Application of Remote Sensing-GIS to renewable energy resource assessment

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28 May 2009

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Outline

A. Why do we need to assess our renewable energy (RE) resources

- ***The importance of biomass as an RE resource***
- ***The importance of solar energy as an RE resource***

B. Introduction to Remote Sensing-GIS

C. Remote sensing-GIS as a tool for RE resource assessment – case study 1: biomass resource assessment

D. Case study 2: solar energy resource assessment

A. Why do we need to assess our renewable energy resources?

- Suppose we wish to install a renewable energy (RE) power generation system (power plant) to provide the energy needs of a community

The essential planning/analysis steps:

RE resources → **RE technology** ← **Energy demand**

What energy resources are available?

Develop appropriate RE technology

What are the energy needs of the community?

Need for renewable energy assessment (cont.)

- We need both an energy demand survey and a resource assessment before choosing the appropriate renewable energy technology (RET)
- We also need to determine the rated capacity of the installation
- No use spending funds on large capacity plant if resources limited – no economic sense
- At the same time we need to maximise the use of the available RE resources
- - i.e. we need to estimate the power factor (actual output/rated output) wisely

Need for RE assessment (cont.)

Resource assessment is an indispensable part of the development of a renewable energy power generation system

The importance of biomass as a RE resource

- Biomass is amongst the four major RE resources: hydro, solar, biomass, wind
- Woody biomass, industry and agricultural residues used for thermal power plants in Fiji (Tropik Wood, FSC, plans for Deuba and Savusavu)
  - Need to assess forest and agricultural cover of PICs
- Biofuels – coconut oil (CNO) as biofuel for transportation and power generation, feedstock for biodiesel
  - Need to assess coconut tree cover of PICs

The importance of biomass as a RE resource

We need to assess our biomass resources to make informed decisions about the development of our stationary and transportation energy needs.

The importance of solar energy as a resource

- Solar energy is abundant and freely available in the tropics –especially the Pacific Island Countries (PICs)
- Need to obtain estimate of incident solar radiation at intended location of solar energy system (e.g solar panel)
- Low resolution information on distribution of solar radiation is readily available (e.g. NASA),
- Information on total radiation at any specific location rendered unreliable by local reflectance effects – need to measure it directly.
- Need a method of accurately predicting solar radiation at any specific location (fine-scale data)

The importance of solar energy as a resource (cont.)

We need to have a method of assessing detailed (fine-scale) distribution of solar radiation reliably to locate PV panels better.

RS-GIS as a tool for RE resource assessment

- Remote Sensing- GIS provides an excellent tool for carrying out both these types of assessments.
- It can cover large areas, and store information conveniently to compare temporal changes in the resources
- No problems of accessibility
- Problems with cloud cover – but use radar-based RS

B. Introduction to Remote Sensing-GIS

- Remote Sensing is the science of acquiring spectral, spatial and temporal information about material objects, land area and phenomena from a distance (e.g. via satellite.)
- Detects (reflected or emitted) electro-magnetic radiation from objects using sensors
- Passive RS – sensors detect reflected or emitted radiation from object
- Active RS- sensors detect reflected responses from objects that are irradiated artificially, e.g. by radar.

Introduction to Remote Sensing-GIS 2– Components of RS technology

The technology used in Remote Sensing may be analysed into

- **Platform** (the vehicle that carries the sensor)
- **Energy source** (passive system – sun; active system – e.g. radar)
- **Sensors** (device to detect EMR – eg. Camera, scanner etc)
- **Detection** (handling signal data – e.g. photograhic, digital etc)
- **Processing and institutionalisation**

Introduction to Remote Sensing-GIS 3 - Platforms

LANDSAT series of satellites

- owned by US institutions (NASA, NOAA, Space Imaging)
- Landsat 1,2 originally called ERTS1, B
- Lansat 3,4,5 launched 1978,82,84 – improved sensors – only 4, 5 still operational

SPOT satellites

- launched by France 1986-2002

New generation satellites

- Quickbird, IKONOS, EROS–A1, SPOT 5

Introduction to Remote Sensing-GIS 4

- ***Important characteristics of image***
  - Spectral characs (wavelength bands, nm)-visible to NIR to microwave
  - Spatial characs (resolution, m)
- ***Key factors affecting RS***
  - Altitude: low altitude = high resolution
  - Instantaneous field of view (IFOV) of sensors

