'RANGEWATCH': An NDVI based method of estimating forage biomass in northern Australia. A case study in the western Kimberly region of Western Australia.

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Keywords: rangeland management, pasture utilisation, remote sensing, biomass assessment, pasture growth, stocking numbers

Abstract

An understanding of the current amount of total green biomass, total biomass and biomass growth rates is necessary for graziers to better manage pasture utilisation in the northern Australian grasslands. This project aims to assess the veracity (and challenges) of applying MODIS satellite-derived NDVI to calculating forage biomass in the complex landscapes of the northern tropical rangelands and to develop a web-based delivery platform providing forage estimates to producers ('Rangewatch'). The study site was located on a ~263 km^2 cattle station, located 250 km south east of Derby in Western Australia, on the Fitzroy River. All site locations were sampled during the 2011-12 and the 2012-13 growing seasons. In this study MODIS satellite NDVI image and climate data were used to produce estimates of pasture total green biomass (RMSE ± 825 kg DM/ha) and total biomass (green + dead) (RMSE ± 1050 kg DM/ha) with a ~6.25 ha (250 m^2) pixel resolution.

Introduction

Assessing pasture growth and estimating daily total green biomass using the normalised difference vegetation index (NDVI) satellite information has been extensively studied (Edirisinghe et al., 2011, Smith et al., 2011) in traditional grazing country of southern Australian temperate pastures. Often stocking rates and grazing windows over an entire annual cycle will be predicated on rainfall and the resulting pasture growth within a relatively short growing window (wet season). Establishing the stocking rate and duration correctly is essential not only to sustain grazing over the ensuing dry season, but to do so in such a way as to maintain the health of the rangelands. The former relates to maintaining livestock performance during the actual grazing period, namely live weight gain, health and reproductive efficiency (effectively avoiding the deleterious effects of over-stocking), while not squandering a potentially valuable resource (the pasture itself) from under-stocking, whilst the latter is related to maintaining, if not improving the 'health' of the rangelands environment itself. This all boils down to the grazier's principal influence, to adjust stock numbers or stocking intervals to suit the available grass cover.

Pasture growth rates and the amount of green pasture have a good correlation to satellite vegetation indices such as the NDVI (Donald et al, 2010). This current project is an attempt to provide Australian rangeland farmers with similar information and deliver them weekly updates via a web platform ('RangeWatch') using regular weekly NDVI.

Method

The study site was located on a cattle station of approx. 263km^2 in area located 100km south of Derby and 250km east of Broome in Western Australia on the Fitzroy river (124°09'E, -18°02'S) (Fig. 1).

