Gradsect theory and practice in biodiversity assessment

An integrated approach to biodiversity assessment using gradient-based survey design, data collection, analysis and mapping of terrestrial habitats

Andy Gillison
Center for Biodiversity Management
P.O. Box 120, Yungaburra 4884
Queensland, Australia
www.cbmglobe.org

Why gradient-based survey design?

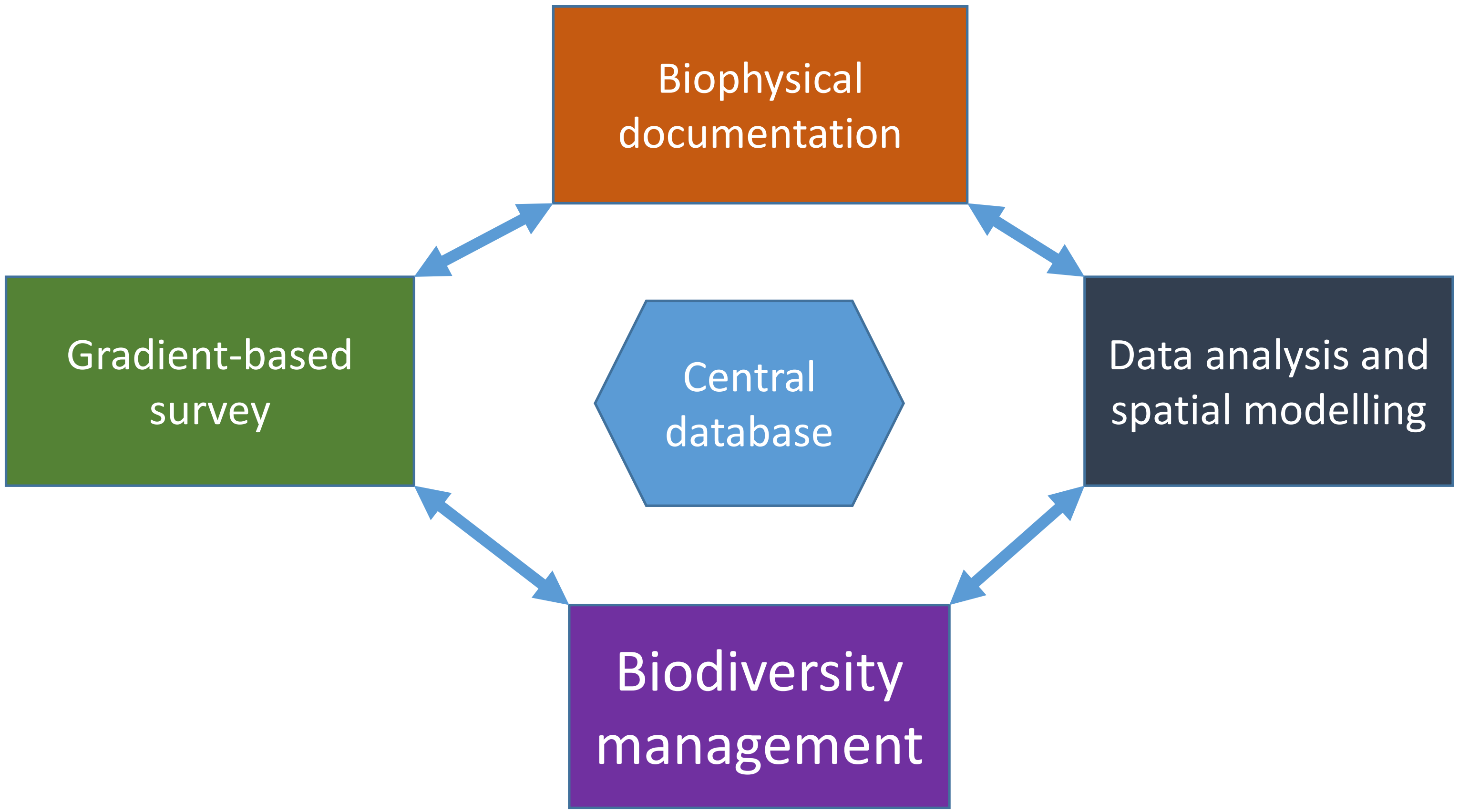
- Living things are rarely distributed at random, their distribution in time and space being controlled largely by environmental gradients
- Linkages between environmental gradients and the distribution of biota indicate a logical preference for gradient-based sampling
- Most practitioners intuitively sample along environmental gradients
- Statistical requirements for random or grid-based sample designs are frequently logistically demanding and rarely capture the required range of environmental gradients in a project area
- Restricted sampling of range distributions can generate misleading species performance models leading to inaccurate forecasts of species response to environmental impacts

Species	Elevation (m)										
	500	700	900	1100	1300	1500	1700	1900	2100	2300	2500
Plants											
Dipterocarpus tuberculatus											
Shorea obtusa											
Castanopsis sp.											
Chromolaena odorata											
Imperata cylindrica											
Smilax sp.											
Melastoma malabathrica											
Arisaema sp.											
Birds											
Collared Falconet											
Sooty-headed Bulbul											
Red Jungle Fowl											
Scarlet Minivet											
Striped Tit-babbler											
Grey-throated Babbler											
Arctic Warbler											

The effect of range distributions

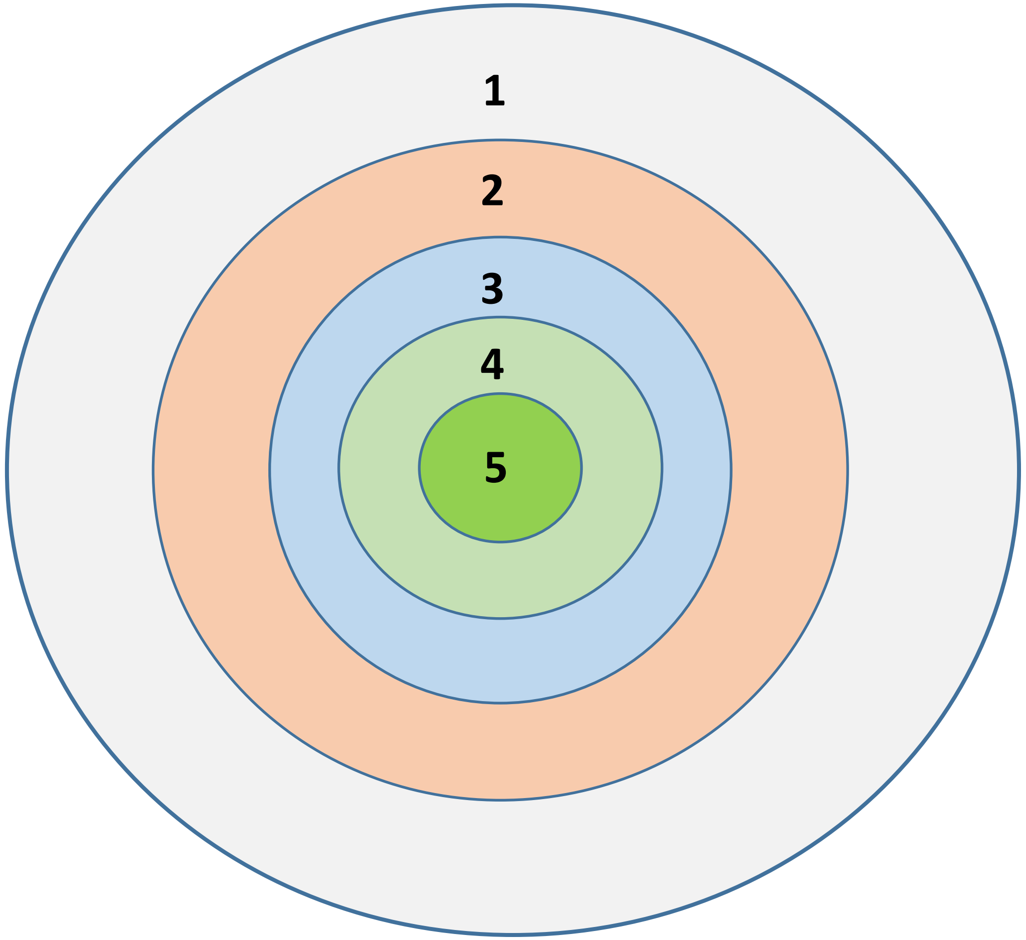
Samples restricted to 900-1100 m will lead to misleading models of species performance (response to environmental change) (Mae Chaem N. Thailand)

Constructing a biodiversity information baseline



What is a gradsect?