Introduction to Remote Sensing-GIS 5 —

Landsat 4,5 characteristics

Band	λ (μm)	Resolution (m)
1	0.45-0.52	30
2	0.52-0.60	30
3	0.63-0.69	30
4	0.76-0.90	30
5	1.55-1.75	30
6	10.40-12.50	120
7	2.08-2.35	30

Introduction to Remote Sensing-GIS 6 – Quickbird characteristics

Band coverage	λ (nm)	Resolution
Black and white	450-900	61 cm
blue	450-520	2.44 m
green	520-600	2.44 m
red	610-680	2.44 m
Infrared	790-900	2.44 m

Introduction to Remote Sensing-GIS 7 – geographical information system (GIS)

- The information collected by RS and ground-based means can be stored in a computer-based information system
- Stored as separate layers
- Includes e.g. digital elevation models (DEMs)
- Used to inform decision-making whenever required

C. Case study 1: biomass resource assessment – CNO as biofuel

- Coconut oil (CNO) as biofuel – Rotuman study by Gerhard Zieroth and Leba Gaunavinaka,(2007) [1].
- Used high-resolution satellite imagery (Quickbird) to assess coconut resources in Rotuma.
- Resolution of 60 cm allows identication of vegetation types

Case study 1:CNO as biofuel (cont.) – stratification of vegetation

- Managed to stratify vegetation cover (visible region) into 7 distinguishable categories
- a) **hill vegetation**
- b) **scrub** and **agricultural vegetation**
- c) **human infrastructure** (housing, airport runway, roads)
- d) **natural forest**
- e) **scattered coconuts**
- f) **natural coconut**
- g) **coconut plantation**

Case study 1:CNO as biofuel (cont.)

