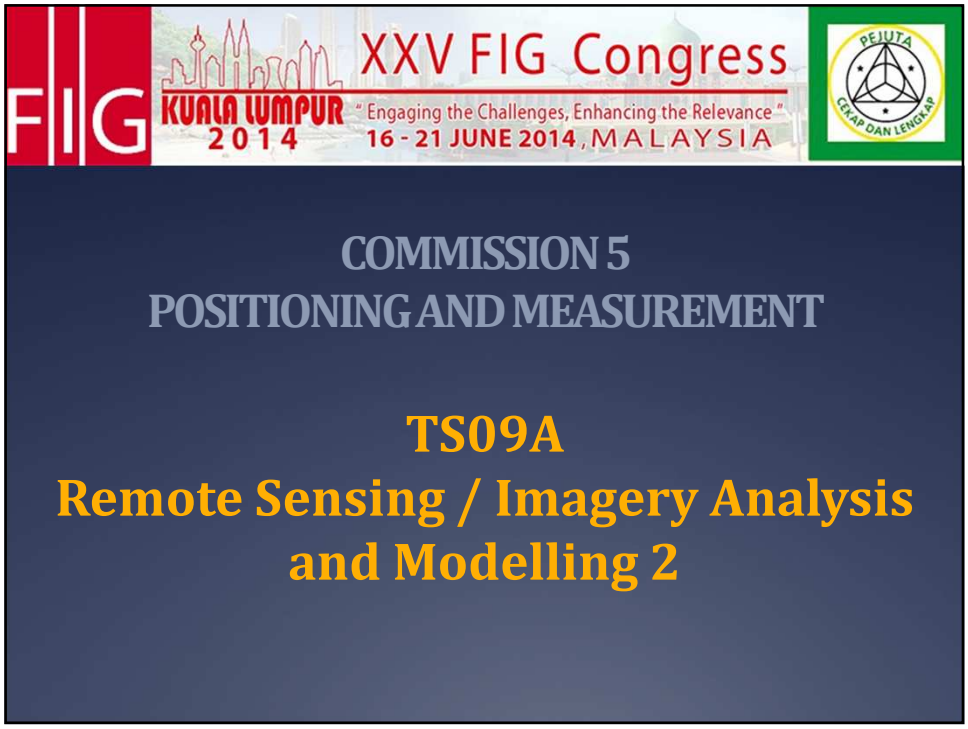
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Mapping and Modelling of Animal Diversity Index in Green Campus Using Integrated Geospatial Technique and in-situ Camera Trapping
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- **Biodiversity**, short for biological diversity, is the term used to describe the variety of life found on Earth and all of the natural processes.
- **Biodiversity index** is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types.
- **Biodiversity index** of the **environment** has been important measures of how living things are found in the natural environment.

Introduction

- Previously, Quantification of animal biodiversity using a **remote sensing approach** have been seen hindered due to the lack of technical familiarity of biodiversity scientists to the science and technology involved.
- Remote sensing applications for biodiversity studies can be implemented by two approaches:
  - **Direct** – species identification and assessment directly by means of measurement of spectral signatures acquired from remote sensing data (e.g in the case of animal, the target must be larger than the pixel's resoultion), or
  - **Indirect** - biodiversity is calculated by means of certain environmental parameters serving as proxies.
- Indirect approaches is widely used due to its simplicity and reliability.

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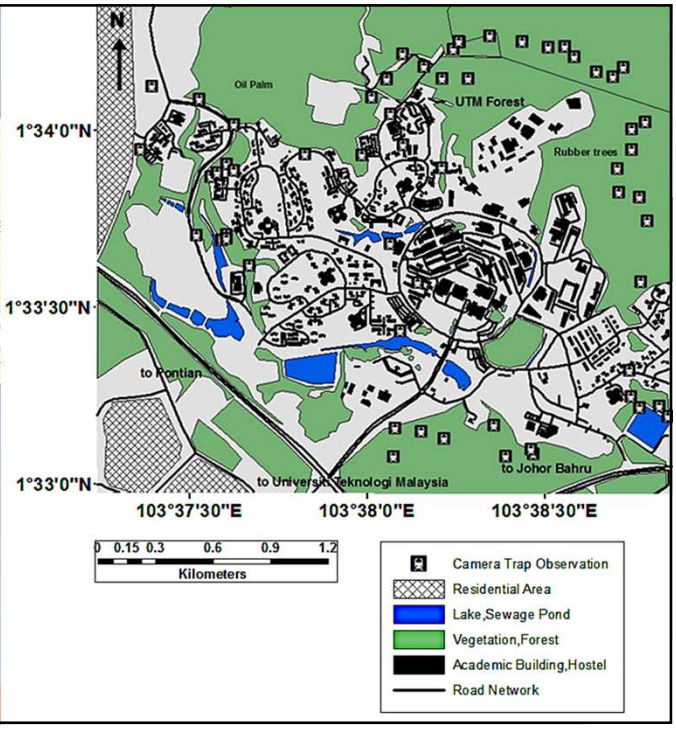
Introduction

