Mapping and Modelling of Animal Diversity Index in Green Campus Using Integrated Geospatial Technique and in-situ Camera Trapping

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Key words: Animal, biodiversity index; remote sensing, World View2

SUMMARY

This paper determined a biodiversity index of ground animal species using the indirect remotesensing approach for large-scale mapping. Remotely sensed data acquired from World View 2 satellite data were used to obtain biophysical parameters, where all these parameters are then utilized for modelling of animal biodiversity mapping in a green landscape of *Universiti Teknologi Malaysia* campus. Three biodiversity indices, namely, species richness, evenness, and diversity were mapped and analyzed against ground truth obtained from unmanned sensor-camera trappings. The biophysical parameters derived from the remote sensing and ancillary information for the mammal habit at heterogeneity was categorized based on relevancy to vegetation density and moisture presence within the canopy and vegetated areas. Results of this study demonstrate the utility of satellite remote sensing, especially with the new generation of fine spatial and spectral data such as World View2data, for mapping animal biodiversity at large scale. The derived richness, diversity and evenness indices were shown to agree fully with the in-situ observations.

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1. INTRODUCTION

Biodiversity index of the environment has been important measures of how living things are found in the natural environment. Such index covers both the flora and fauna. This paper addresses the fauna or animal diversity index mapping and modelling using remote sensing and related geospatial techniques.Whilst the quantificationoffauna or animalbiodiversityusing a remotesensing approach is not entirely new, operational monitoring practices have been seen hindered by the lack of technical familiarity of biodiversity scientists to the science and technology involved. Remotesensing applications for biodiversity studies can be implemented in either director indirect approaches. The first approach refers to species identification and assessment of means of measurement of spectral signatures acquired from remotesensing data (e.g in the case of the target animal is larger than the pixel's resoultion) can be done directly.In the latter approach that is widely used due to its simplicity and reliability, is the indirect remotesensing method that biodiversity is calculated by means of certain environmental parameters serving as proxies (Plotkins et al., 2007, Petroelli et al. 2005, and Turner et al. 2003). Large scale diversity mapping of mammal diversity however, is rarely reported, as most previous studies have focused on regional diversities, where gap analysis is the ultimate aim. Currently available fine spatial and spectral resolution satellite remote sensing data provide an opportunity for medium to large scale(1:50,000to1:5,000) biodiversity mapping. These mapping scales provide systematic diversity indices able to be cross-tabulated with the corresponding land use/ land cover to understand the effects of landscape development on mammal diversity.

This paper emphasizes on the mapping and modelling animal diversity index in green campus landscape using integrated approcah of terrestrial camera trappings with fine resolution satellite data, the World-View 2 for green campus landscape of Universiti Teknologi Malaysia. In addition, the biodiversity index derived, namely the Richness, Evenness and Diversity were analysed against the corresponding environmental spatial parameter derived from satellite data. Thus, model for predicting biodiversity index to any proposed landscape development within any particular areas can be pre-determined to minimise effect to the animal biodiversity.

There are three main challenges in using spatial parameters as proxies in assessing biodiversity by remote sensing (Oindo 2002, Leyequien *et al.* 2006, Louis *et al.* 2006), : (i) suitable selection of the environmental parameters in characterizing the animal species habitats or niche; (ii) the selection of appropriate remotely sensed data to extract the environmental parameter either directly or indirectly (such index, ratio, etc.); and (iii) the comprehensive understanding of the physical and biological aspects of the animal species. Since every species has its own physical and biological characteristics, studying the abundance of a group of animal species diversity, such as mammals, depends greatly on their basic habitats heterogeneity. In this study, we used only spatial parameters related to vegetation, as these are main characteristic of the green campus. Furthermore, other spatial parameters,such as lakes, rivers and topography within the campus are artificial as most of them are reconstructed as part of the landscape development.

2. MATERIALS AND METHOD

2.1 Study area

The study was conducted in an area of 1222 ha green landscape of *Universiti Teknologi Malaysia* campus, Johor Bahru. The mean annual rainfall from nearest meteorological station at Senai Airport, 10 km north of the campus, was 2631 mm, with rainfall peaks during November–January.The soil type, mainly from shale, granite, and fluviatile granite alluvium parent materials(based on data provided by the Malaysian Soil Science Division). Indeed, the topography consists mainly of flat alluvial areas, with several smaller river line areas, streams and gently undulating rolling hills.

