A BIOMASS MAP OF AFRICA'S WOODLANDS AND SAVANNAS

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1. INTRODUCTION

We present the first high-resolution (100 m) map of biomass covering the woodlands and savannas of Africa. This is based on an ALOS PALSAR L-band radar mosaic from 2009 and a unique field dataset of almost 3000 ground plots from across the forests, woodlands and savannas of 11 countries in sub-Saharan Africa. In addition the results were compared with variables and maps developed from 9.5 years of daily optical remote sensing data. 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. The one Africa-specific map that has been published at a relatively high resolution (1 km) [1] is based on optical data alone, 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Ground data were collated from a number of previously published and unpublished studies, giving 3000 ground plots ranging in size from 0.08 ha to 2 ha from across 11 different countries.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 pixels varies (due to differing field methodologies, geolocation accuracies, measurements dates 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.

L-band radar data from the ALOS PALSAR satellite has previously been shown to relate strongly to aboveground biomass [2], up to a variable saturation point. There are however problems with simply applying a relationship across a large mosaic, as the individual scenes will have different moisture and seasonal conditions, potentially greatly affecting the relationship between backscatter and biomass. In addition the structure of vegetation differs markedly across Africa, again suggesting that one unique equation relating biomass to backscatter might not be appropriate. There are also difficulties in areas with significant topography. The large field dataset we have here allows us to explore some of these problems, but we do not have a complete solution as yet.

Optical data do also contain information on biomass, even if they do not measure it directly [3,4], and given sufficient field data it was hoped that multi-dimensional relationships could be found between a variety of optical layers that allowed the prediction of biomass, in order to compliment the radar map. We decided to use the MODIS sensor, as its data are known to be of a very high quality and its high temporal resolution removes problems of cloud-cover and allows phonological differences across the continent to aid rather than hinder the analysis. Remote sensing data were thus taken from the MODIS sensors on the Terra and Aqua satellites, using the BRDF-corrected 16-day composites imagery, with data that did not achieve at least a magnitude inversion with 3 or more observations during the 16-day window excluded. All data collected from March 2000 until the end of August 2009 were used. For all seven bands the average of the whole 9.5 years of data were taken.

In addition we wanted to use the different phonological patterns of the landscape to try to better distinguish grass from woody vegetation and include the length of the growing season in the models, and thus decided to use the 9.5 years of data at a 16-day resolution to do a Fast Fourier Transform (FFT) analysis to find out the strength of the annual vegetation signal, 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 of the NDVI data was the best at distinguishing the different landcover 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.

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 averaged) were then analyzed and a map made using the multiple tree-regression algorithm Random Forest [7]. This map differed significantly from that derived from the radar data, though similar broad trends were observed. Reasons for these differences were investigated, and suggested that the relationship between optical data and biomass differed markedly by location, suggesting the radar-derived map has a higher accuracy.

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 100 m resolution can be combined with the new 500 m resolution MODIS burned area product to enable a more accurate estimate of emissions than was previously possible.

The differences between the optical and radar derived maps are very interesting and the reasons behind them should be investigated in order to provide recommendations on the best methodologies for mapping aboveground biomass elsewhere.

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