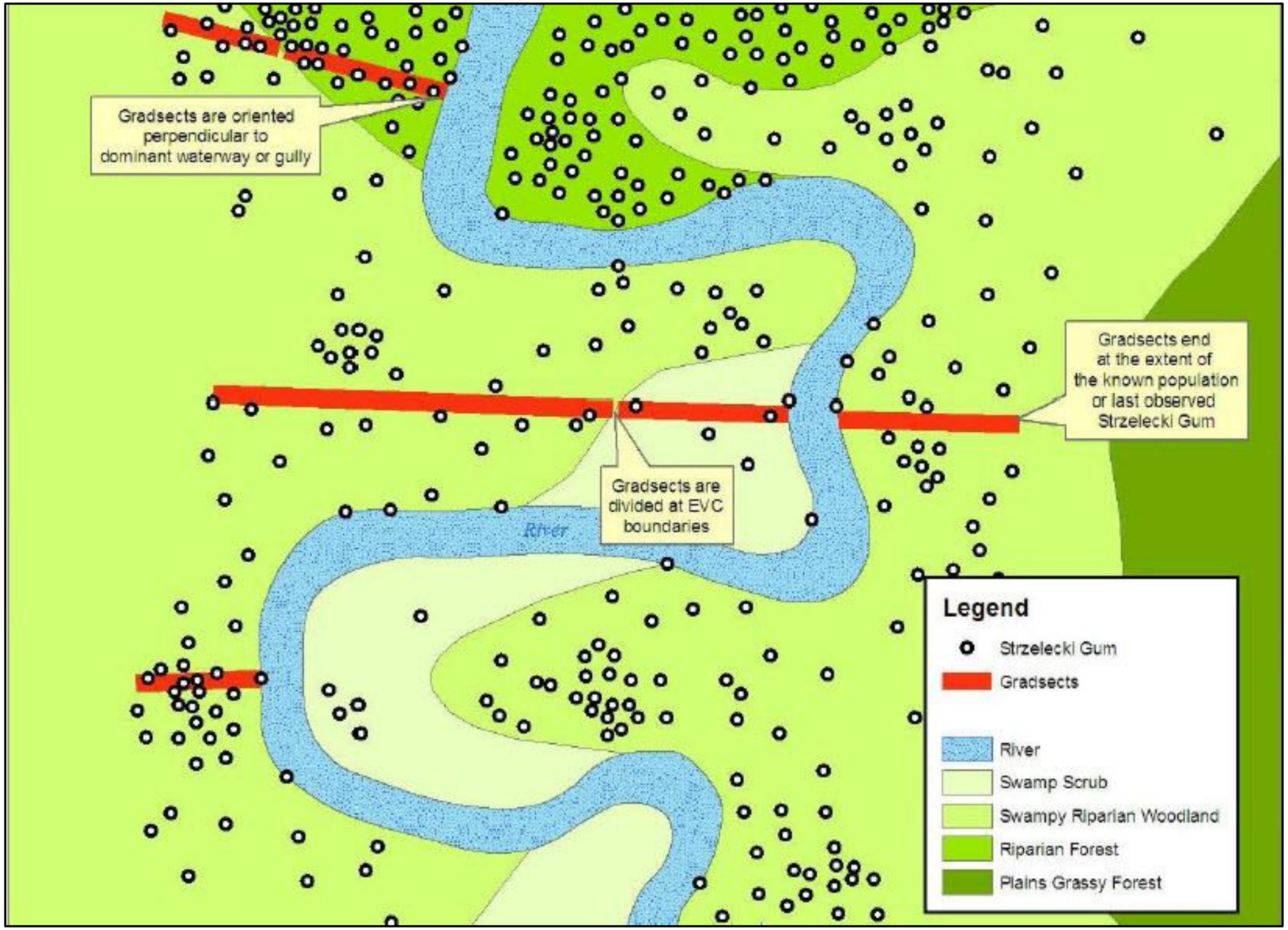
- **A gradsect** or *gradient-directed transect* is a low-input, high-return sampling method where the aim is to maximize information about the distribution of biota (Gillison 1984)
- **Gradsect design** is based on a hierarchy of environmental factors arranged according to perceived levels of importance (e.g. thermal, moisture, geomorphology, hydrology, soil, land use..)
- **Gradsect theory** allows for purposive selection of sample sites, avoiding the need for costly or ineffective random or systematic (e.g. grid) design (Gillison & Brewer 1985)



Example of a gradsect hierarchy

1. Elevation/ thermal (e.g. 0->1000 m asl) (primary)
2. Geomorphology/ lithology/ soil
3. Hydrology/ seasonality
4. Forest type/ cropping system
5. Riparian strip/ soil catena

Sample discipline requires that priority is given in descending order of environmental significance to achieve maximum environmental representation



Example of gradsect layout in a Eucalypt recruitment study (Schinagl et al. 2013)

Gradsect sampling principles

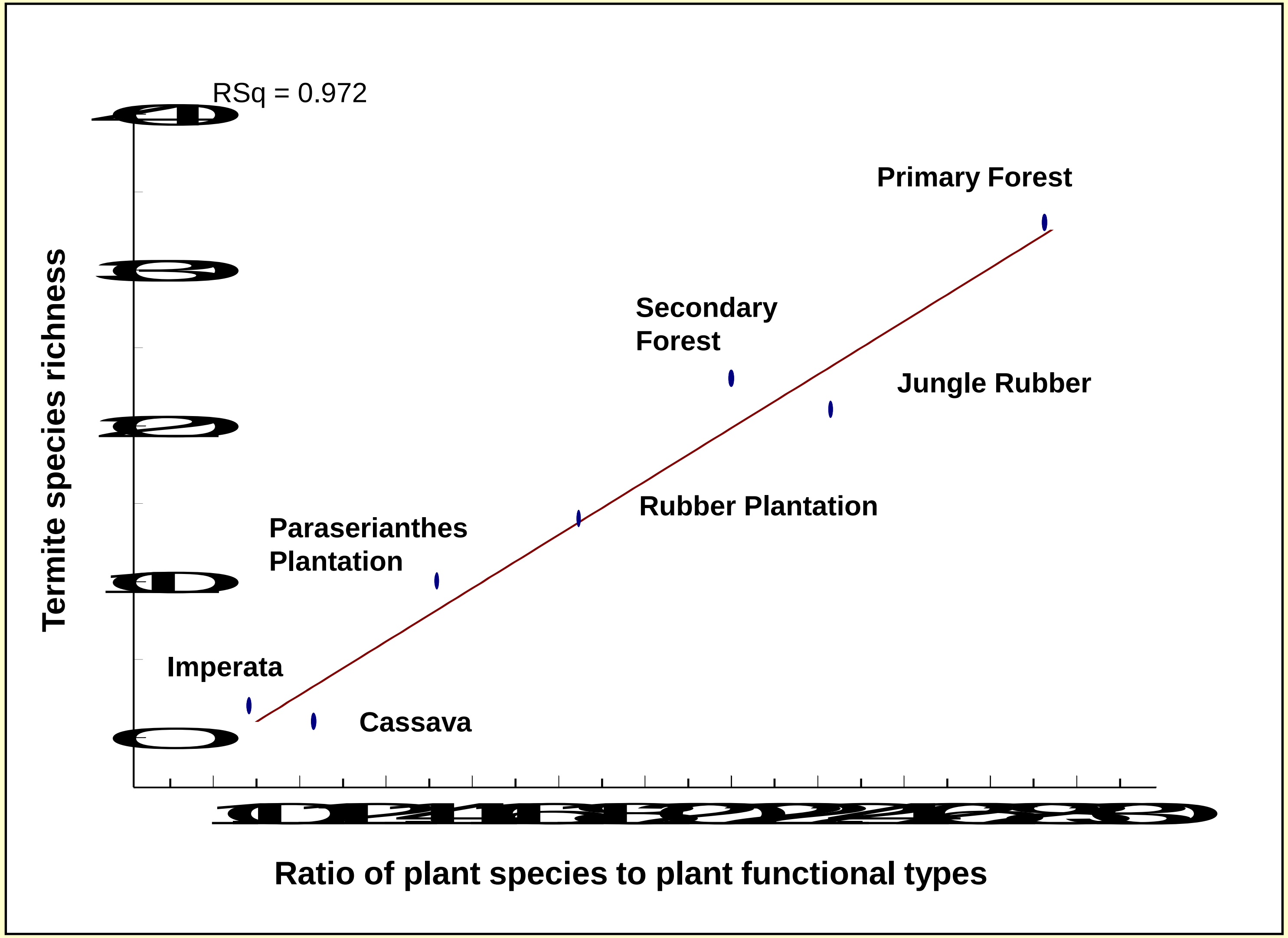
- The methodology should be statistically acceptable, logical and repeatable by different observers, and geared to purpose and scale
- Site documentation requires a standard sampling protocol such as uniform plot size and site descriptors and should encompass the maximum possible range of identifiable gradients
- Vegetation and land cover attributes should, as far as possible be sensitive to environmental variation and relevant to the project aims
- Species data complemented by plant functional types and vegetation structure provide a useful platform for characterising plant and animal habitat