The main vegetation type in the area is mixed of scrubs and old unattended rubber that is dominated by a high proportion of belucar pioneering species. The campus area was surrounded on three sides by oil palm, rubber plantations and residential areas. Animals found here were categorized into three area habitats, namely: i) scrubs mixed with old unattended rubber plantation, ii), oil palm plantation, and iii) isolated green areas made of ornamental trees and scrubs surrounded by hostels. Figure 1 shows the location of study area and its vicinity.

2.2 In-situ Measurements

The mammal abundance information was derived from observations by camera trappings for 8 weeks after the satellite data acquisition. The camera are placed in first phase in scrubs mixed with old unattended rubber and oil palm plantation, and in second phase the cameras were placed in green areas of the ornamental trees surrounding the administration, faculties and hostels.

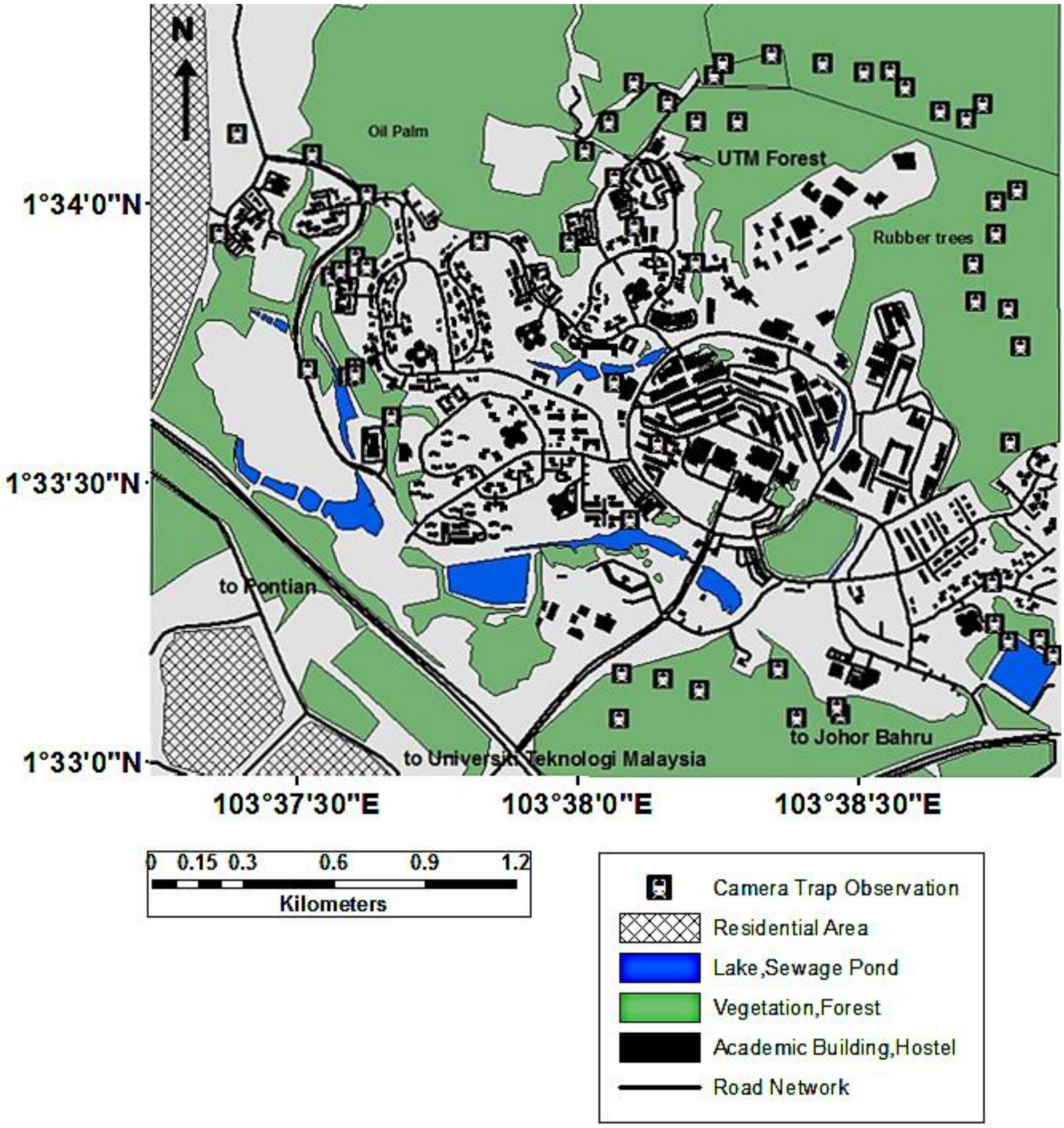

Figure 1. Study area, the green areas of *Universiti Teknologi Malaysia* campus including recreation forest, scrubs and surrounding rubber and oil plantations. Boxed icons are sensor camera locations used for trapping animal presence.

In total, the camera observations were carried out at 103 selected locations (Figure 2), and recorded 10 type mammal species, 2 type lizard and 3 bird species. Table 1 below charts the animal recorded by the camera trappings. Location and height of the camera above the ground are also recorded so to enable spatial analysis later for deriving the diversity index. The information from the 103 locations are divided into 2 mutual sets: set 1 used as induction to create the abundance map and also input into the computation of biodiversity index, and set 2 is used a independent test set for assessment of the biodiversity deduced fully using satellite WV2 data set employing the created model. Figure 2 shows the configuration of camera points for set 1 and set 2, used as induction and deduction for the generation and assessment of relationship model generated.