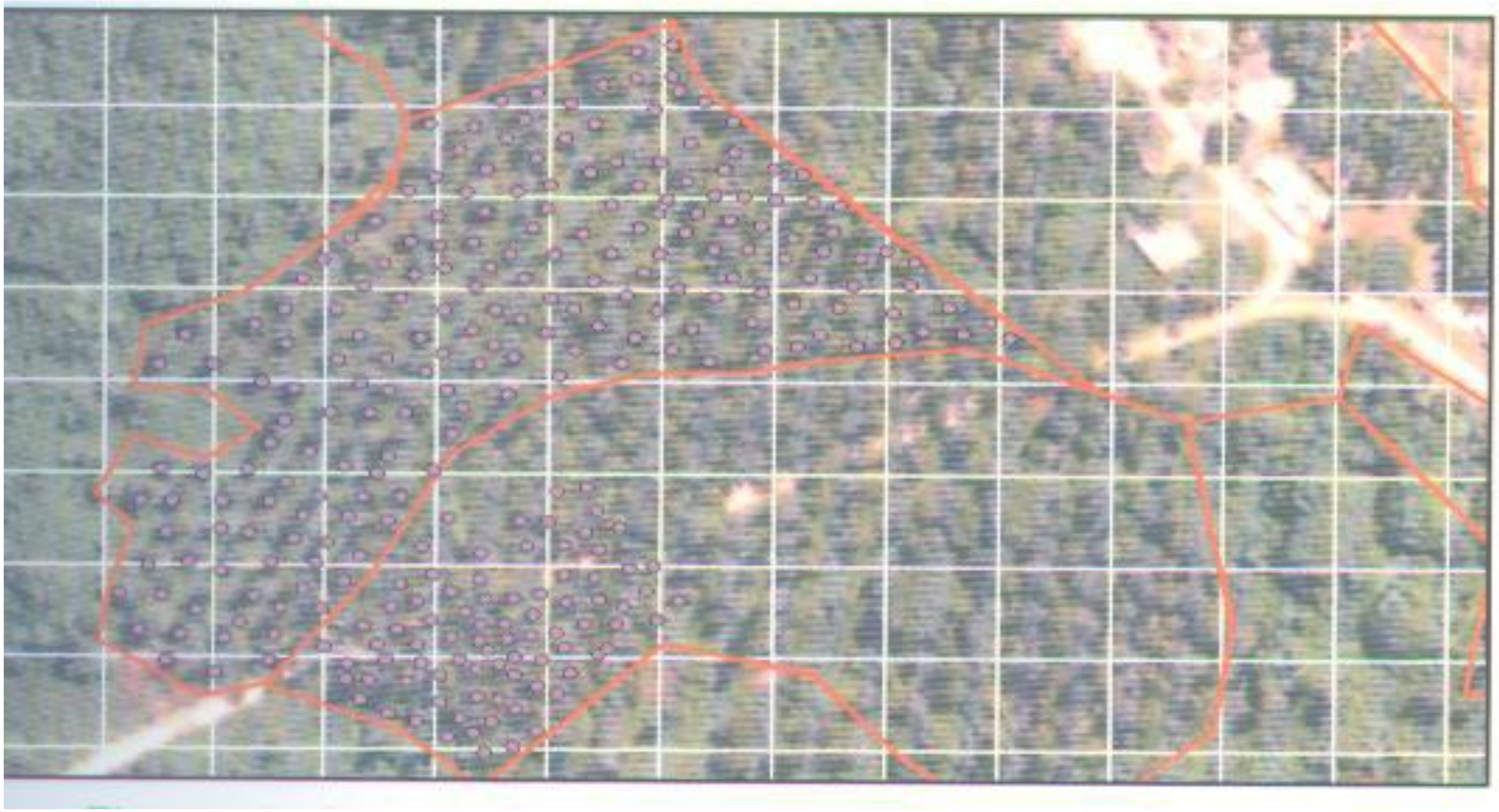
Found

- a) and b) strata had no coconut palms of note
- Some palms existed in c) around houses but not viable for biofuel production
- Natural forest (d) formed 83% of Rotuma, but very low density of palms (< 10 palms/ha)
- Scattered coconuts occurred over 8% of land area – very costly to harvest

Case study 1:CNO as biofuel (cont.)

- Natural forests – remnant or unmanaged plantations, palms of all ages - harvesting possible, but costly due to scatttered distribution, undergrowth poses accessibility problems
- Coconut plantations (g) – where plantation lines clearly visible, formed 8% of land – easy to harvest
- Low undergrowth means easy access during harvesting

Case study 1:CNO as biofuel (cont.) – pan-sharpened image of coconut plantation in Rotuma



Case study 1:CNO as biofuel (cont.) - Conclusion

- ***The last 2 strata (coconut plantation and natural coconut) considered viable for biofuel production*** (i.e. coconut harvest on a commercial scale)
- Area of above was 880 Ha or 20% of land area
- Coconut plantations had density of palms = 128.6 $\pm$ 34.5 per ha

D. Case study 2: solar energy radiation resource assessment

- There is a need to estimate the local (fine scale) direct solar radiation to accurately assess the potential solar radiation (i.e. solar energy resources) at any location.
- A method has been developed by Kumar et al (1997) [2] of the University of New England, Australia:
  - Used an algorithm to calculate direct solar radiation at any geographical location from solar azimuth, altitude, and declination
  - Allowed for attenuation through atmosphere