Gradsects can be applied at multiple scales

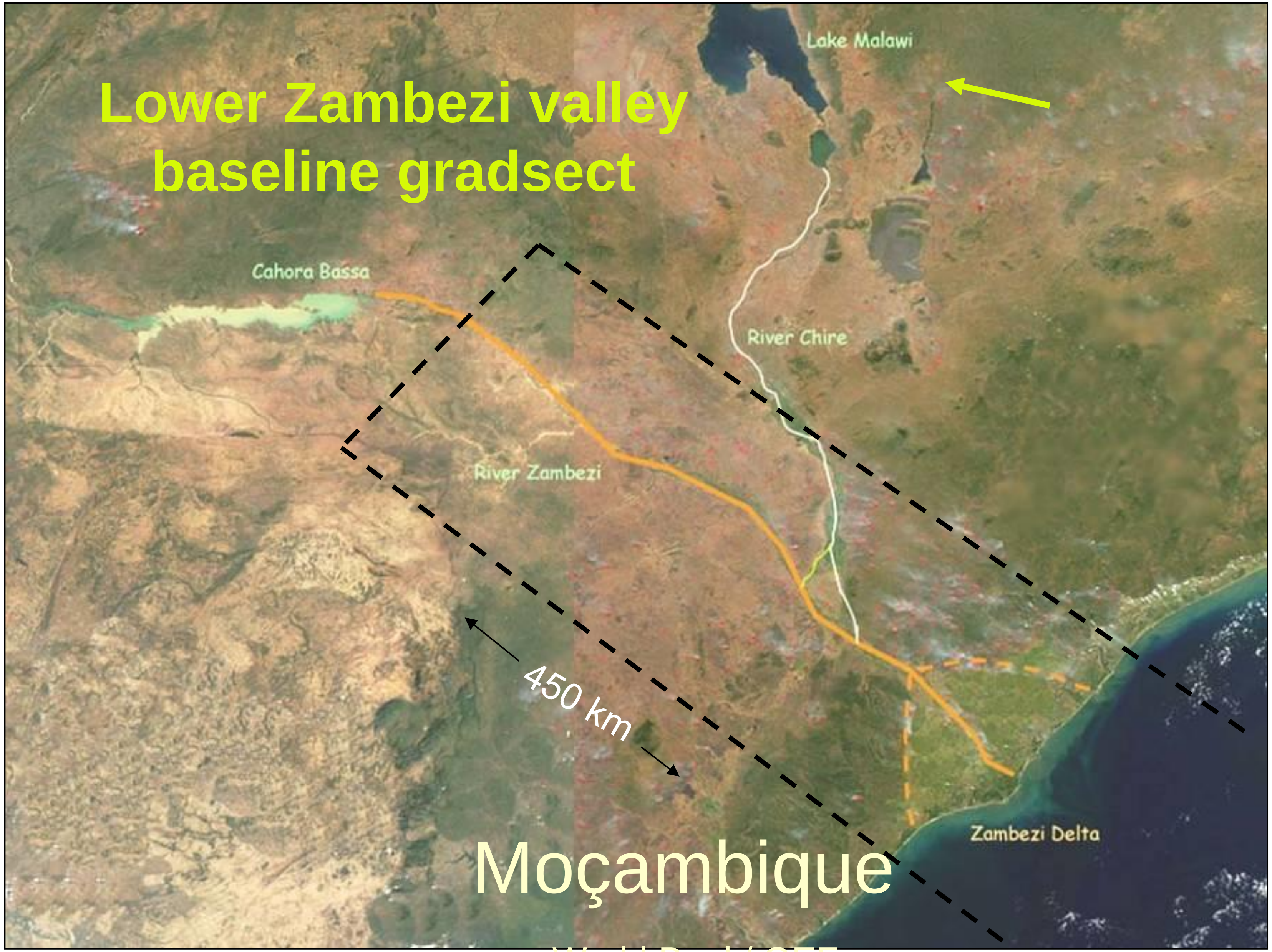
- Gradsects can be applied wherever there are detectable and measureable gradients of environmental drivers of species survival and persistence
- The following slides illustrate applications at local (Sumatra, Indonesia), regional (Mozambique, E. Africa) scales.

Example of a within-country gradsect

Ratio of plant species richness to plant functional types as an indicator of Termite species richness along a land use intensity gradient : Sumatra, Indonesia