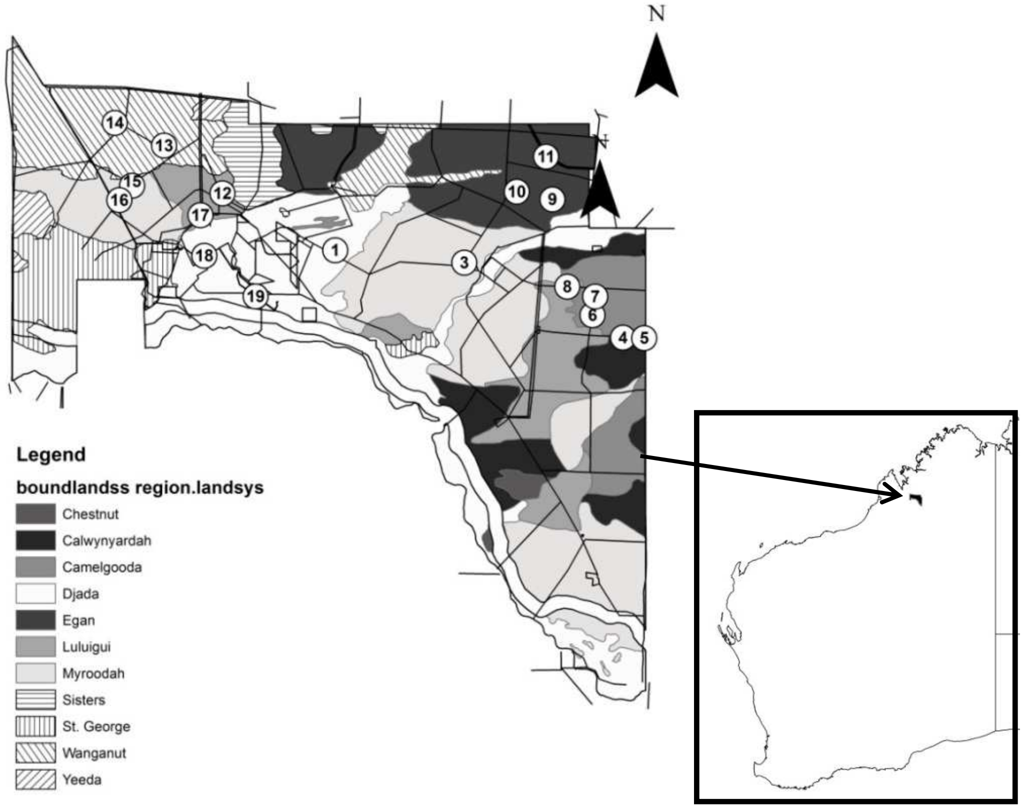


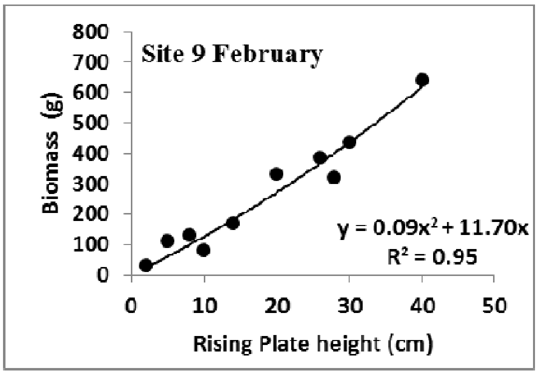
Figure 1: Land systems and sampling site locations; its position in northern Western Australia

The region has a sub-tropical monsoonal climate with two distinct seasons. The wet season (November-April), is characterised by rainfall ranging from monthly 20 – 152 mm. The dry season falls between May-October with maximum temperatures of 36 ° C, and rainfall ranging from 0 – 12 mm with a long term annual rainfall of 520 mm.

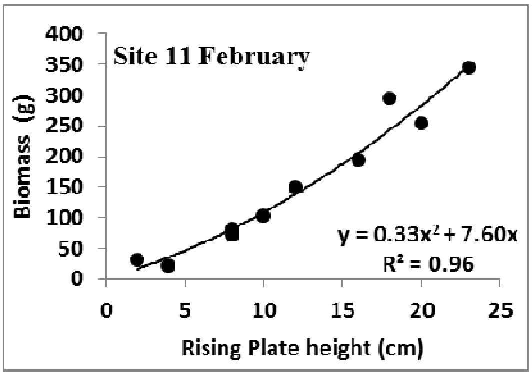
The station's grass cover comprises of mainly open plains grass, bunch grass and spinifex (Mundava et al, 2014). Field data were obtained from quadrats across all 19 sites for two seasons (2011-12 and 2012-13), in December, February, April and June, following the protocol outlined by Mundava et al (2013). The December data collections were timed to occur just after the break of season and the June data collections after the end of the growing season. 4 quadrats (50 cm^2) were cut to ground level from each site in the first season and 6 in the second season to enable construction of a calibration curve for each field data collection time. The two seasons' quadrat data for each sampling month were combined for each site (n = 10) and the coincident biomass and rising plate measurements for the given month used to create month-specific rising plate calibration equations. Samples at each site at collection were combined and sorted into green and dead and a representative sample was dried at 60^oC for 72 hours to determine dry matter percentage (DM%). Total biomass, total DM%, green DM% and green : dead ratio were recorded. From these values total biomass (kg DM/ha), total green biomass (kg DM/ha) and percentage green content were used in further analysis. MODIS NDVI for the individual sites matched to the nearest 250 m^2 pixel centroid was extracted for each individual site. For each of the 4 sampling weeks the MODIS NDVI value was correlated to total green biomass as inferred from the calibrated rising plate surveys.

Results

Of the 19 sites sampled, 13 were grass dominant, i.e. not spinifex. Examples of the site/month-specific rising plate calibration curves used to provide an overall estimate and variation of total fresh biomass at each site are given in Fig. 2a & b.



(a)



(b)

Figure. 2: Rising plate meter calibration curve for fresh total grass cuts quadrats, (a) for spinifex dominant site, (b) grass dominant site, for both seasons combined.

Examples of the relationship between MODIS NDVI-and total green biomass are given in Fig. 3.

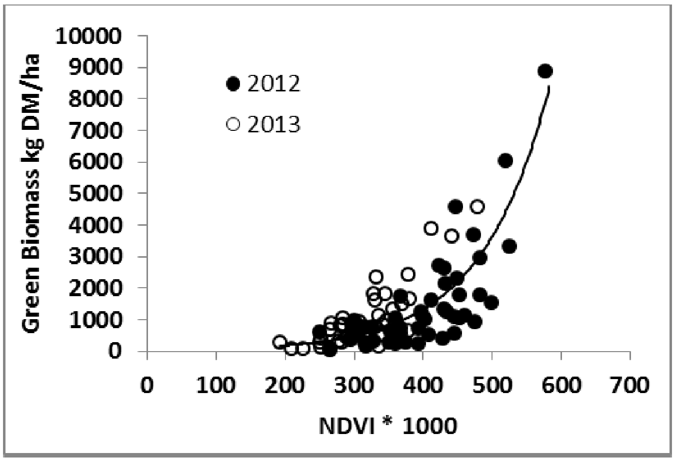


Figure. 3: Measured green total biomass (rising plate surveys) against MODIS NDVI (x 1000) for all grass dominant sites for both seasons. (R^2 0.65, ± RMSE 825 kg DM/ha)