- Most of the study for mammal diversity focused on regional scale, where gap analysis is the ultimate aim. **Large scale** diversity mapping of mammal diversity is rarely reported.
- There are 3 main challenges in using spatial parameters as proxies in assessing biodiversity by remote sensing indirect approches :
  1. Selection suitable **environmental parameters** in characterizing the animal species habitats or niche;
  2. Selection of appropriate **remotely sensed data** to extract the environmental parameters either directly or indirectly methods; and
  3. Comprehensive understanding of the physical and biological aspects of the animal species.

Study Area

- The study was conducted in an area of 1222 ha green landscape of Universiti Teknologi Malaysia campus, Johor Bahru.
- Mean annual rainfall was 2631 mm, with rainfall peaks during November–January.
- The campus area was surrounded on three sides by oil palm, rubber plantations and residential areas;
- Topography consists mainly of flat alluvial areas, with several smaller river line areas, streams and gently undulating rolling hills.

Study area



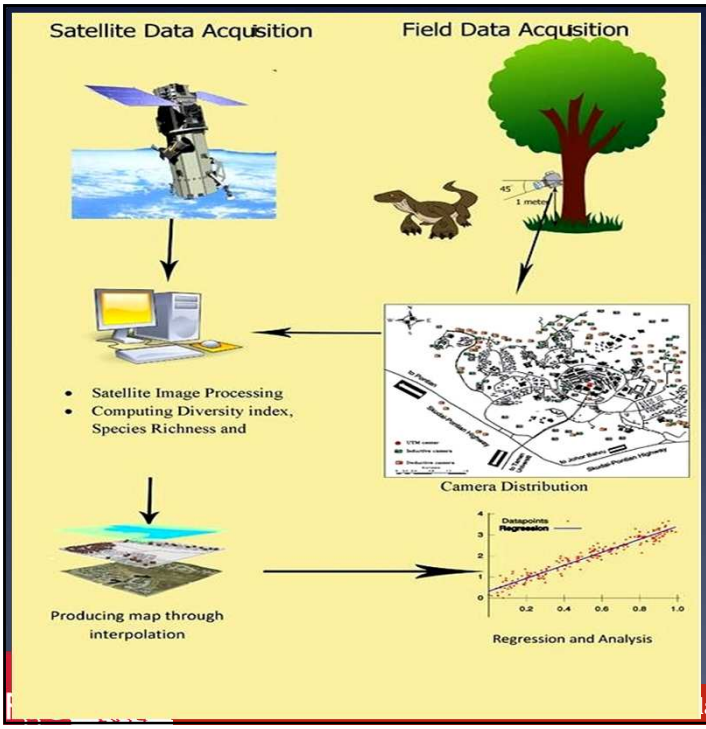
Materials & Instruments

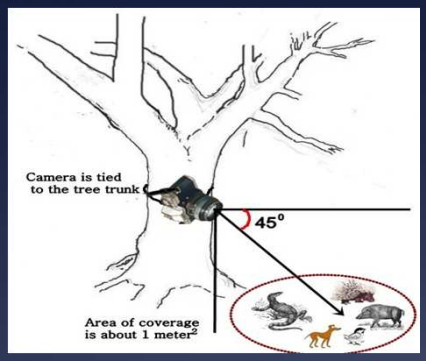
- Terrestrial Sensor Camera (built-in IR Motion Sensor), Film
- Handheld GPS Rhino 120
- Worldview-2 satellite image (Date acquired: 29 Feb 2012)
- Digital Image Processing System and GIS