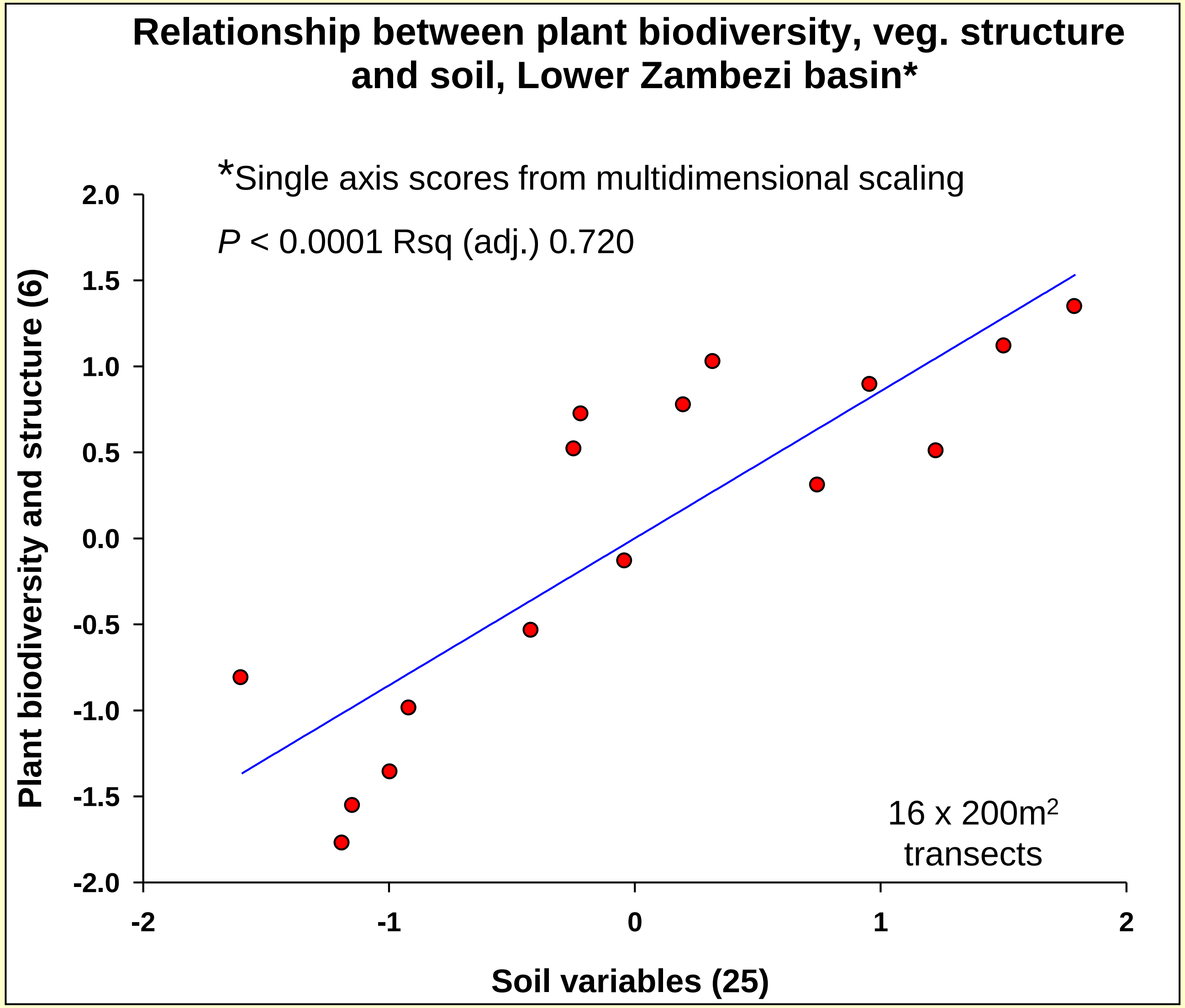


Source: Gillison *et al*. 2004, Bardgett (2005), ***The Biology of Soil***, Oxford Univ. Press



World Bank/ GEF
project 2006

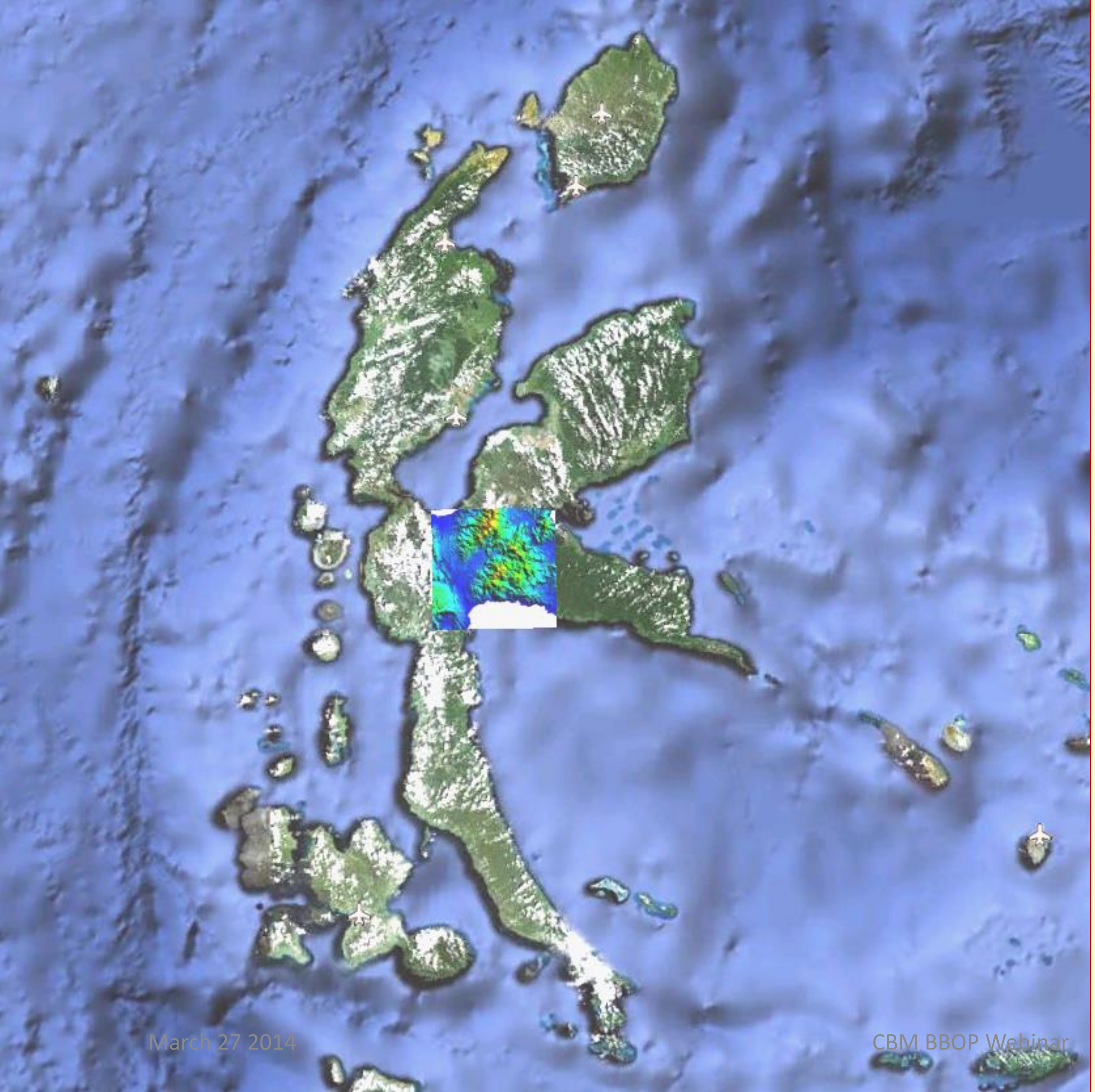
Biophysical predictors in a regional gradsect, Mozambique



Best soil predictors are: P (P <0.0001), O.M. (P <0.002), N (P <0.007), Sand% (P <0.006), Silt% (P < 0.010), Clay% (P <0.011).

Best plant predictors are: Crown cover woody plants (P <0.0001), Basal area all woody plants (P <0.0001), Mean canopy height (P <0.002), Species richness (P <0.0.017), PFT richness (P <0.023)