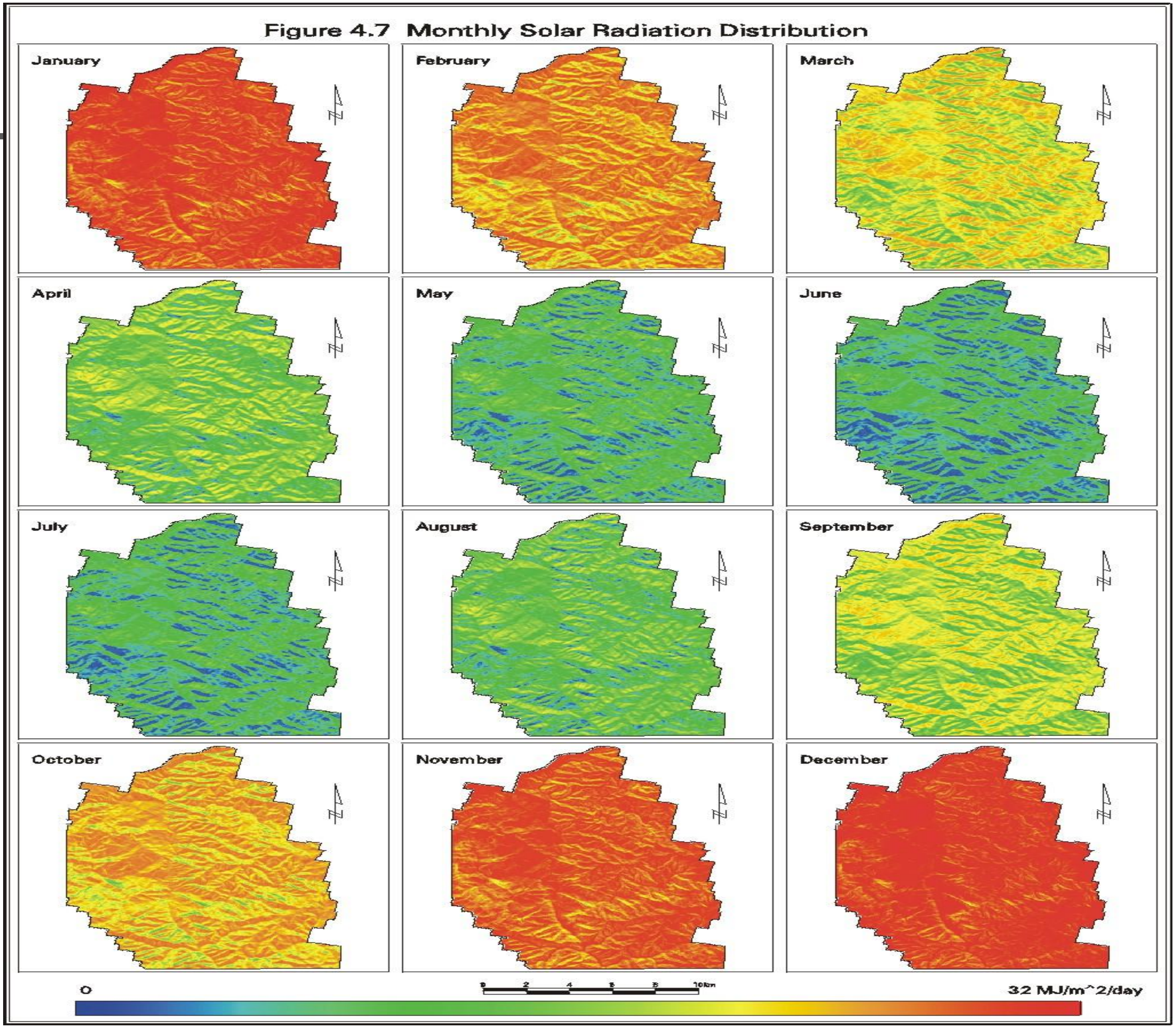
Case study 2: solar energy radiation resource assessment

- Input elevation, slope, aspect data from a **Digital Elevation Model (DEM)** of the region to evaluate the incident radiation flux on any surface
- Tested the model on an actual site to predict the distribution of direct solar radiation in space and time
- Used actual data to find correlation between model predictions and measured data
- Used correlation equation to predict values of actual data

Case study 2: model testing

- Algorithm first used to compute potential shortwave radiation at Nullica State Forest (latitude 36.5^{o} S) near Eden, NSW.
- Site is rugged, with elevation ranging from 9 to 880 m.
- Total area of 16406 ha was divided into 182288 grid cells each of area 30m x 30m.
- Solar radiation calculated every 30 mins, and then integrated to yield daily values.
- Monthly results are displayed in next slide – note summer months highest, winter months almost zero. Also effect of shadowing esp in winter months.