Specifications of Satellite Data

Satellite /sensor	Worldview-2
Date launched	8th Oct 2013
Altitude	770 km
Inclination	98.2°
Swath width	16.4 km
Orbit type	Sun-synchronous
Equatorial crossing time	10.30 am ± 15 minute
Quantization	11-bits (DN range:0-2047)
Spatial resolution	0.46 m (PAN), 1.8 m (MS)
Wavelength	Band 1: 0.45-0.52 µm Band 2: 0.52-0.60 µm Band 3: 0.63-0.69 µm Band 4: 0.76-0.90 µm Band 5: 1.55-1.75 µm Band 6: 10.4-12.5 µm Band 7: 2.08-2.35 µm Band 8: 2.08-2.35 µm

Methodology





Depression angle = 45^0. Height of camera position is 60-70 cm above the ground.

Camera ready on ground

In-situ measurements

- The trapping activities performed in two different periods, first phase (2 weeks) to cover half portion of the campus and second phase (another 2 weeks) the remaining area.
- 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 administrative, faculties and hostels.

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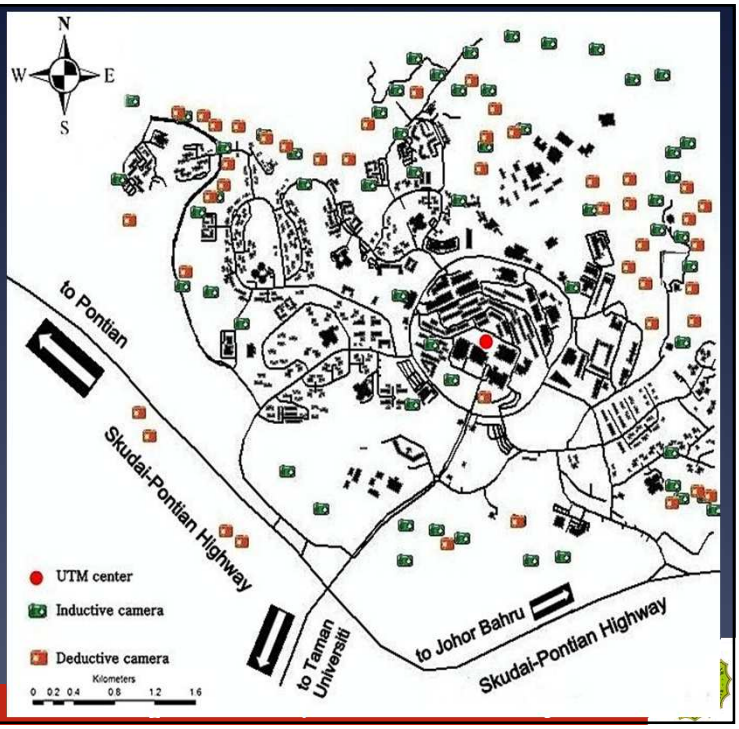
Camera placement



- Total camera observations is located at 103 location. Location and height of the camera above the ground are recorded to enable spatial analysis for deriving the diversity index.
- Recorded 10 type mammal species, 2 type lizard and 3 bird species.
- 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 computation of biodiversity index, and
  - set 2 is used a independent test set for assessment of the biodiversity deducted from satellite WV2 dataset.

Animal species		Total no. of animal within 8 weeks
Scientific Name	Common Name	
Long-tailed Macaque	Monkey	270
Hystrix brachyura	Porcupine	54
Sus scrofa	Wild boar	474
Paradoxurus hermaphroditus	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
Amaurornis phoenicurus	Kiwi	30
Acridotheses tristis	Myna	8
Felis silvestris catus	Domestic cat	1
Tragulus kanchil	Wild Deer	1
Scotophilus kuhlii	Bat	1
Copsychus saularis	Robin	1
Eutropis multifasciata	Mabuya Lizard	1

In-situ observations, derived abundance

Animal: Wild Boar
Species Name: *sus scrofa*

Animal: Monkey
Species Name: *Long-tailed Macaque*

Animal: Porcupine
Species Name: *Hystrix brachyura*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Animal: Leopard cat
Species Name: Prionailurus bengalensis
Animal: Common palm civet
Species Name:
Paradoxurus hermaphroditus
Animal: Mouse deer
Species Name: Tragulus kanchil
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Animal: Chicken
Species Name: Gallus gallus domesticus
Animal: Monitor Lizard
Species Name: Varanus salvator
Animal: Squirrel
Species Name: Callosciurus notatus
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Satellite Derived Biophysical Parameters