Source: The World Bank, GEF 2006

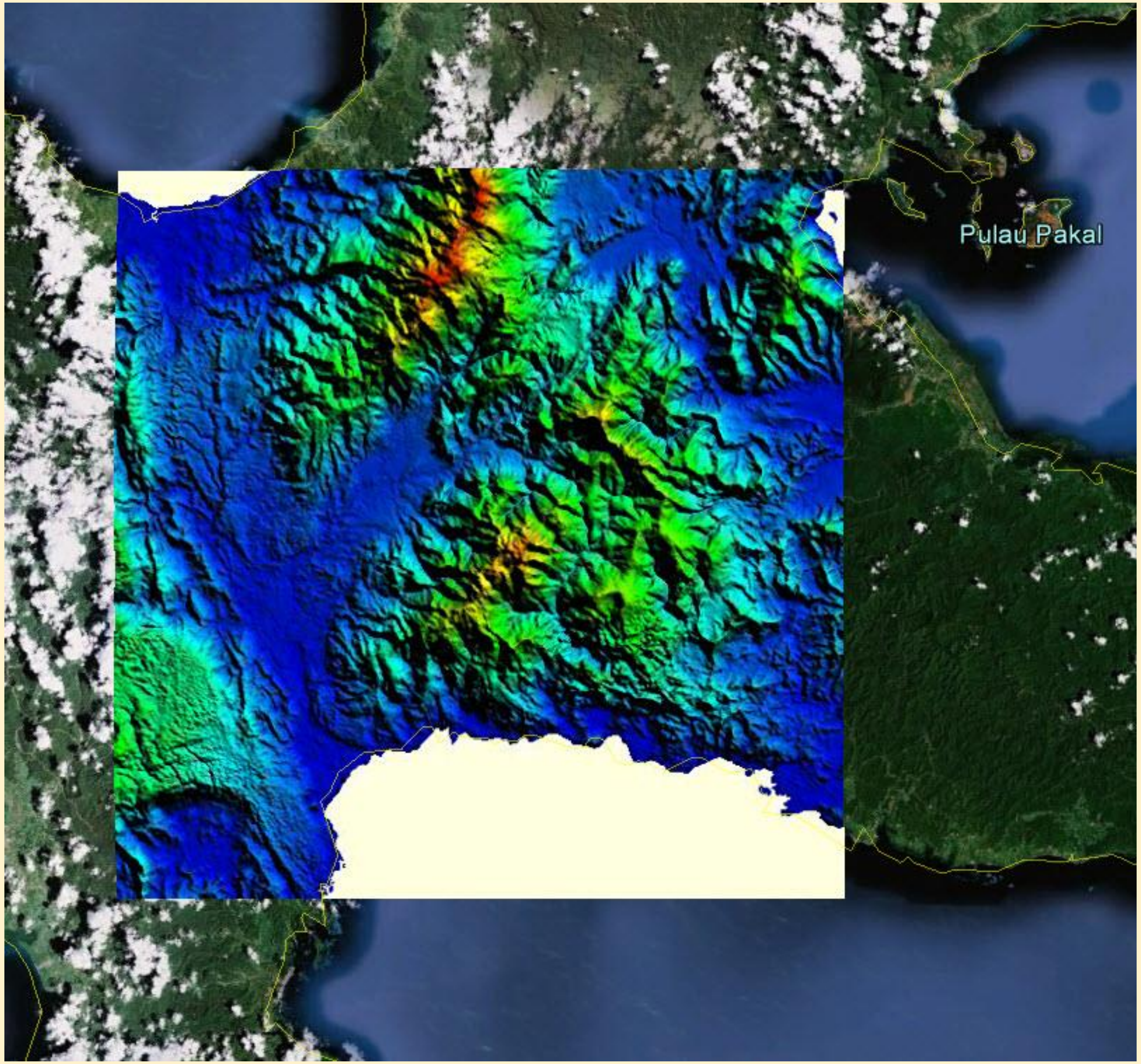


Gradsect case study in a resource impact area

Weda Bay Nickel: A world-class nickel and cobalt mining and hydrometallurgical processing project being developed on Halmahera Island, Moluccas, Indonesia

Aims: To facilitate accurate quantification of predicted biodiversity losses from residual impacts and to help ascertain critical offset feasibility determination and offset design specifications and to identify and refine appropriate mitigation.

Environmental data: were acquired from institutional sources and from aerial and ground reconnaissance



Section of Weda Bay relief

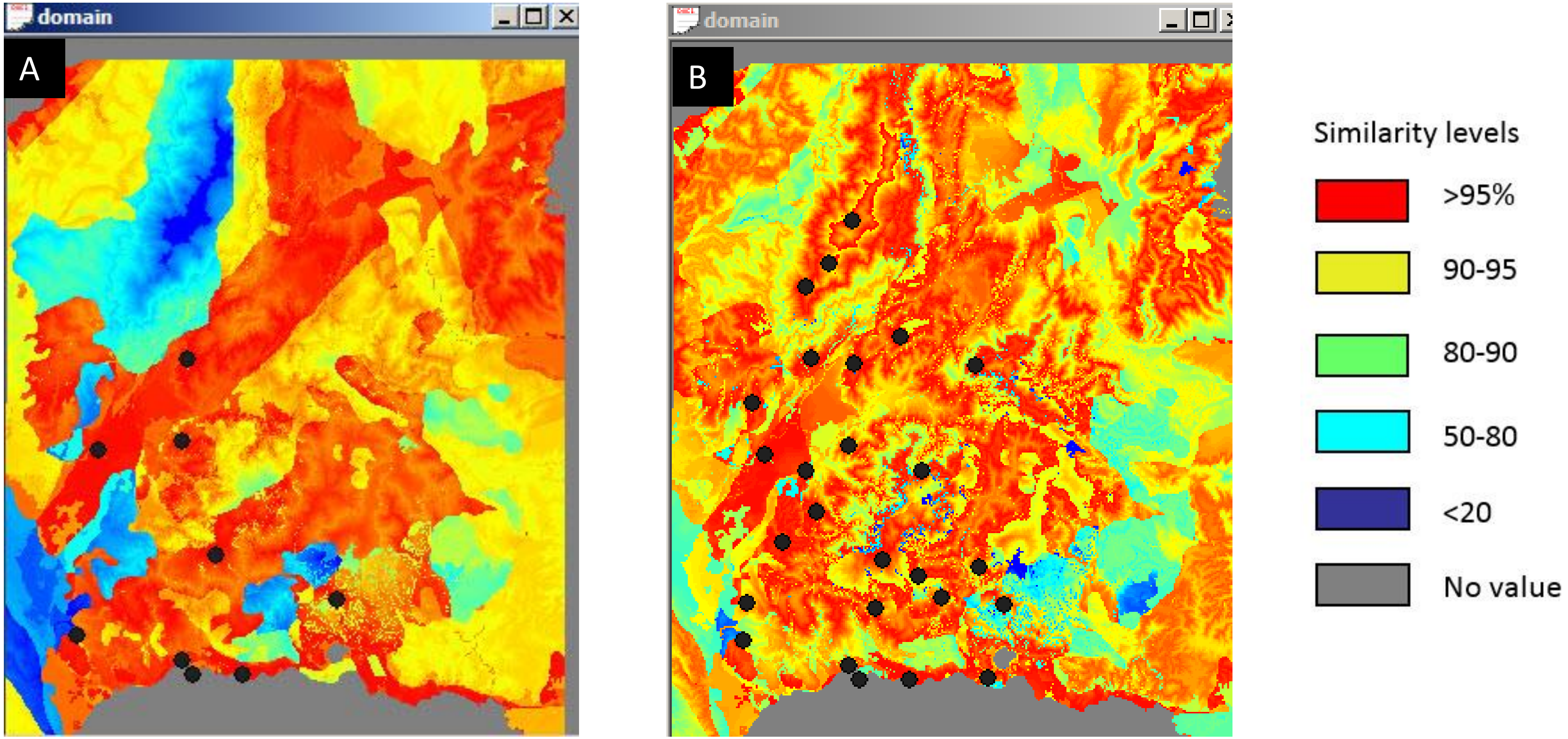
Section of Halmahera island, Moluccas, Indonesia showing topographic relief

