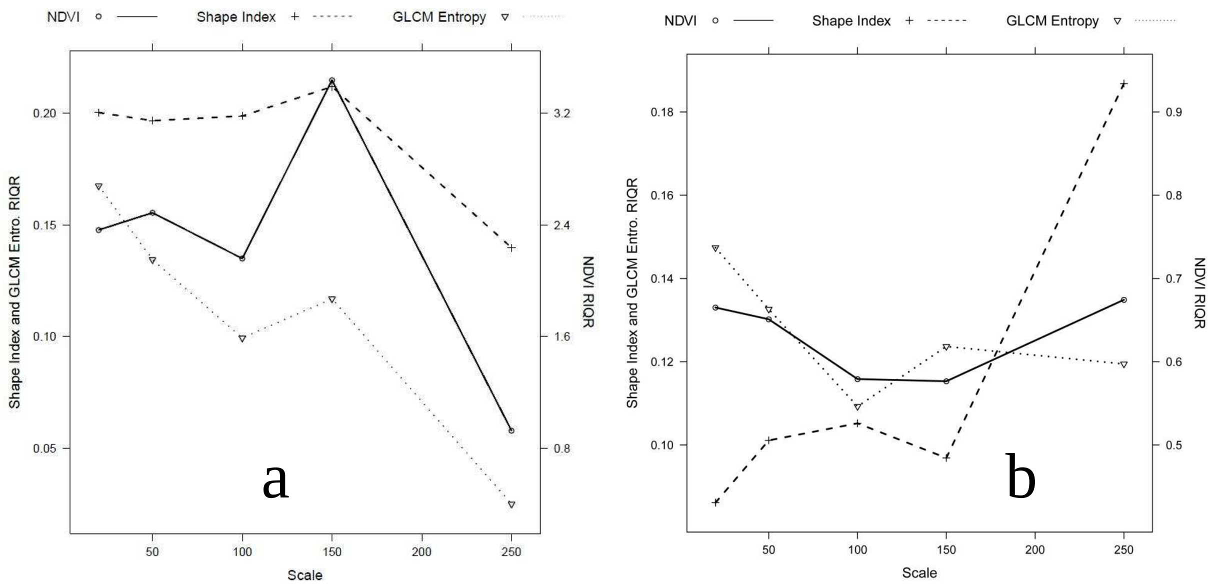


**Figure 4.** The measurement of variability with relative interquartile range of indices namely NDVI, shape Index and GLCM Entropy in multi-scales (a) New Zealand site and (b) Nepalese site.

We found that scale 150 is pertinent for NDVI and shape index (Figure 4) for New Zealand site as the indices converged in this scale with maximum value. On the other hand, for the Nepalese site, it is observed that scale 250 is pertinent for NDVI and shape index.

## 4. DISCUSSIONS AND CONCLUSIONS

It is very important to study the combination of indices for an effective interpretation of landscape pattern and their association to ecological processes. Taking this aspect into account we have chosen the combination of thematic, geometric and topological attributes of the vegetation patches in extracting the meaningful information. Such information exists in multiple scales. In a generalised concept we can think of upper scale, focal scale and lower scale in discussing the pertinent scale. The focal scale is the pertinent one for specific diversity analysis. In the New Zealand site, we observed that 150 scale is globally pertinent while in the Nepalese site, this is 250 scale. Within the global pertinent scale, the local pertinent scales are different according to the relative interquartile range of spatial attributes. This showed us that pertinent issue is not only associated with interpreters' objective it is also associated with the territory and its content and the homogeneity. In the New Zealand site, the territory is heterogeneous and constitutes of sea, city, and plantation. On the other hand in the case of Nepalese site, it constitutes a city and a homogeneous vegetation area of 'Shivapuri National Park'. The results further showed us that the pertinent scale issue is governed by the land cover of the area under study.

