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A BIOMASS MAP OF AFRICA'S WOODLANDS AND SAVANNAS

Edward T.A. Mitchard[1], Patrick Meir[1], Sassan S. Saatchi[2], & France Gerard[3]

[1]School of Geosciences, University of Edinburgh, Drummond St, Edinburgh, EH8 9XP, UK
[2]NASA Jet Propulsion Laboratory, 4800 Oak Grove Blvd, Pasadena, CA 91109, USA
[3]CEH Wallingford, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire, OX10 8BB, UK

1. INTRODUCTION

We present the first high-resolution (500 m) map of biomass covering the woodlands and savannas of Africa. This is based on 9.5 years of daily remote sensing data and a unique dataset of over 3000 biomass plots from 11 countries across the continent. The few extant global maps are of too low resolution to be of much use for conservation planning or estimating carbon stocks and emissions accurately in this ecosystem, as savannas and woodlands are highly heterogeneous at every scale. Hitherto, the one Africa-specific map that has been published at a relatively high resolution (1 km) [1] is focused on forests, and only covers a small subset of the African continent. Our data from savannas, woodlands and forest-savanna transition regions across the continent should produce a map of higher accuracy for these biomes.

2. METHODS AND RESULTS

Ground data were collated from a number of previously published and unpublished studies, giving 3000 ground plots ranging in size from 0.08 ha to 2 ha from across 11 different countries. Though the confidence to which we can assign their biomass value to a 500 m pixel varies (due to differing field methodologies and plot sizes), the high number of plots mean that the overall map has high confidence. The plots date from the mid-1990s until 2009, with most plots measured from 2001-2009; as such the map is not given a specific date, but should be thought of as c. 2005.

Although radar technology has proven to be very effective for biomass mapping from satellite data, unfortunately no radar data is available as yet at a sufficiently high resolution for this analysis. Once the 50 m ALOS PALSAR mosaic of Africa is released a new iteration will be performed with higher accuracies. However, optical data do contain information on biomass even if they do not measure it directly [2,3], and given sufficient field data it was hoped that multi-dimensional relationships could be found between a variety of optical layers that allowed the accurate prediction of biomass. We decided to use the MODIS sensor on the Terra and Aqua satellites, as its data are known to be of a very high quality and its high temporal resolution removes problems of cloud-cover and allows phenological differences across the continent to aid rather than hinder the analysis. We used the BRDF-corrected 16-day composites reflectance data collected from March 2000 until the end of August 2009, excluding data that did not achieve a magnitude inversion with at least 3 or more observations during the 16-day window. For all seven bands (459-2155 nm) the average reflectance value of the whole 9.5 years of data were taken, and in addition the average of the annual maximum reflectance value was calculated, giving 14 layers.

In addition we wanted to use the different phenological patterns observed in the landscape to try to better distinguish grass from woody vegetation and include the length of the growing season in the models. We applied a Fast Fourier Transform (FFT) analysis on the 9.5 years of data (in the form of Vegetation Indices) to find out the strength of the annual vegetation signal (annual harmonic), and to characterize the shape of the annual phenological cycle observed by the VIs (annual and other sub-annual harmonics). We were uncertain as to which vegetation index to use, with the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI [4]) and Modified Soil Adjusted Vegetation Index (MSAVI, [5]) all likely candidates. We could not use all three as they are very highly correlated, and thus could cause inaccurate prediction in the model output. Comparisons of the three in sites in Cameroon, Mozambique and Uganda (where we have a high density of field plots and knowledge of the vegetation cover) showed that, though the signals were similar, FFT (annual and other sub-annual harmonics) of the NDVI data was the best at distinguishing the different grass and woody cover types. Thus we calculated the average, minimum and maximum NDVI over all the study sites, as well as the magnitude of the annual, biannual (twice a year) and triannual (three times a year) FFT harmonics, giving 20 layers in total.

These layers and 2100 ground points (a reduction from the original 3000 plots as often more than one plot fell in the same 500 m pixel and was thus average) were then analyzed and a map made using two very different multi-dimensional models – Maximum Entropy (Maxent [6]) and the multiple tree-regression algorithm Random Forest [7]. The resulting maps from the two methods were remarkably similar, greatly increasing our confidence in the methods and our data. The variables chosen as most important to the models were also very similar, namely the FFT layers (defining the strength and the shape of the annual cycle) were most important for distinguishing the lowest biomass values, and maximum NDVI most important for higher biomass values.

3. DISCUSSION

This map represents a useful development for a large number of different fields. It will be of use for a number of different purposes, including:

- the estimation of carbon stocks for REDD projects (Reducing Emissions from Deforestation and Degradation), and other conservation projects where knowing carbon stocks is important;
- for conservation planning and management knowing the distribution of carbon stocks within an area (for example a National Park) is very important, and the map will provide a useful step beyond the normal land-cover maps available for such purposes;
- helping to independently verify and parameterize global and regional vegetation and climate models;
- allowing the accurate estimation of emissions from the annual burning of African savannas, which is an important contribution to the global carbon cycle but is highly uncertain [8]. Knowledge of the carbon stocks of Africa at a 500 m resolution can be combined with the recently released 500 m resolution MODIS burned area product to enable a more accurate estimate of emissions than was previously possible.

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5. REFERENCES

[1] Baccini, A., Laporte, N., Goezt, S.J., Sun, M., and Dong, H. "A first map of tropical Africa's above-ground biomass derived from satellite imagery." *Environmental Research Letters,* 3, 045011, 2008.

[2] Saatchi, S.S., Houghton, R.A., Alvala, R., Soares, J.V., and Yu, Y. "Distribution of aboveground live biomass in the Amazon basin." *Global Change Biology,* 13, pp. 816-837, 2007.

[3] Mitchard, E.T.A., Saatchi, S.S., Gerard, F., Lewis, S., and Meir, P. "Measuring woody encroachment along a forest-savanna boundary in central Africa." *Earth Interactions*, **13**, 8, 2009. DOI: 10.1175/2009EI278.1

[4] Huete, A., Justice, C. and Liu, H. "Development of vegetation and soil indices for MODIS-EOS." *Remote Sensing of Environment*, 49, pp. 224-234, 1994.

[5] Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H. & Sorooshian, S. " A modified soil adjusted vegetation index." *Remote Sensing of Environment*, 48, pp. 119-126, 1994.

[6] Phillips, S.J., Anderson, R.P., & Schapire, R.E. " Maximum entropy modelling of species geographic distributions." *Ecological Modelling*, 190, pp. 231-259, 2006.

[7] Breiman, L. "Random Forests." *Machine Learning* 45, pp. 5–32, 2001.

[8] Bombelli, A., Henry, M., Castaldi, S., Adu-Bredu, S., Arneth, A., de Grandcourt, A., Grieco, E., Kutsch, W. L., Lehsten, V., Rasile, A., Reichstein, M., Tansey, K., Weber, U., and Valentini, R. "An outlook on the Sub-Saharan Africa carbon balance." *Biogeosciences*, 6, pp. 2193-2205, 2009.