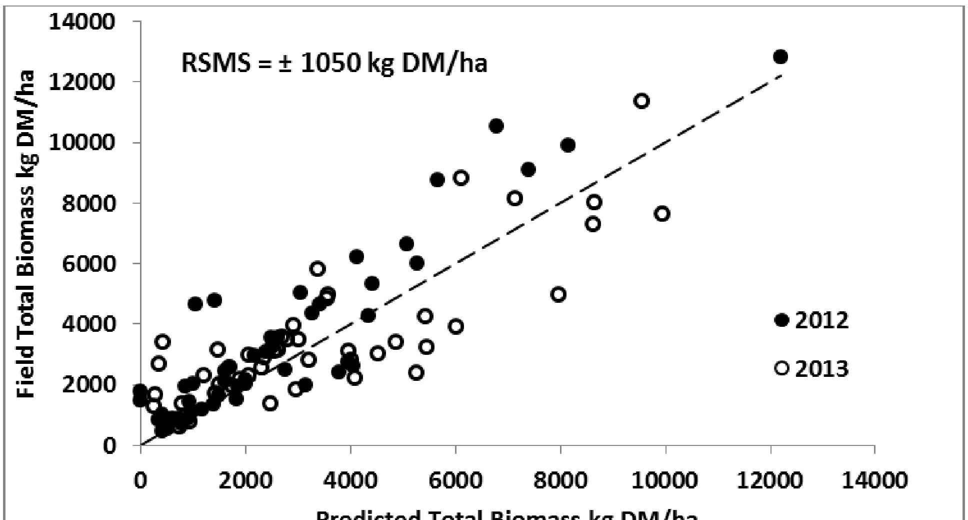


Figure. 4: MODIS NDVI-estimated total biomass for all grass dominant sites and all months.

From the field data a statistically significant relationship (R^2 0.97, data not shown) was observed between the DM% and green:dead ratio, hence made it possible to convert the derived estimates of green biomass to total (green and dead) biomass. Predicted total biomass was derived from a step-wise regression allowing for seasonal variation and this was facilitated with the introduction of a potential growth index factoring in local soil moisture and temperature indices (Nix et al, 1981) which were accessed from regional climate datasets. The relationship between predicted and field observed total biomass are shown in Fig. 4.

Discussion and Conclusion

The ability to infer forage biomass using satellite-derived NDVI values in northern tropical rangelands is challenged by significant spatial and temporal variation in land cover. Moreover the 6.25 ha spatial resolution of the satellite system means that pixels will more often than not be contaminated with non-forage vegetation signals. The empirical relationships developed in this investigation provide an insight into the analytical challenges, although it is pleasing to note the prediction error in forage biomass, over 7 different land systems are within 10% of the ranges observed.

Acknowledgements

We wish to thank the station manager Peter O'Brien, property manager Brett Blanchett and research manager Jenny Davis of Liveringa station, and the owners Milne Agriculture and their teams. Also, the skilled technical assistance of Waqar Ahmad, Elizabeth Hulm, Zhen-g-Shu Zhou, Michael Schaefer and Andrew Toovey of CSIRO, Derek Schneider of the University of New England, Andrew Buchanan and Brendon McAtee of Landgate Western Australia, Antonius Schut of Curtin University and Bob McCartney of the Dept. of Agriculture and Food Western Australia is gratefully acknowledged.

References

Donald GE, Edirisinghe A, Henry DA, Gherardi SG, Gittins S and Mata G, 2010, Pasture growth rate for individual paddocks can be accurately predicted real-time from MODIS imagery, climate and soil data, Australian Society of Animal Production 28th Biennial Conference, J. Anim Prod Sc, 50:611-615

Edirisinghe A, Hill MJ, Donald GE and Hyder M, 2011, Quantative mapping of pasture biomass using satellite imagery, International Journal of Remote Sensing, 32, No.10, pp 2699-2724.

Mundava C, Schut AGT, Stovold R, Donald G, Lamb DW and Helmholz P, 2013, Ground truthing protocols for biomass estimation in rangeland environments, Geoscience and Remote Sensing Symposium (IGARSS), IEEE International, pp. 2122-2124.

Mundava C, Helmholtz P, Schut AGT, Stovold, R, Corner R, McAtee B and Lamb D, 2014, Evaluation of vegetation indices for rangeland biomass estimation. Evaluation of vegetation indices for rangeland biomass estimation in the Kimberley area of Western Australia, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., II-7, 47-53, doi:10.5194/isprsannals-II-7-47-2014

Nix H, 1981, Simplified simulation models based on specified minimum data sets: The CROPEVAL concept. In, Application of Remote Sensing to Agricultural Production Forecasting, A Berg, Ed., A. A. Balkema: Rotterdam, pp 151-169.

Smith CGR, Adams M, Gittins S, Gharardi S, Wood D, Maier S, Stovold R, Donald G, Khokar S, and Allen A, 2011, Near real-time Feed on Offer from MODIS for the early season grazing management of Mediterranean annual pastures, Int. J. Rem. Sens., 32-16, 4445-4460.