Methodology for the WBN baseline survey

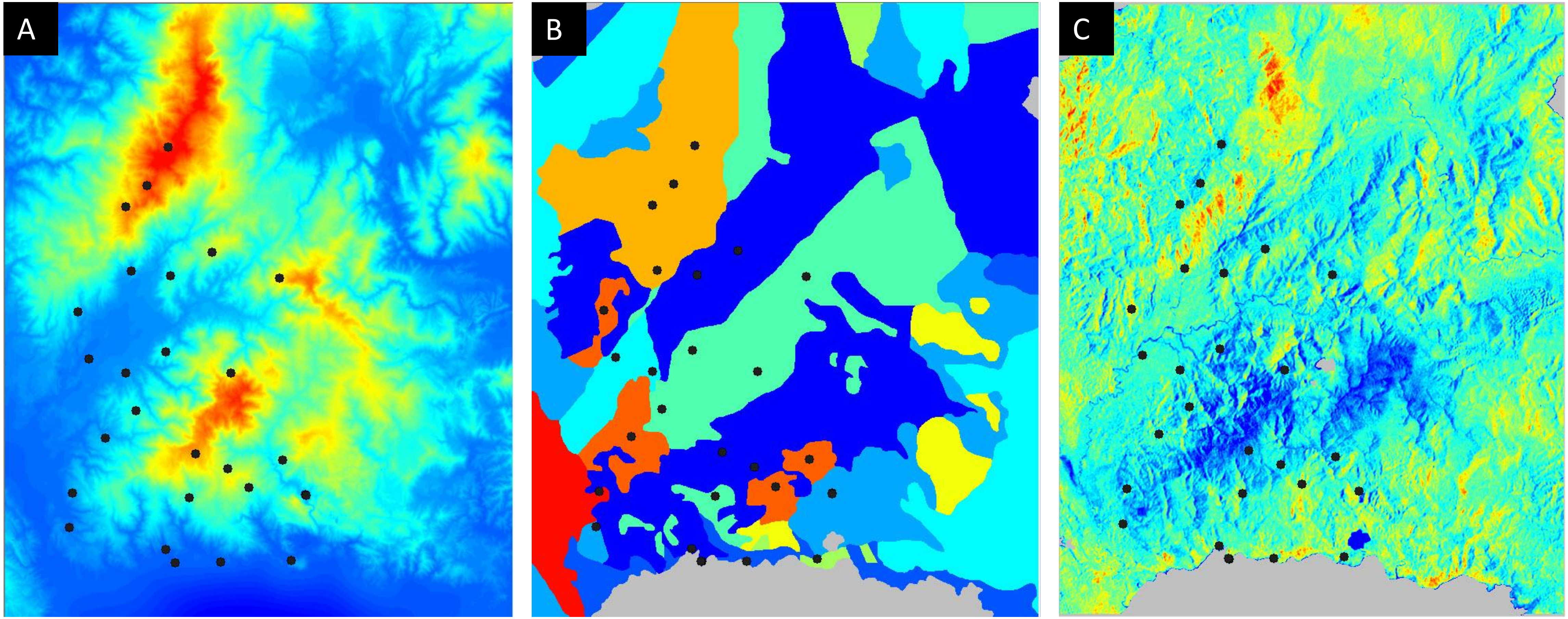
- All available institutional data and information were examined for evidence of environmental structure
- Ground and aerial reconnaissance enabled the location of 11 sample sites as a pilot gradsect
- Follow up, detailed ground survey of pilot sites provided key data on plant species, PFTs, vegetation structure, geology, soil properties and land use history
- Cluster analysis was used to identify putative ecosystems and habitats
- Iterative spatial modelling enabled the identification of 17 additional sites that were considered the minimum needed for a comprehensive survey

Spatial modelling of gradsects (DOMAIN)

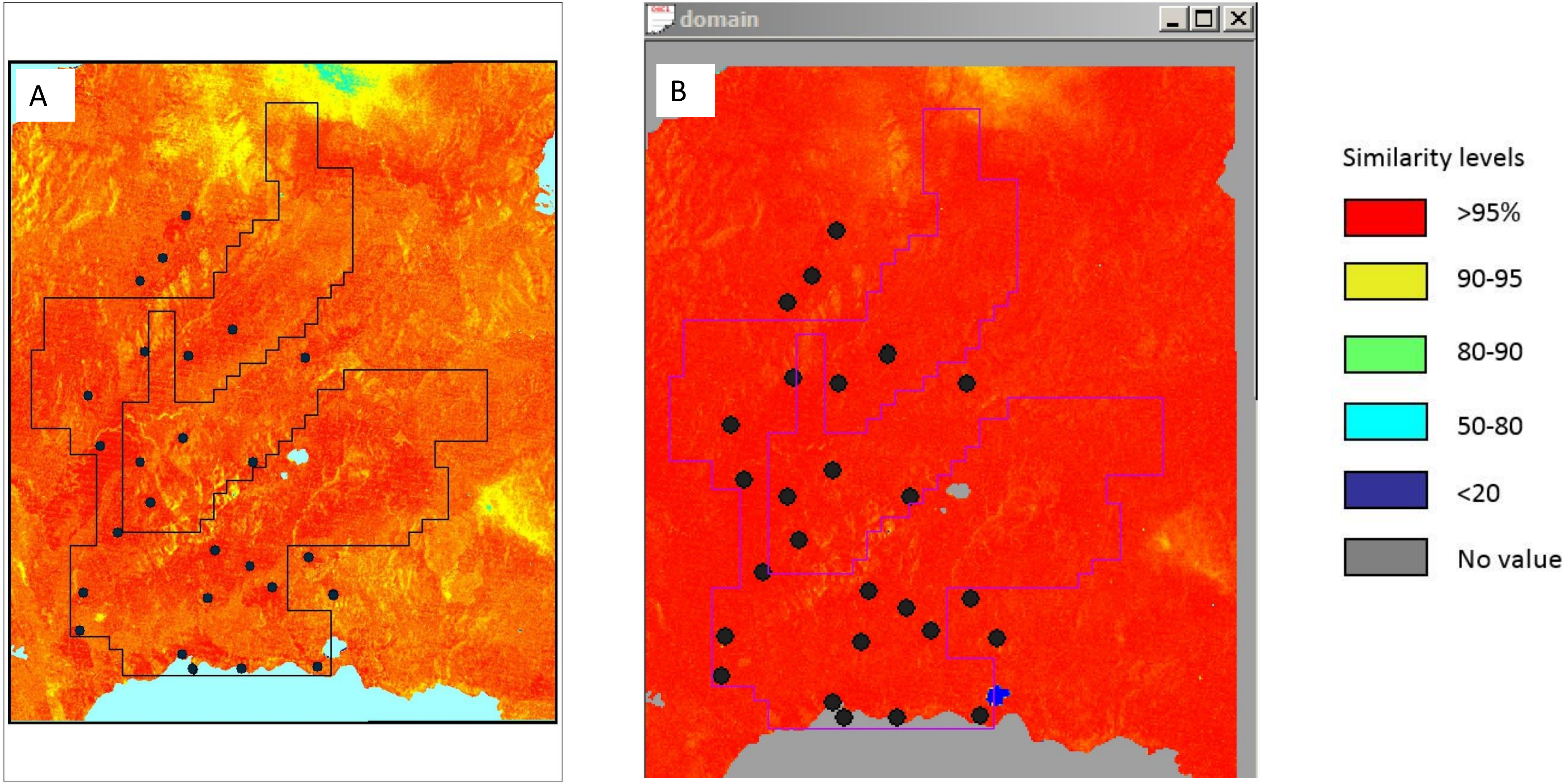
- DOMAIN: a public domain software package that generates maps of similarity or distance. For example to predict the potential distribution of a particular taxon, DOMAIN maps those regions which are most similar to areas where the taxon is known to occur.
- The measure of similarity is calculated for each coordinate (pixel) that intercepts 'n' environmental layers e.g. elevation, geology, remote sensing.
- DOMAIN is not limited to mapping potential distribution of taxa. For example in constructing gradsects it may be useful to map the regions which are least similar to a set of survey sites to test the adequacy of a sampling strategy. (see www.cbmglobe.org to download software) (see also Maxent)