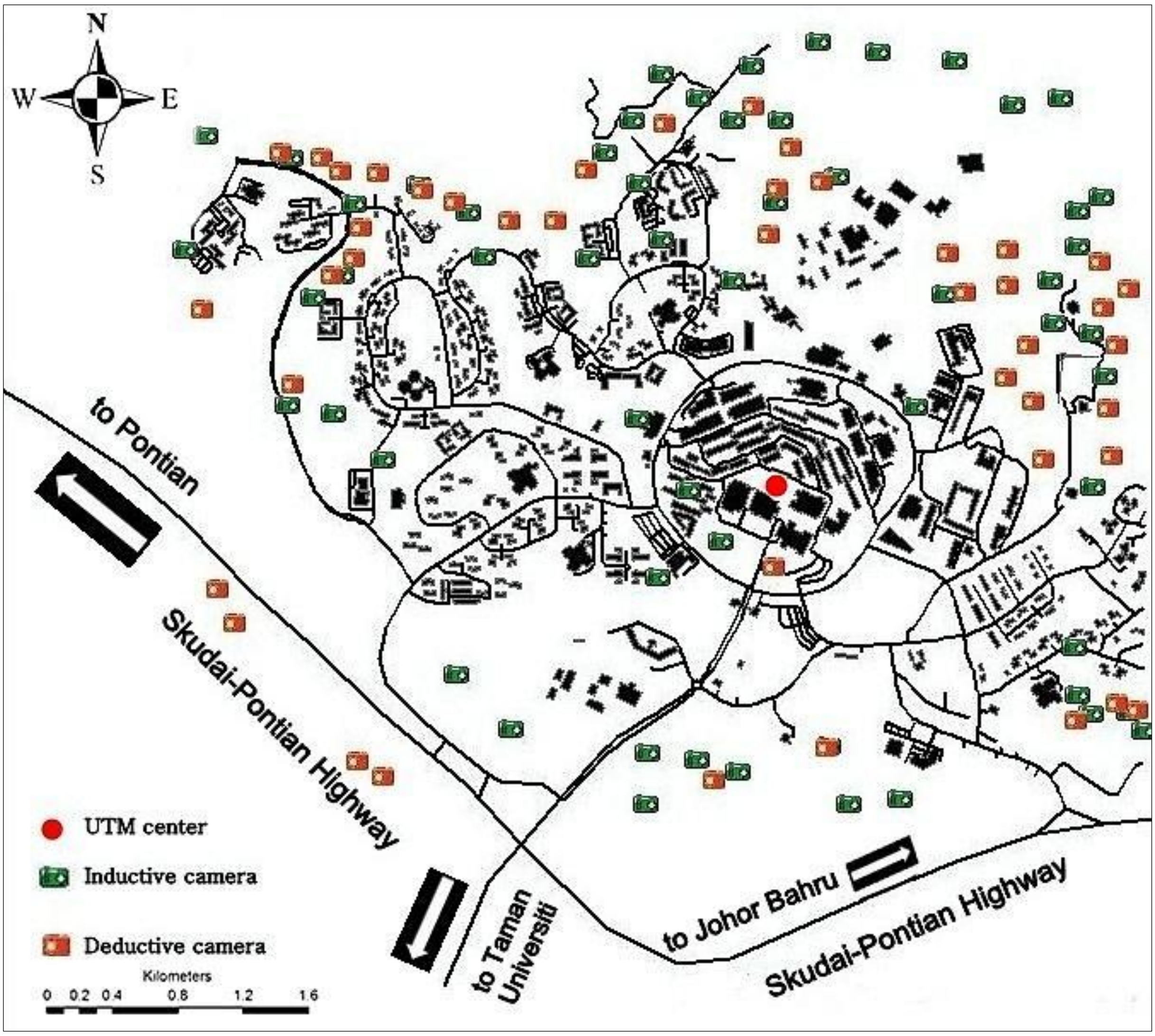

Figure 2. Configuration of palacement of terrestrial sensor camera for determination of animal abundance.

Table 1. Summary of animal abundance observed in the camera trappings.

Animal species	Total no. of animal

		within 8 weeks
Scientific Name	Common Name	
Long-tailed Macaque	Monkey	270
Hystrixbrachyura	Porcupine	54
Susscrofa	Wild boar	474
Paradoxurushermaphroditus	Palm Civet	7
Prionailurus bengalensis	Leopard cat	1
Varanus salvator	Monitor Lizard	6
Canis lupus	Domestic Dog	8
Callosciurus notatus	Squirrel	15
Tupaia glis	Tree shrew	7
Gallus gallus	Domestic chicken	7
Amaurornisphoenicurus	Kiwi	30
Acridothesestristis	Myna	8
Felissilvestriscatus	Domestic cat	1
Traguluskanchil	Wild Deer	1
Scotophiluskuhlii	Bat	1
Copsychussaularis	Robin	1
Eutropismultifasciata	Mabuya Lizard	1

2.3 Satellite remote sensing data

The World-View2 (WV2) satellite data used in the study were acquired during the period of in-situ observation of the animal abundance. The data was acquired 29 Jan 2012 with Panchromatic and Multispectral data set with 0.46 and 1.84 m spatial resolution, respectively. Both the data sets were in level 1B, and has been systematically radiometric corrected. The multispectral data set comes in 8 spectral bands. The WV2 data were pre-processed for geometric corrected to corresponding mapping coordinate system of the area, hence enable all the sample points where all the camera trappings and other in situ validation or verification activities.

2.4 Satellite Derived Biophysical Parameters