- This study requires identification of the presence of vegetation and moisture within the vegetated area. These information can be use as probable factors favorable to mammal habitat environment, thus became proxies to examine the animal biodiversity in the campus.
- Two biophysical parameters were derived from satellite data sets are:
  - Normalized difference **vegetation** index (NDVI)
  - Normalized difference **water** index (NDWI)

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Normalized Difference Vegetation Index (NDVI)

- NDVI usefull for quantification of the primary productivity and total above ground biomass of the ecosystems. NDVI 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, NDVI was used as an indicator of high animal presence in the primary productivity forest which represented their living habitats and food sources. The high primary productivity forest area has a high abundance of animals include various mammal species.

Normalized Difference Vegetation Index (NDVI)

- The NDVI calculation involves the infrared (IR) 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 infrared (IR) spectral region.

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

- For WorldView-2 data, IR and R are the reflectance for Channel 7 and Channel 5

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Normalized Difference Water Index (NDWI)

- NDWI are used as an indicator for 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 animal observed, most of the mammals in the study area and its surrounding areas are herbivores and omnivores. These mammals search their foods within areas of healthy vegetation with adequate source of moisture.

$$NDWI = \frac{Coastal - NIR2}{Coastal + NIR2}$$

- For WorldView-2 data, Coastal and NIR2 are the reflectance for Channel 1 and Channel 8,

Mammal Abundance & Biodiversity Index

- The **mammal abundance** obtained from in-situ camera trappings were used to compute biodiversity indices for the campus area, i.e.
  1. **Richness** - a measure of the number of mammal
  2. **Diversity** - the relationship between number of mammal and the number of individuals which will provides information on species rarity, commonness, and diversity .
  3. **Evenness** - expresses how evenly the individual species in a community are distributed among different species.

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* In this study, the Menhinick's richness index used to estimate the mammal species number which probably occurred. 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.

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

where

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

* Richness index is only concerned with the number of species occurrences

* Species diversity index provides information about the rarity, commonness and diversity of species in a community. The Shannon's diversity index was adopted due to its reliability and simplicity of computation. The diversity index ranges from 0 to 4, representing non-existence and perfect diversity.

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

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.

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* The evenness index describe the evenness of the number of mammals of each species in the particular area. The evenness index (**E) ranges from 0 to 1, representing non-existence and perfect** evenness.

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

where

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

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. NDVI and NDWI were adapted as spatial parameters to best represent the habitat of the animal.
* In addition, each of the spatial parameter 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.

RESULTS AND DISCUSSION

- The animal abundance map is created by Inverse Distance Weighted (IDW) interpolation of all set 1 camera trappings .
- There are 6 hotspots of abundance of the animal in the study area. Crosstabulating the abundance hotspots with campus plan.
- Note: all hotspots 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 source of food or attract smaller animals that in turn larger mammal predators. Evidently the abundance-generated map agreed independent set 2 test points.

6 main hotspots of wildlife in UTM campus

Table below shows the dominant species of animal at every hotspot in UTM campus.

Hotspot	Animal number	Dominant Animal Species
1	44	Wild boar
2	30	Long-tailed Macaque
3	30	Long-tailed Macaque
4	37	Long-tailed Macaque
5	34	Wild boar
6	30	Long-tailed Macaque

Hotspot	1	2	3	4	5	6
NDVI	0.317918	0.318393	0.082261	0.431036	0.364139	0.501157
Richness	3.999948	5.999949	4.999885	3.999876	3.999979	8.999472
Evenness	0.073546	0.501109	0.131856	0.735265	0.543112	0.296785
Diversity	3.27266	2.880776	3.249923	2.611701	2.685176	5.327552