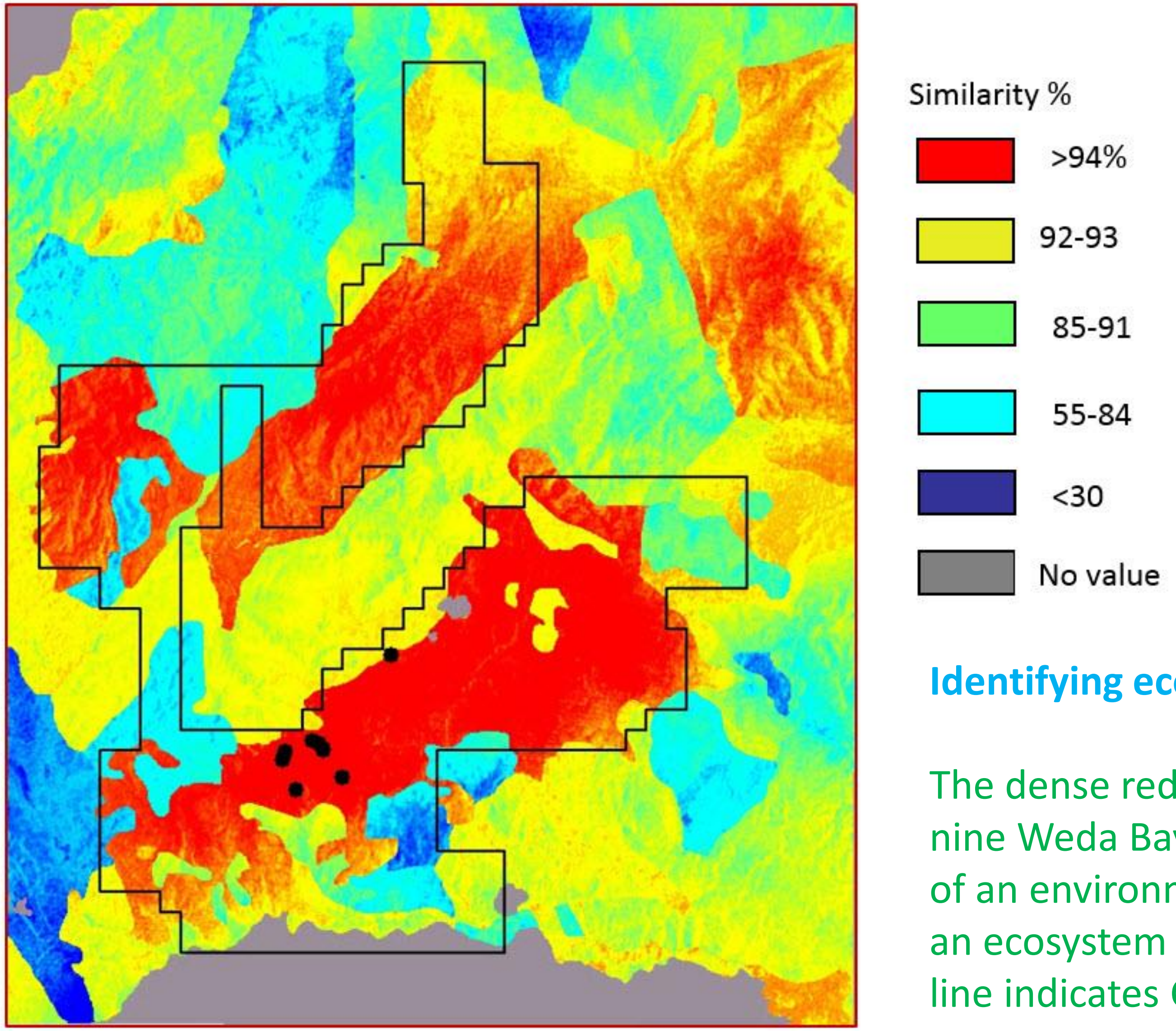
DOMAIN Spatial modelling of **pilot gradsect** point intercepts of elevation, geology and habitat classes in A) allows iterative placement of additional sample points to achieve maximum tradeoff between environmental coverage and logistics in B). This procedure can be repeated for additional biophysical layers **(Weda Bay Nickel)**



Gradsect sample points overlaid for maximum coverage of variation in A) Elevation, B) Geology C) Landsat band 7 Weda Bay, Halmahera Island, Moluccas, Indonesia (Source Weda Bay Nickel)



Environmental coverage when A) elevation, geology and Landsat Band 7 are added, B) When all remotely sensed data are added. Black line shows Contract of Work (CoW) boundary