Two biophysical parameters were derived from WV2 satellite data sets, namely: (i) the NDVI and (ii) NDWI. Both these parameters are related closely with the presence of vegetation and moisture within the vegetation area so as to close proxies of preference of animal habitats and foraging grounds.

These parameters were then integrated further with related ancillary information for producing the spatial parameters, and subsequently used in modeling the biodiversity indices. The spatial parameters generated for most probable factors favorable to mammal habitat environment, thus became proxies to examine the animal biodiversity in the campus.

2.4.1 Normalized difference vegetation index (NDVI)

The NDVI was used in this study as the parameter for quantification of the primary productivity and total above ground biomass of the ecosystems as elaborated in Tucker (1979). NDVI is able to indicate the degree of vigour of the vegetation/forest based on the spectral responses acquired in the red and infrared bands. In this study, the NDVI was used as an indicator of high animal presence in the primary forest productivity which represented their living habitats and food sources. The high primary forest productivity area has a high abundance of animals include various mammal species. The NDVI calculation involves the near infrared (NIR) and visible red (R) region of the spectrum, which is based on the strong absorption of the incident radiation by chlorophyll in red, and contrasting high reflectance by plant cells in the near infrared (NIR) spectral region. Red and near infrared ASTER satellite data were used to compute the NDVI values, similar to the approach of Tucker (1979).

$$NDVI = \frac{IR - R}{IR + R} \tag{1}$$

Where,

IR and R are the reflectance for WV2 Channel 7 and Channel 5, respectively.