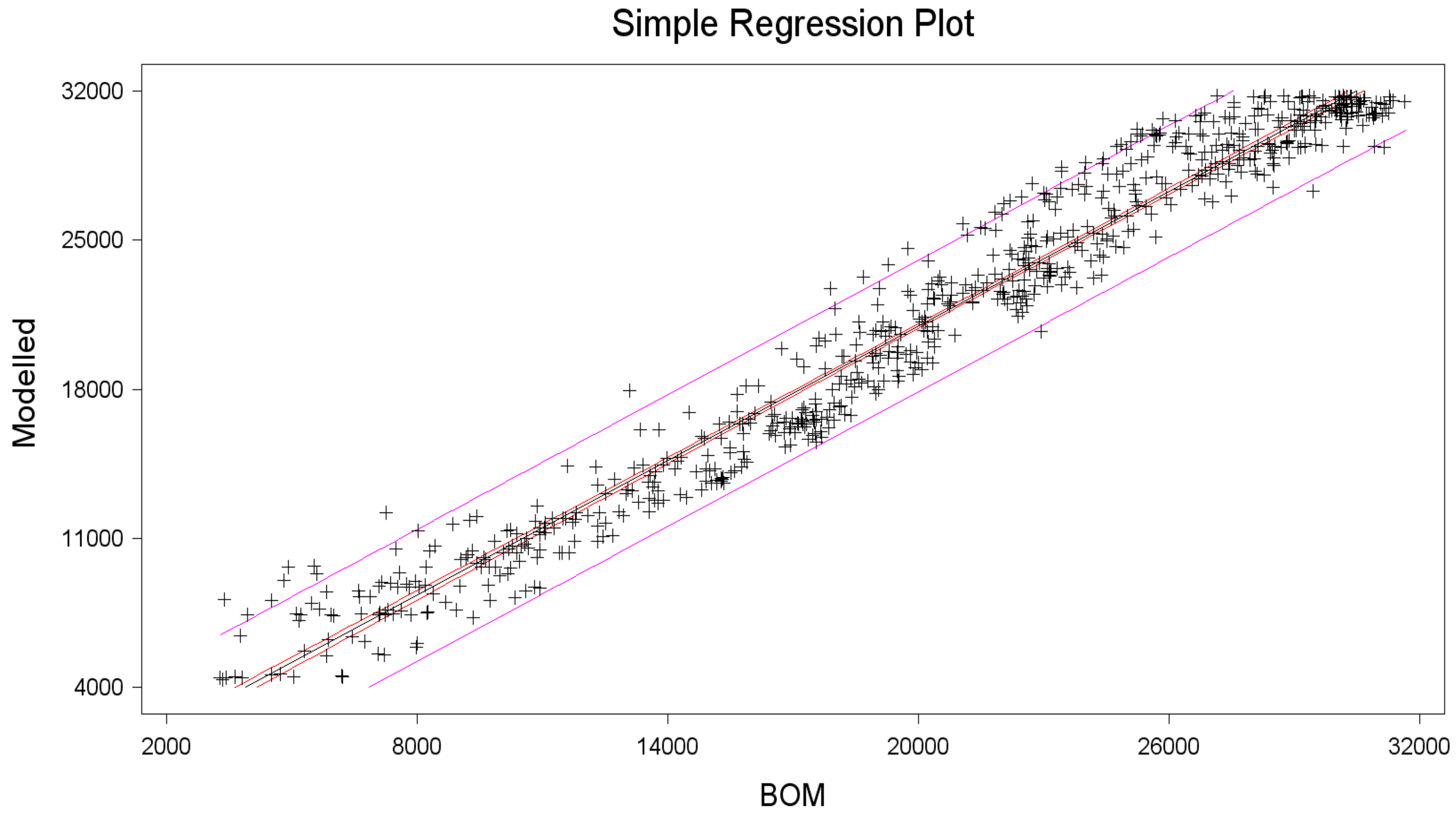
Model testing at Nullica Hills



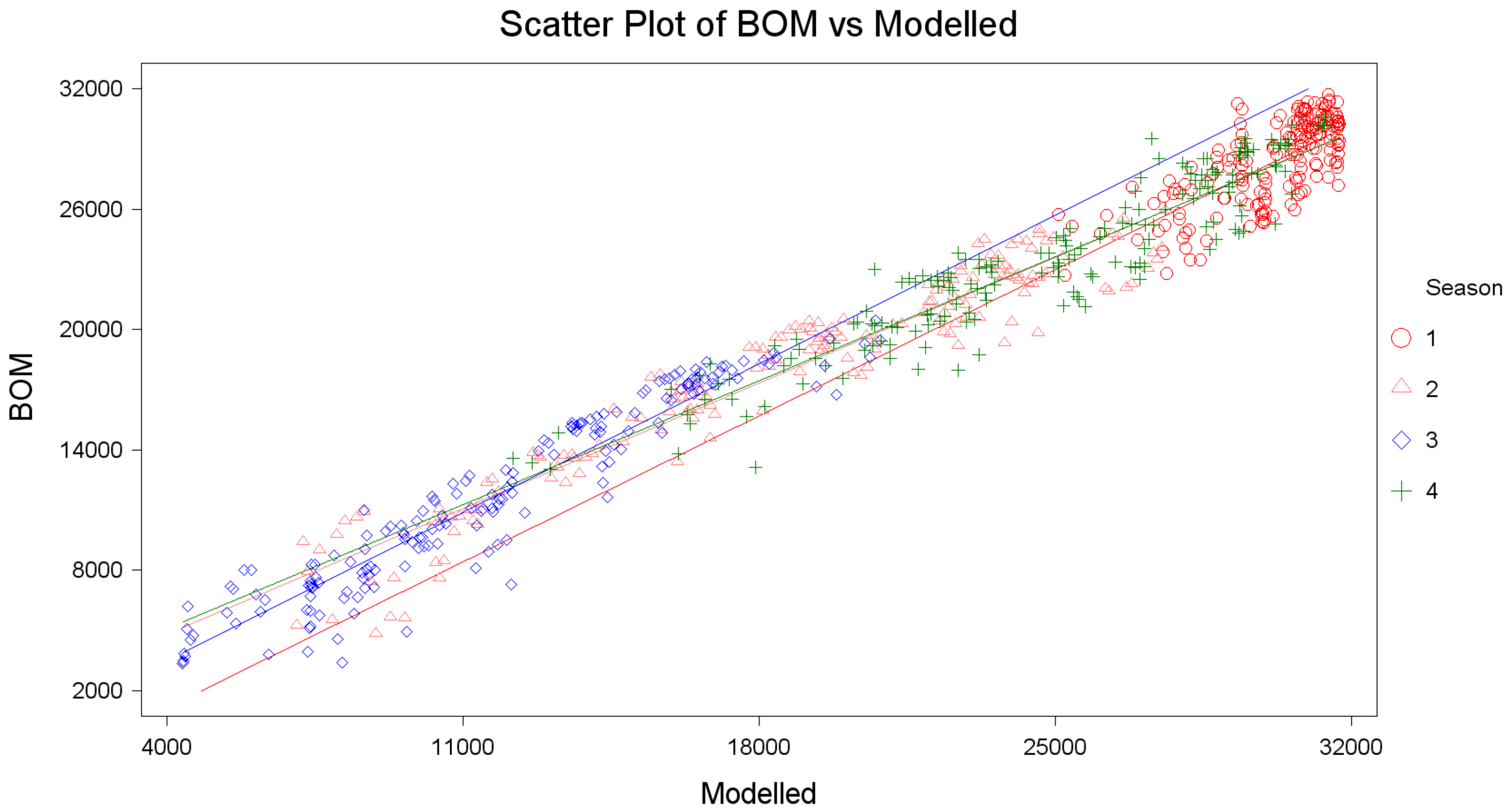
Correlating model predictions with actual BOM data

- The predictions of annual solar radiation were correlated with actual data collected by the Bureau of Meteorology (BOM), Australia at 14 different stations.
- Regression equations were developed, and then used to predict actual data collected at the same stations at other times.