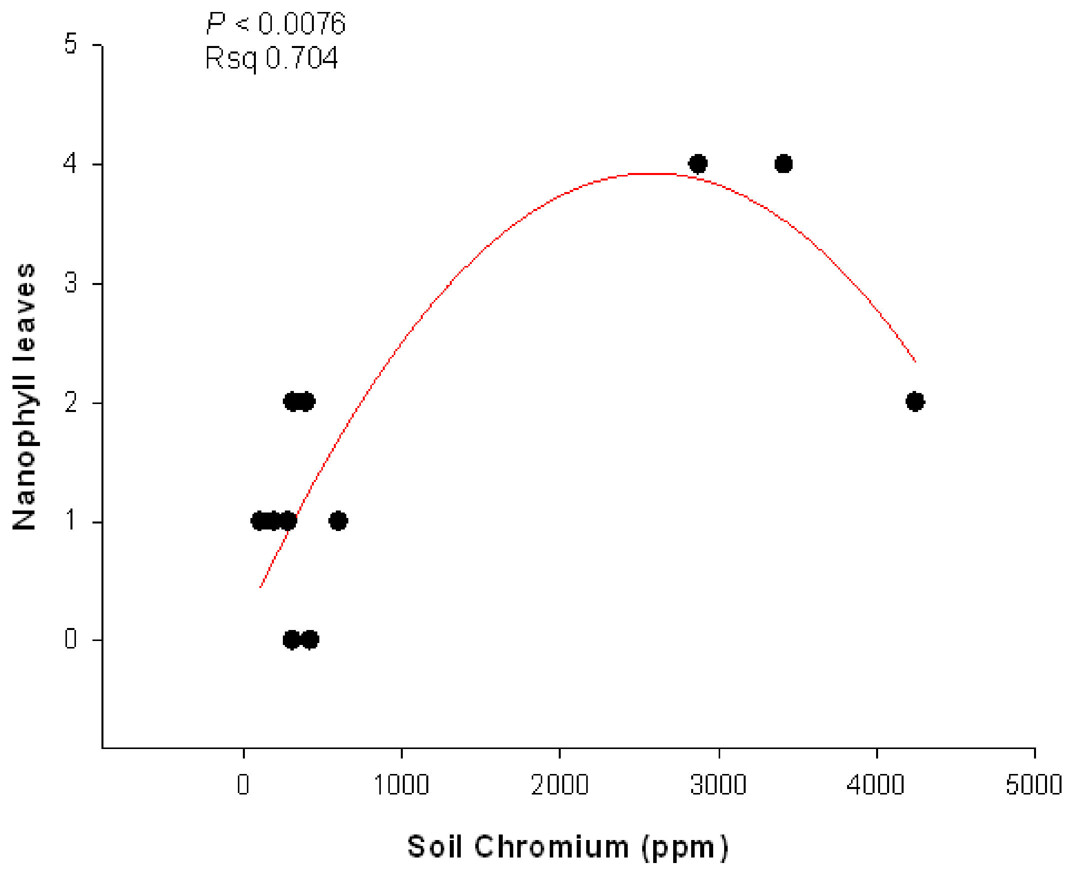


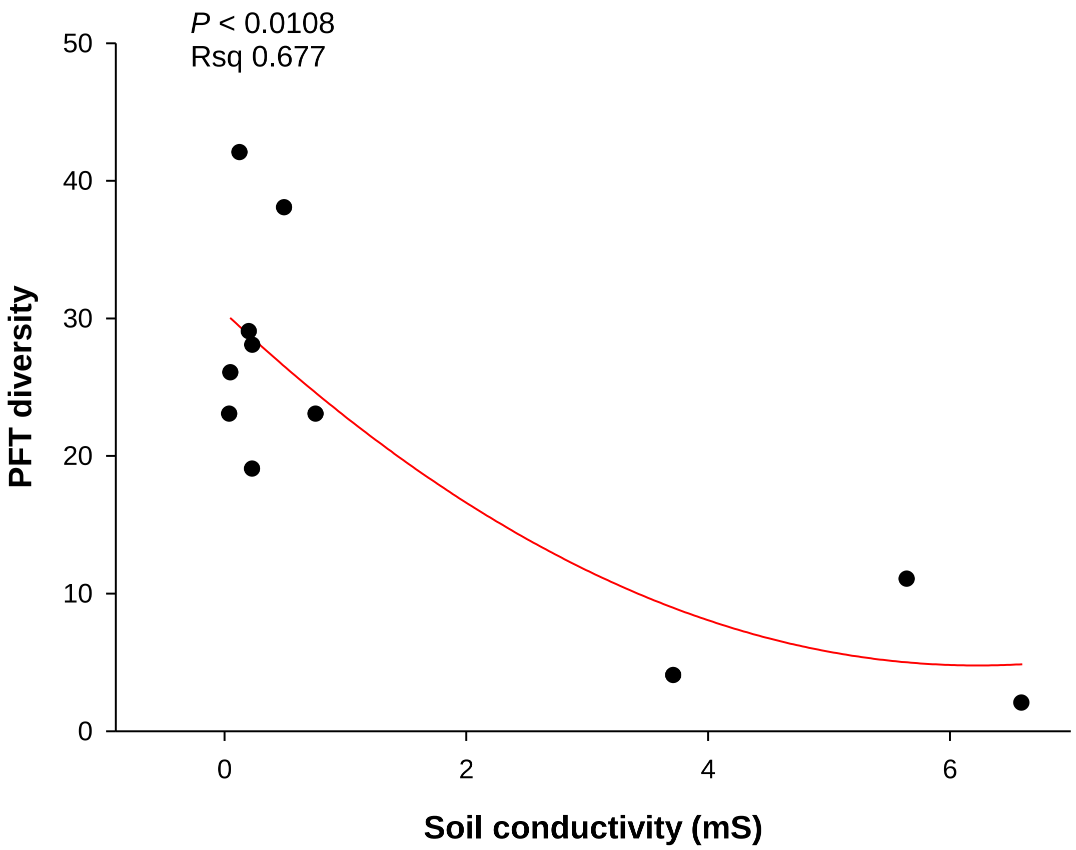
Ecosystem classification derived from cluster analysis of all Pilot sites

The Wallace golden birdwing
Weda Bay gradsect

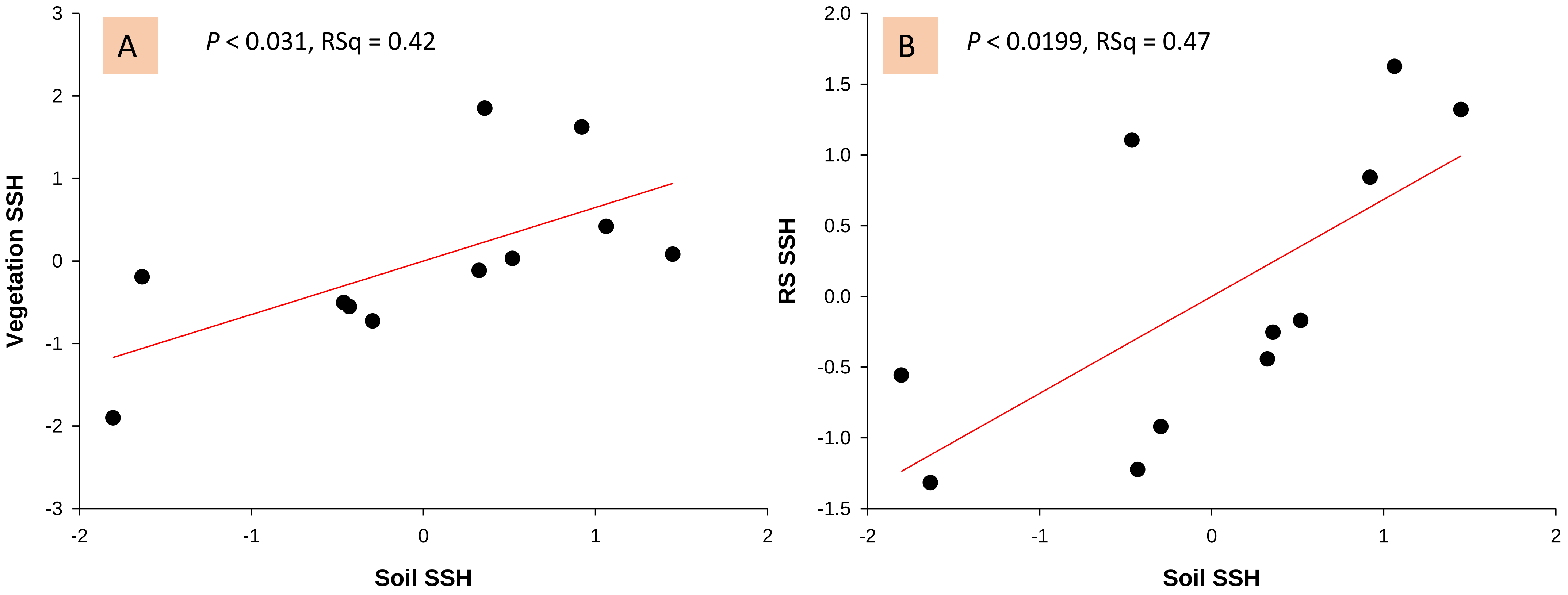
Identifying ecosystems based on gradsects

The dense red (similarity >95%) area surrounding the nine Weda Bay field sites (black closed dots) is indicative of an environmental domain that could be classified as an ecosystem for biodiversity mapping purposes. Black line indicates CoW boundary.





Two examples showing how data from a **pilot gradsect** indicate response patterns of plant functional traits and types (Trait assemblages) to soil mineral properties. This type of information is useful in designing a more complete survey and in prescriptive applications for species re-establishment (Source Weda Bay Nickel)



Ordination of **pilot gradsect** data show significant correlations between A) key vegetation (species, PFTs, structure) and B) remotely sensed (Landsat bands 4,5,7, NDVI) attributes and soil physico-chemical properties. (SSH = semi-strong hybrid scaling). Black dots indicate sample sites along gradsect. (Source Weda Bay Nickel).

Outcomes of a WBN pilot gradsect

- Spatial modelling of the integrated biophysical data enabled the detection of 'best bet' locations for biodiversity offsets and mitigation procedures as well as new and significant landscape-based information about ecosystems and biodiversity in WBN and Halmahera.
- The developing biodiversity baseline provides cost-effective and scientifically robust guidelines for three sequential phases of data acquisition and management and habitat mapping
- Finally, the outcome will help refine a set of criteria and indicators for critical habitat assessment and for managing and monitoring biodiversity impacts and mitigation outcomes both within and beyond the CoW
- **With thanks to Steven Dickinson, Gavin Lee, Robin Mitchell & staff at WBN**

From gradsects to biodiversity management

- Comprehensive environmental coverage combined with detailed land cover attributes provide predictive and testable linkages between species performance and environment
- Testable models of ecosystem and habitat classes facilitate matching biodiversity offsets at species and community level
- Fine scale models of individual species response to environmental variables provide basic information for prescribing target species re-establishment
- Species distribution and performance can be assessed within and beyond the project area when assessing net conservation gains

Gradsect pros and cons

Pros:

- Gradsects outperform standard statistical designs in all comparative studies thus far, improving capacity to locate species, rarities, functional types and habitat types
- Improved environmental representation leads to better spatial modelling outcomes such as habitat mapping
- When combined with plant functional traits gradsects add value to biodiversity management where species identification is problematic
- Provide a comprehensive, spatially referenced environmental framework for other project personnel

Cons:

- May require environmental data that are unavailable
- Gradsects cannot be used to estimate species occurrences per unit area – for which a stratified random sample design may be needed
- Subjective site selection can vary between observers and projects

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Thankyou !

Contacts and other references

- andygillison@gmail.com,
- andyg@cbmglobe.org
- www.cbmglobe.org (publications on gradsect applications)

Center for Biodiversity Management

P.O. Box 120 Yungaburra Qld 4884,

Australia Tel: +61-740-953224