2.4.2 Normalized difference water index (NDWI)

The NDWI were derived from the WV2 data are used as an indicator for the presence of moisture at the canopy level, or in scrubs top. These moisture presence are vital to animal habitats. Based on the record of the number of animals observed (Table 1), most of the mammals in the study area and its surrounding areas are herbivores and omnivores. These mammals search for their foods within areas of healthy vegetation with an adequate source of moisture. The NDWI using WV2 data was derived using equation 5:

$$\text{NDWI}=\frac{\text{Coastal}-\text{NIR2}}{\text{Coastal}+\text{NIR2}} \tag{2}$$

Where,

Coastal and NIR2 are the reflectance for WV2 Channel 1 and Channel 8, respectively.

2.5 Biodiversity Index and Mammal Abundance

The mammal abundance obtained from the *in situ* camera trappings were input to compute the widely used biodiversity indices for the campus area. The indices were: (i) richness , (ii) diversity, and (iii) evenness index. Both the richness and diversity indices are used to refer to the same effect in diversity measures (Magurran 2004), while the diversity is concerned with the number of type of animal species found in any given area. Diversity also provides information on species rarity, commonness, and diversity in a community. Evenness expresses how evenly the individual species in a community are distributed among different species.

In this study, the Menhinick's richness index (Magurran 2004) was used to estimate the mammal species number which probably occurred in the study area. This is a commonly used index that describes species richness as being the ratio of the number of taxa to the square root of sample size (equation 3) in the controlled sampling environment. The absolute value of the richness index (R) ranges from 0 to 10, representing non-presence and perfect evenness to all the species found in the area.

$$R = \frac{S - 1}{\sqrt{N}} \tag{3}$$

where

R = species richness index;
S = Number of recorded mammal species; and
N = Total size of recorded mammal population.

While the richness index is only concerned with the number of species occurrences, the species diversity index on the other hand, provides information about the rarity, commonness and diversity of species in a community. The Shannon's diversity index (Magurran 2004), was adopted for this study, due to its reliability and simplicity of computation. The major advantage of the Shannon's diversity index is that it takes into account both abundance, and evenness of present species, as described in equation 4 below. The diversity index ranges from 0 to 4, representing non-existence and perfect diversity, respectively.

$$D = -\sum_{i=1}^{m} (P_i * \ln P_i) \tag{4}$$

where

D = Shannon's diversity index;
m = total number of species in the community (richness); and
Pi = proportion of *m* made up of the *i*th species.

The evenness index was computed to describe the evenness of the number of mammals of each species in the particular area. The Evenness Index (Magurran 2004) takes the proportion of diversity indices and the natural logarithmic of the total maximum diversity of a particular area. The evenness index (*E*) ranges from 0 to1, representing non-existence and perfect evenness, respectively. There are many arguments stating the diversity index (*D*) and evenness (*E*) are reporting the same effects to the diversity measure, and is expressed as:

$$E = \frac{D}{\ln S} \tag{5}$$

where

E = Evenness Index;
D = Shannon's diversity index; and
S = number of species recorded

For all three indices, the inputs were based on the field camera trap observation data, where for each camera trap, records were made on that site's own species abundance data at specific locations in the UTM campus green landscape and surrounding areas.

2.6 Animal Biodiversity Index and Abundance Estimation

The linear regression analysis was performed to imply the relationship of the biodiversity indices to the NDVI and NDWI, respectively. Both the NDVI and NDWI were adapted as spatial parameters to best represent the habitat of the animal. In addition, each of the spatial parameters was also examined through linear regression to show the relationship between the mammal biodiversity index and their respective abundance. Using the generated model, the continual surface of mammal biodiversity was estimated for the whole study area. The summation determined the abundance of the observations made for each animal counts at individual camera locations.