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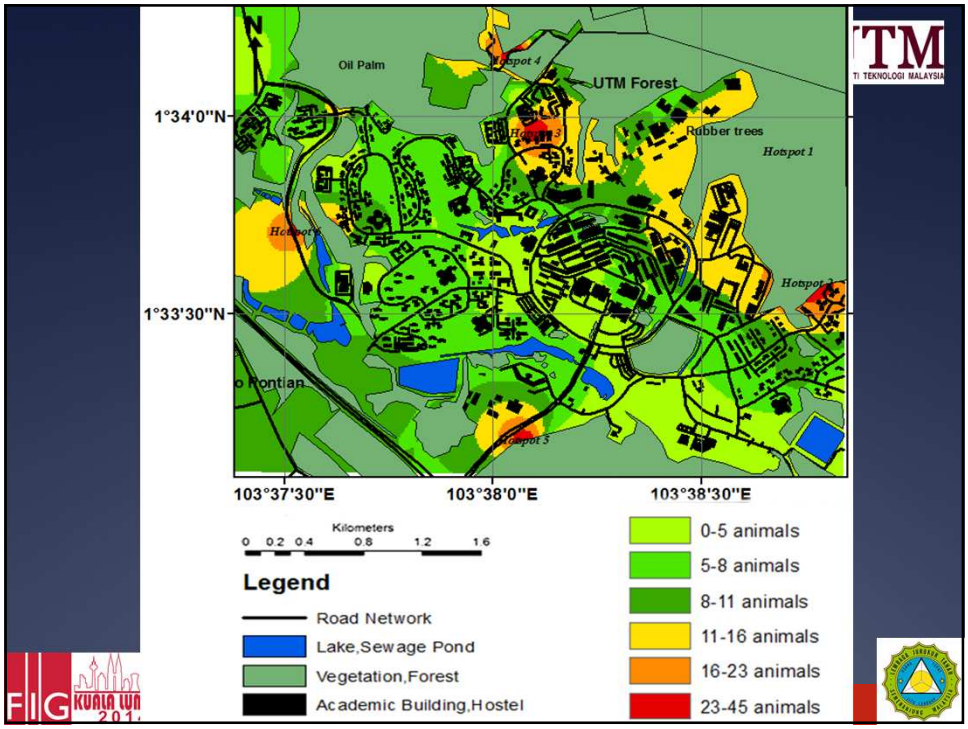
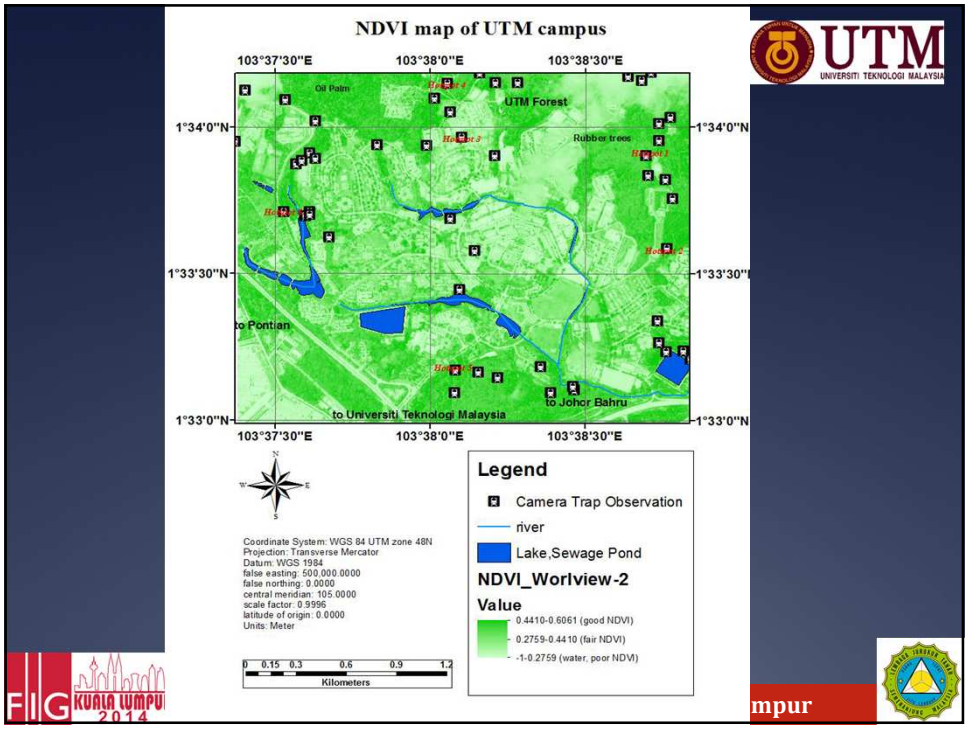
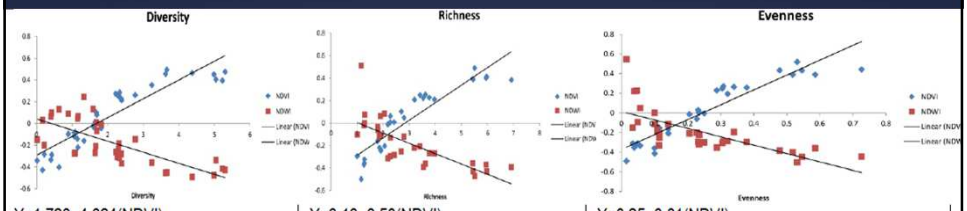