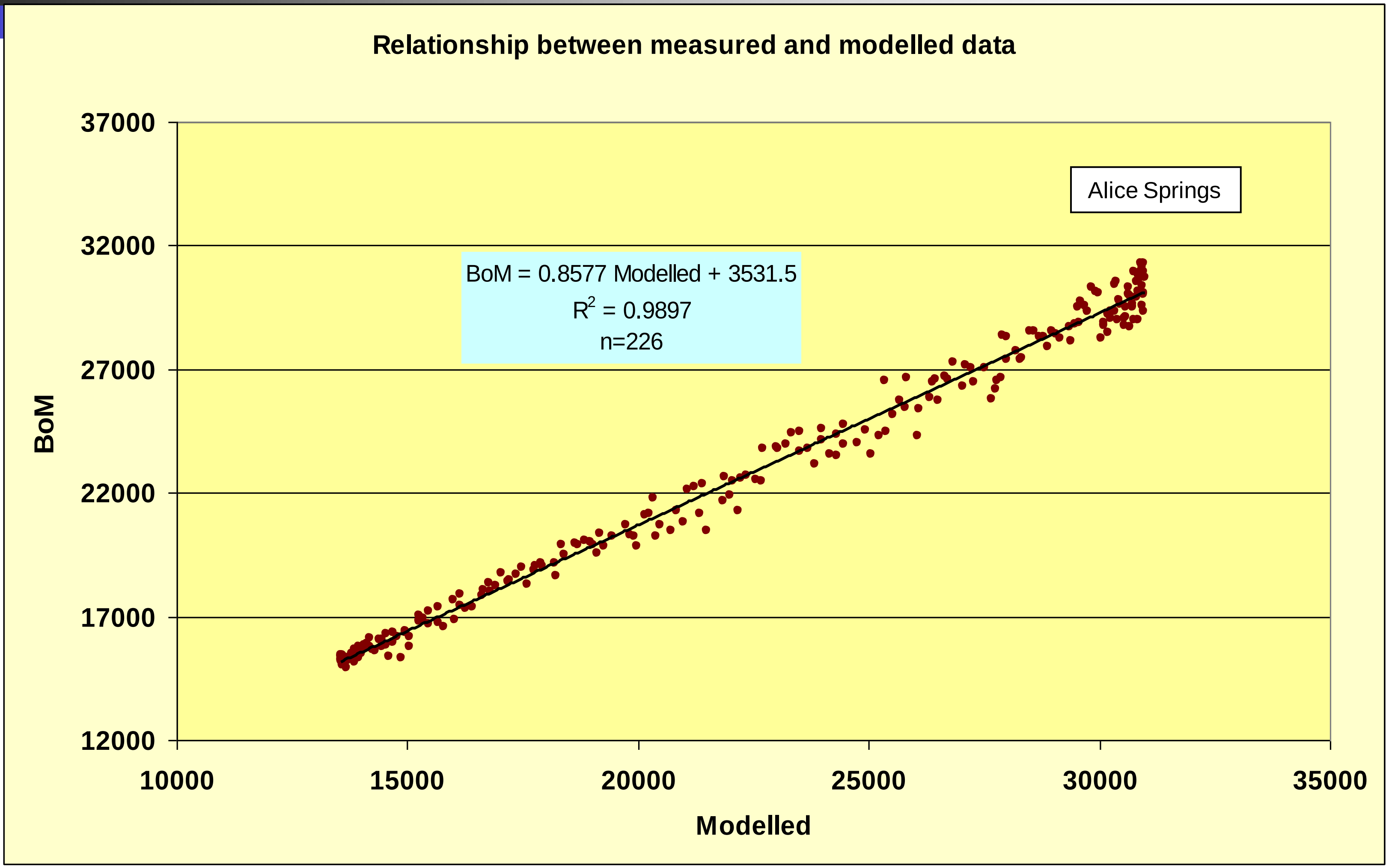
Correlating model predictions with actual BOM data