3. RESULTS AND DISCUSSION

The animal abundance map is created by IDW interpolation of all set 1 camera trappings is shown in Figure 3. There are 6 hotspots of abundance of the animal in the study area. Crosstabulating the abundance hotspots with campus plan, it is interesting to note that all these are at fringe of college residents with scrubs, unattended rubber trees and even oil palm plantations. Cursory in-situ found all the hotspots are the refusal bins are located, and the garbage provide sources of food or attract smaller animals that in turn larger mammal predators. Evidently the abundance-generated map agreed independent set 2 test points.

In addition to abundance map, the diversity, richness and evenness index were also generated. The corresponding spatial parameters NDVI and NDWI at all locations of set 1 observation were created using WV2 image set. The NDVI and NDWI empirically regressed against corresponding diversity, richness and evenness indices. The results are summarized in Figure 4, where spatial parameters from WV2 can optimally be used to model the diversity, richness and evenness index. The NDVI are directly proportional to the all the three indicies (with $R^2 > 0.8$ and $P < 0.0001$) tested at 30 random points. It is interestingly to note that NDWI is inversely proportional to the all the three indicies, again it was evident with very sifgnificant $R^2$and P values. In-situ verifications confirmed that areas with high NDWI attracts less wildlife and less moist area noted high number of individuals.

Figure 5 illustrates the final biodiversity index of UTM campus determined from WV2 multi-spectral data set using the empirical models created. Independent assessment of the WV2-based biodiversity indices using set 2 test points confirmed high accuracy as tabulated in Table 2.