- NDVI and NDWI were created using WV2 dataset using set 1 camera trapping. The NDVI and NDWI empirically regressed against corresponding diversity, richness and evenness indices.
- The NDVI are directly proportional to all indicies (with $R^2 > 0.8$ and $P < 0.0001$) tested at 30 random points.



Empirical biodiversity model

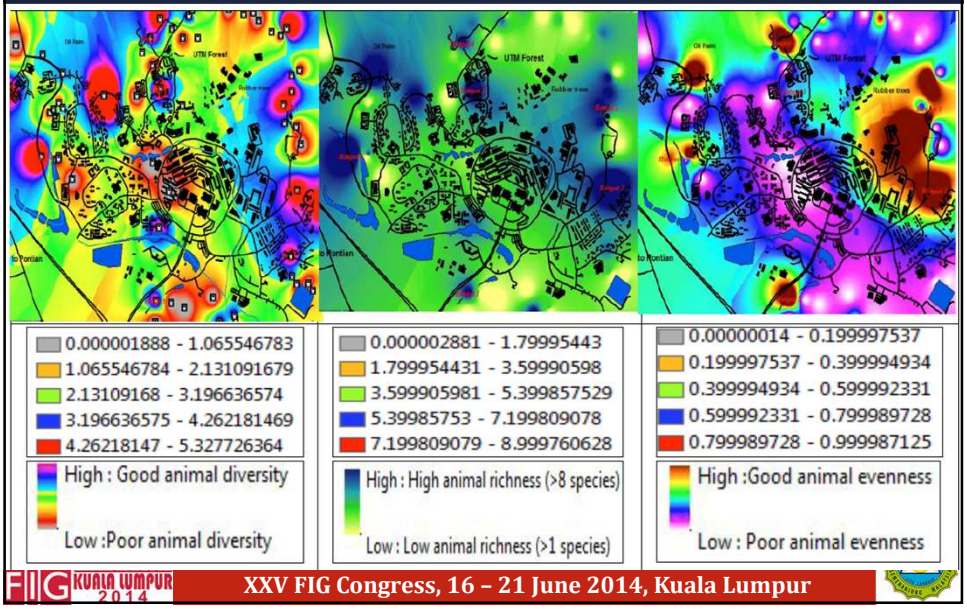
* Empirical model depicting relationship of spatial parameters derived from WV2 multispectral data.



Diversity	Richness	Evenness
Y=1.726+4.624(NDVI)	Y=3.13+6.50(NDVI)	Y=0.25+0.61(NDVI)
R^2=0.82	R^2=0.88	R^2=0.85
P=9.03E-12	P=5.26E-13	P=7.48E-14
N=30	N=30	N=30

- It is interestingly to note that NDWI is inversely proportional to all 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.