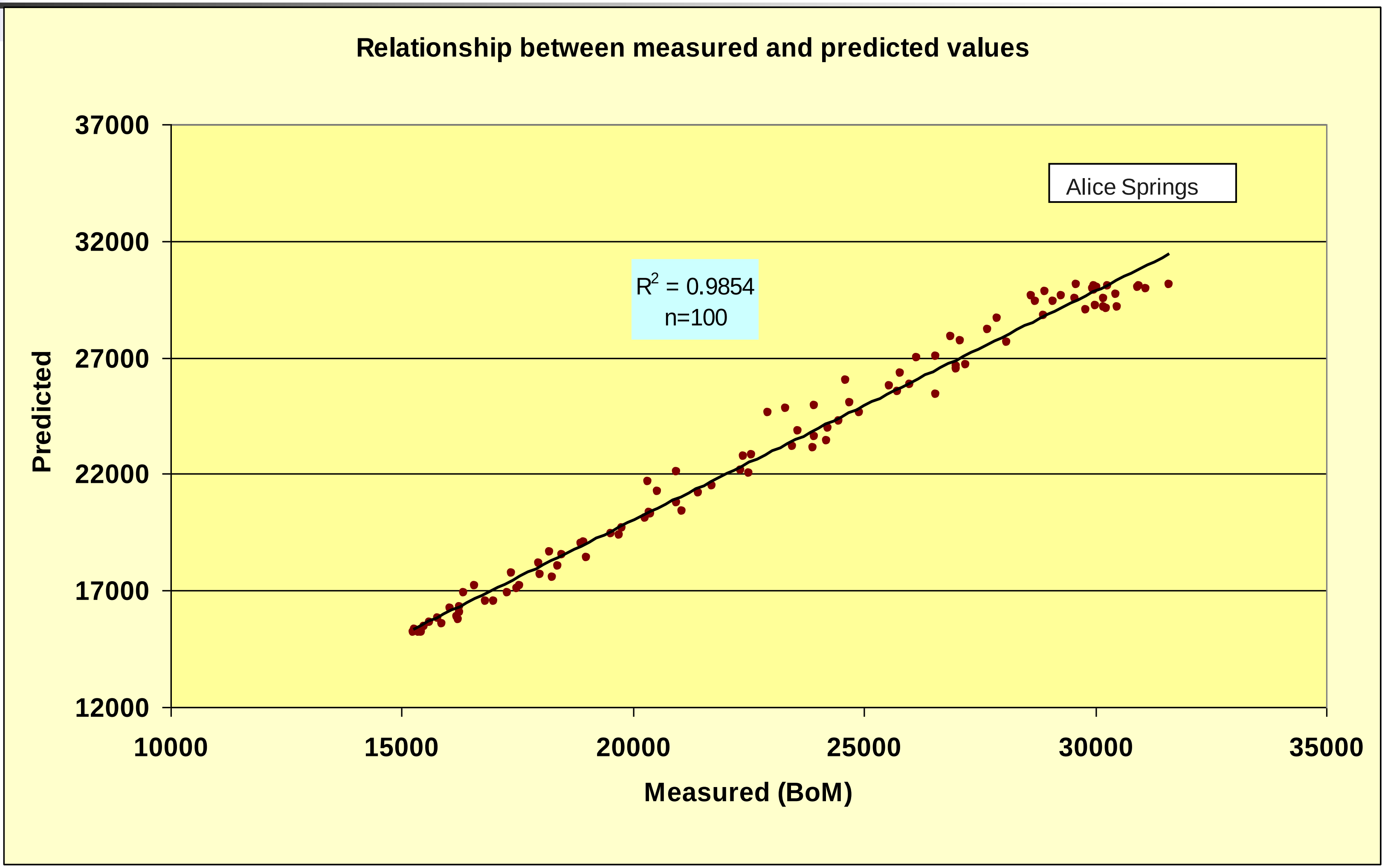
Correlations for different seasons



Alice Spring – relation between measured and modelled



Alice – relation between predicted and measured



Conclusions

- Remote Sensing-GIS provides a convenient means of estimating the biomass and solar energy resources of a country.
- High resolution satellite imagery is now able to differentiate between different species in a vegetation cover, thus enabling the quantitative assessment of a variety of woody biomass as well as plantations producing biofuels.
- Algorithms (such as that of Kumar et al) that combine basic solar data with information on local terrain stored in Digital Elevation Models are now able to accurately predict incident solar energy at any given geographical location.

References

- [1] Gerhard Zieroth and Leba Gaunavinaka, "*Biofuel from coconut resources in Rotuma – a feasibility study on the establishment of an electification scheme using local energy resources*", SOPAC, October 2007.
- [2] Lalit Kumar, Andrew Skidmore and Edmund Knowles (1997), "*Modelling topographic variation in solar radiation in a GIS environment*", Int J. Geographical Information Science, 1997, vol 11, No 5, 475-497

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Thank you for your attention!