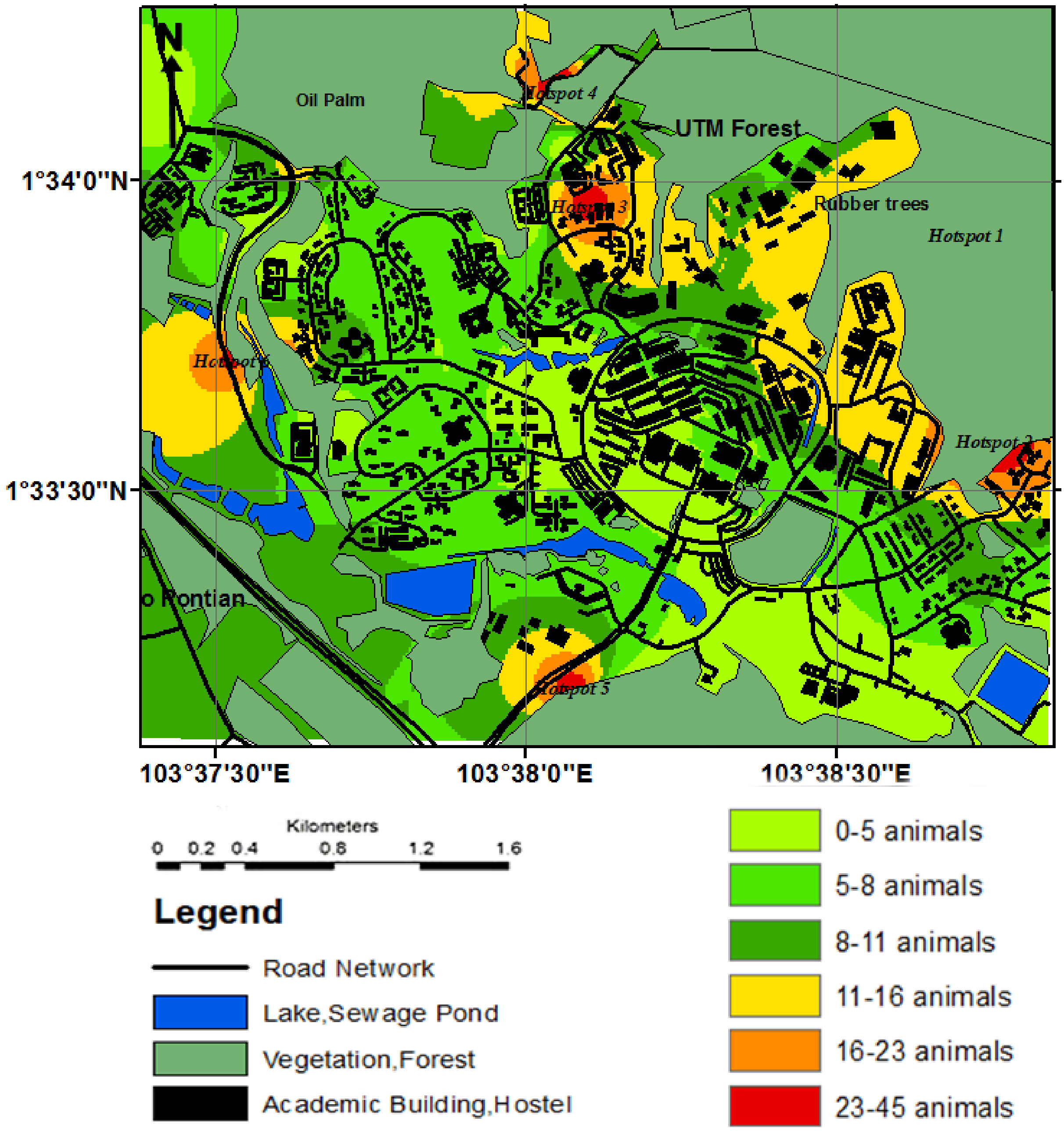

Figure 3.Animal abundance map, and generated abundance hotspots

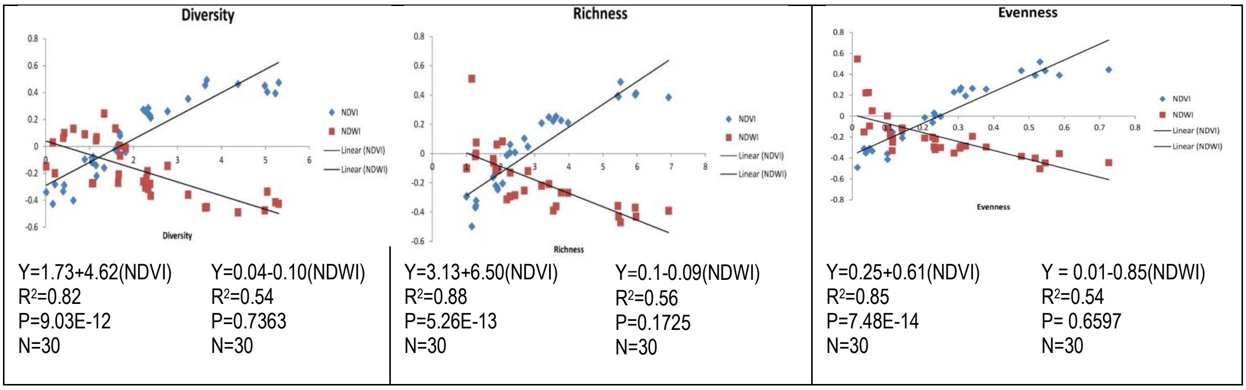

Figure 4. Empirical model depicting relationship of spatial parameters derived from WV2 multispectral data with: (a) richness, (b) diversity, and (c) evenness indicies, respectively.