We have demonstrated that remote sensing images along with object based image analysis in conjunction with the landscape indices are capable enough to characterise the landscape objects in hierarchical patch dynamics paradigm. Moreover, we are aware that observing the patterns of nature and comparing those patterns in diverse geographical territories is not a straightforward task and it demands the consideration of many other characteristics. We conclude that it is possible to develop a generalised methodology to analyse the landscape of diverse geographical territories by defining landscape characters in terms of structured objects. Such a methodology would open up further research in diverse areas including biological diversity and ecological processes like climate change issues.

**REFERENCES**


Benz, U. C., Hofmann, P., Willhauck, G., Lingenfelder, I., and Heynen, M., 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS Journal of Photogrammetry and Remote Sensing, 58, pp. 239-258.

Blaschke, T., 2010. Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing, 65, pp. 2-16.

Brown, L. J., Beetham, R. D., Paterson, B. R. and Weeber, J. H., 1995. Geology of Christchurch, New Zealand. Environmental & Engineering Geoscience, 1, pp. 427-488.

Christchurch city Council, 2008. Biodiversity strategy, http://www.ccc.govt.nz/thecouncil/policiesreportsstrategies/strategies/healthyenvironmentstrategies/biodiversity.aspx

Gillespie, T. W., Foody, G. M., Rocchini, D., Giorgi, A. P., and Saatchi, S., 2008. Measuring and modelling biodiversity from space. Progress in Physical Geography, 32, pp. 203-221.

Given, D., 2000. Biodiversity of the urban environment: The importance of indigenous species and the role urban environments can play in their preservation. In Urban biodiversity and ecology as a basis for holistic planning and design, pp. 22-33. Wickliffe Press, Lincoln University, Christchurch, New Zealand.

Groom, G., Mücher, C., Ihse, M., and Wrbka, T., 2006. Remote Sensing in Landscape Ecology: Experiences and Perspectives in a European Context. Landscape Ecology, 21, pp. 391-408.

Hall, O., Hay, G.J., Bouchard, A., and Marceau, D. J., 2004. Detecting dominant landscape objects through multiple scales: An integration of object-specific methods and watershed segmentation. Landscape Ecology, 19, pp. 59-76.

Hay, G. J., Blaschke, T., Marceau, D. J., and Bouchard, A., 2003. A comparison of three image-object methods for the multiscale analysis of landscape structure. ISPRS Journal of Photogrammetry and Remote Sensing, 57, pp. 327-345.

Kerr, J. T., and Ostrovsky, M., 2003. From space to species:ecological applications for remote sensing. Trends in Ecology and Evolution, 18, pp. 299-305.

Lathrop, R. G., Montesano, P., and Haag, S., 2006. A multi-scale segmentation approach to mapping sea grass habitats using airborne digital camera imagery. Photogrammetric Engineering and Remote Sensing, 72, pp. 665-675.

Marceau, D. J., Gratton, D. J., Fournier, R. A., and Fortin, J.-P., 1994. Remote sensing and the measurement of geographical entities in a forested environment the optimal spatial resolution. Remote Sensing of Environment, 49, pp. 105-117.

Mathieu, R., Aryal, J., and Chong, A. K., 2007. Object-Based Classification of Ikonos Imagery for Mapping Large-Scale Vegetation Communities in Urban Areas. Sensors, 7, pp. 2860-2880.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B., and Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature, 403, pp. 853-858.

Oldeland, J., Wesuls, D., Rocchini, D., Schmidt, M.; and Ju¨rgens, N., 2010. Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity? Ecological Indicators, 10, pp. 390–396.

Shakya, P. R., Adhikari, M., Rajbhandari, K. R., Choudhary, R. P., and Shrestha, K. K. 1997. Flora of Nepal In International Seminar cum Workshop on Flora of Nepal, Kathmandu, Nepal.

Shrestha, T. B., and Joshi, R. M., 1996. Rare, Endemic and Endangered Plants of Nepal. WWF Nepal Program, Kathmandu, Nepal.

Trimble, 2010. User Guide, http://www.ecognition.com/

United States Geological Survey, 2011. http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/NLDC. U.S. Department of the Interior.

Wu, J. and Loucks O. L., 1995. From Balance of Nature to Hierarchical Patch Dynamics: A Paradigm Shift in Ecology. The Quarterly Review of Biology, 70.