Biodiversity index for derived fully with WV2 dataset



Assessments

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

Biodiversity Index	RMSE
Diversity	1.860
Richness	3.654
Evenness	0.324

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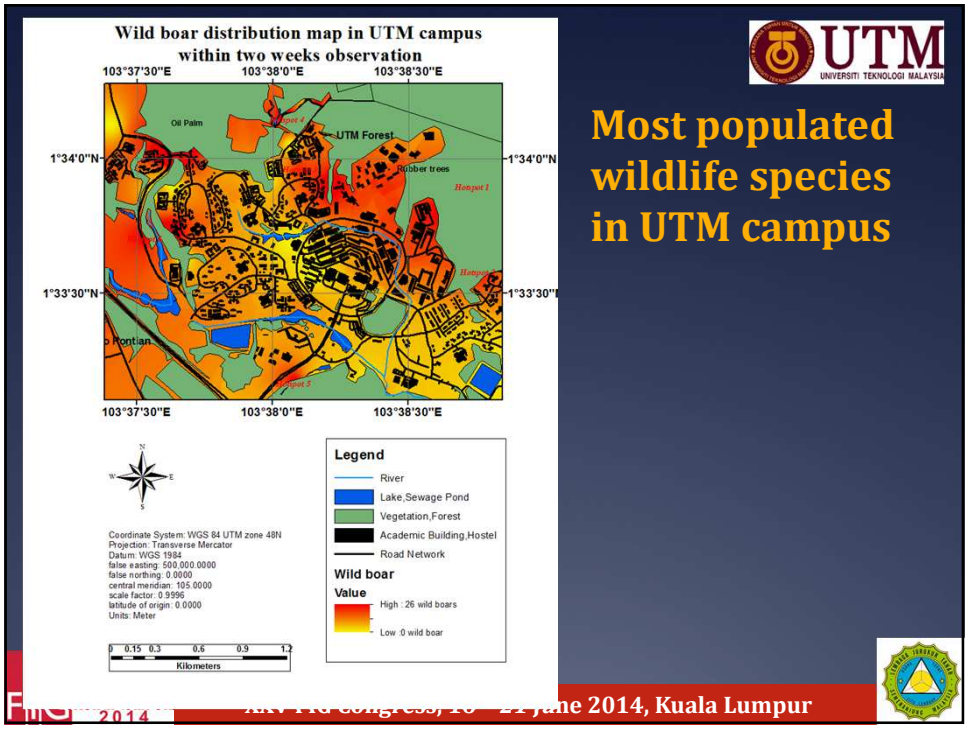
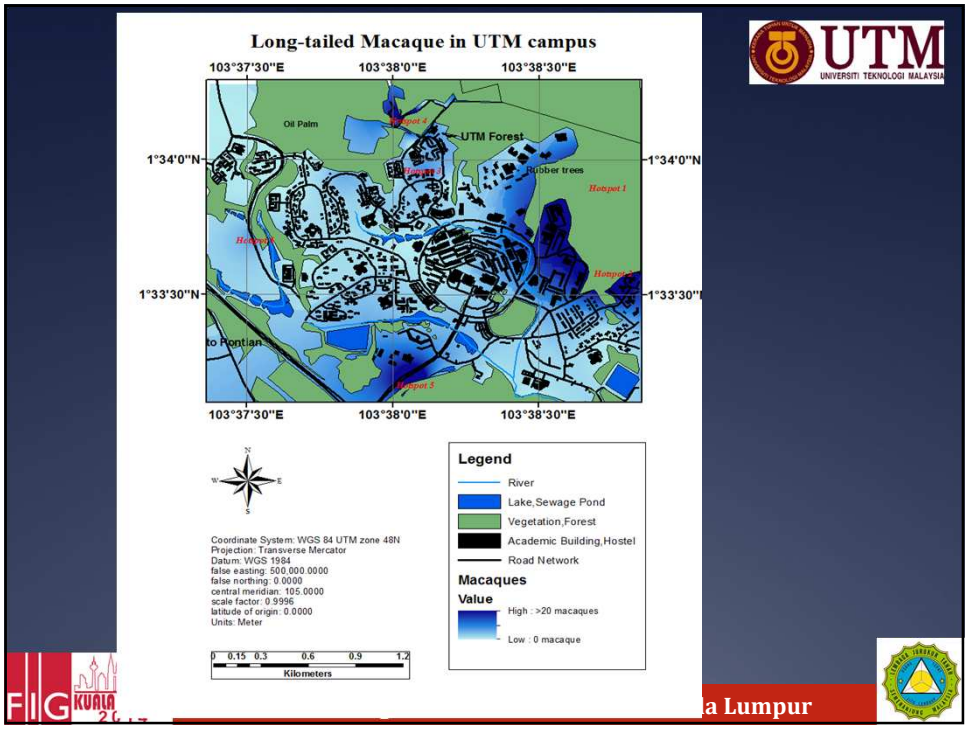


Most populated wildlife species in UTM campus



Conclusion

- The information derived from remotely sensed data with in-situ camera trappings offers an effective animal biodiversity monitoring and inventory activities, particularly for large areas requiring scheduled monitoring.
- This study also 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 eveness estimation.
- The mapping approach developed, with good accuracy, offers the method suitable for operational use. Furthermore the only nondestructive method for mapping of animal biodiversity for large areas, in timely and economically viable way.

Acknowledgment

- **Universiti Teknologi Malaysia.**
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