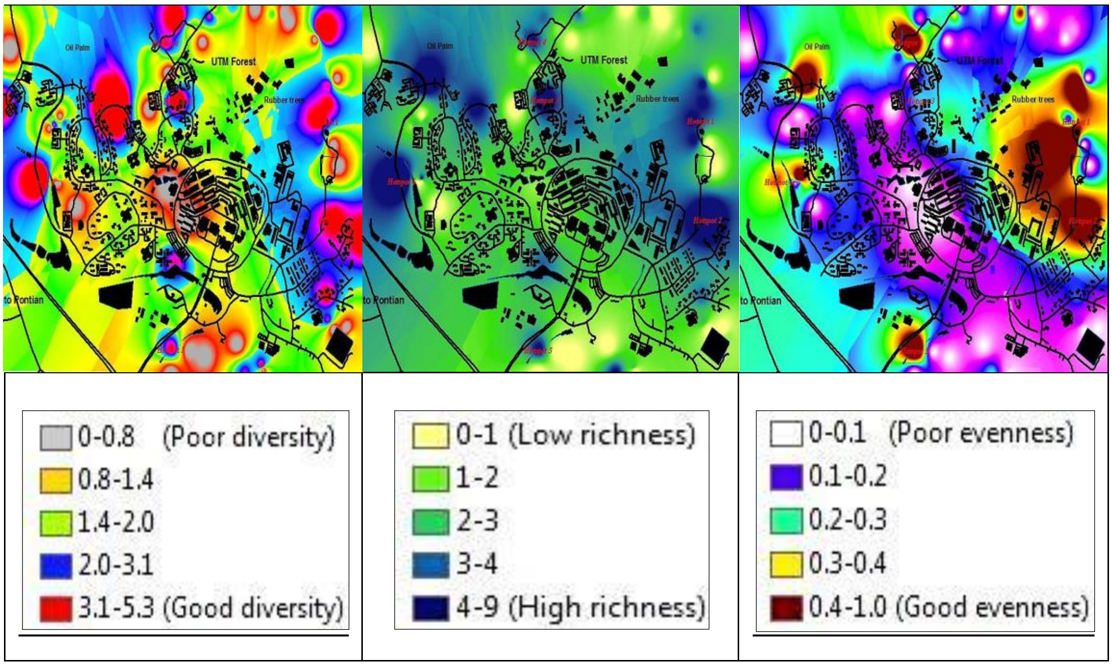

Figure 5. Biodiversity index for derived fully with WV2 data set.

Table 2. Summary of assessment of biodiversity index map derived from WV2 data set.

Biodiversity Index	RMSE
Diversity	1.860
Richness	3.654
Evenness	0.324

Comparing the results obtained, especially in the biodiversity index pattern derived from the model created using satellite remote sensing data in the humid tropical environment, there are rarely reported as detailed in the present study. Hence the most near comparative analysis is on the pattern indices derived using in-situ observation only. The main concerns are the phenomena of hotspots on the derived biodiversity indicies. Numata *et al*. (2006) showed a indicies were also noted near the fringes of forest and plantations for studies on biodiversity of mammals in Pasoh Forest Reserve. Such differences in forest environment (including densed scrubs, as in our unattended old rubber class) may cause a difference in mammal species richness and diversity in the area, and therefore it is reasonable to accept that there will be differences in animal biodiversity indices among different vegetation types.

However, higher abundance in secondary forests and forest edges than primary forest was different from the expected result because, as Yasuda et al. (2003) have suggested, primary forest provides a higher carrying capacity than secondary logged, forests and seasonal riparian forest, because primary forest habitat is rich in food resources and spatial heterogeneity. This evidences by the dominant species such as the, long-tailed macaque (*M. fascicularis*), and wild boar (*Sus scrofa*) as recorded in camera trapping observation we used. In Numata *et al*. (2005), they reported that more than 95% of our photographs were of these two species, and high trapping rates for the two species may not correspond to abundance of mammal species. Therefore, validity of our biodiversity indices for mammals should be carefully developed by including information on home rage and habitat preference for each species in a future study. In the larger context for similar studies using satellite remote sensing in temperate planted forest scape and much less mammal biodiversity such as in Wasser et al 2004, the results on the higher biodiversity indices at the hotspots are found similar to edges of forests with forage sources, which also noted in the present study.

4. CONCLUSION

This study has shown that satellite remotelysenseddata can be reliably used for estimating and studying animal diversity at landscape level exemplified by the green campus in study. The information derived from integrated fine spatial resolution with the in-situ camera trappings offers an effective animal biodiversity monitoring and inventory activities, particularly for large areas requiring scheduled monitoring. In this paper, it also have highlighted the analysis of spatial parameters and in-situ animal observation, and the derivation of species abundance using the remote sensing approach. Reliable agreements were evident between the model generated and the field records and the derived of such animal richness, diversity and evenness estimation. The mapping approach developed, with good accuracy, offers the method suitable for operational use. Furthermore, the only non-destructive method for mapping of animal biodiversity for large areas, in timely and economically viable way.

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BIOGRAPHICAL NOTES`

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