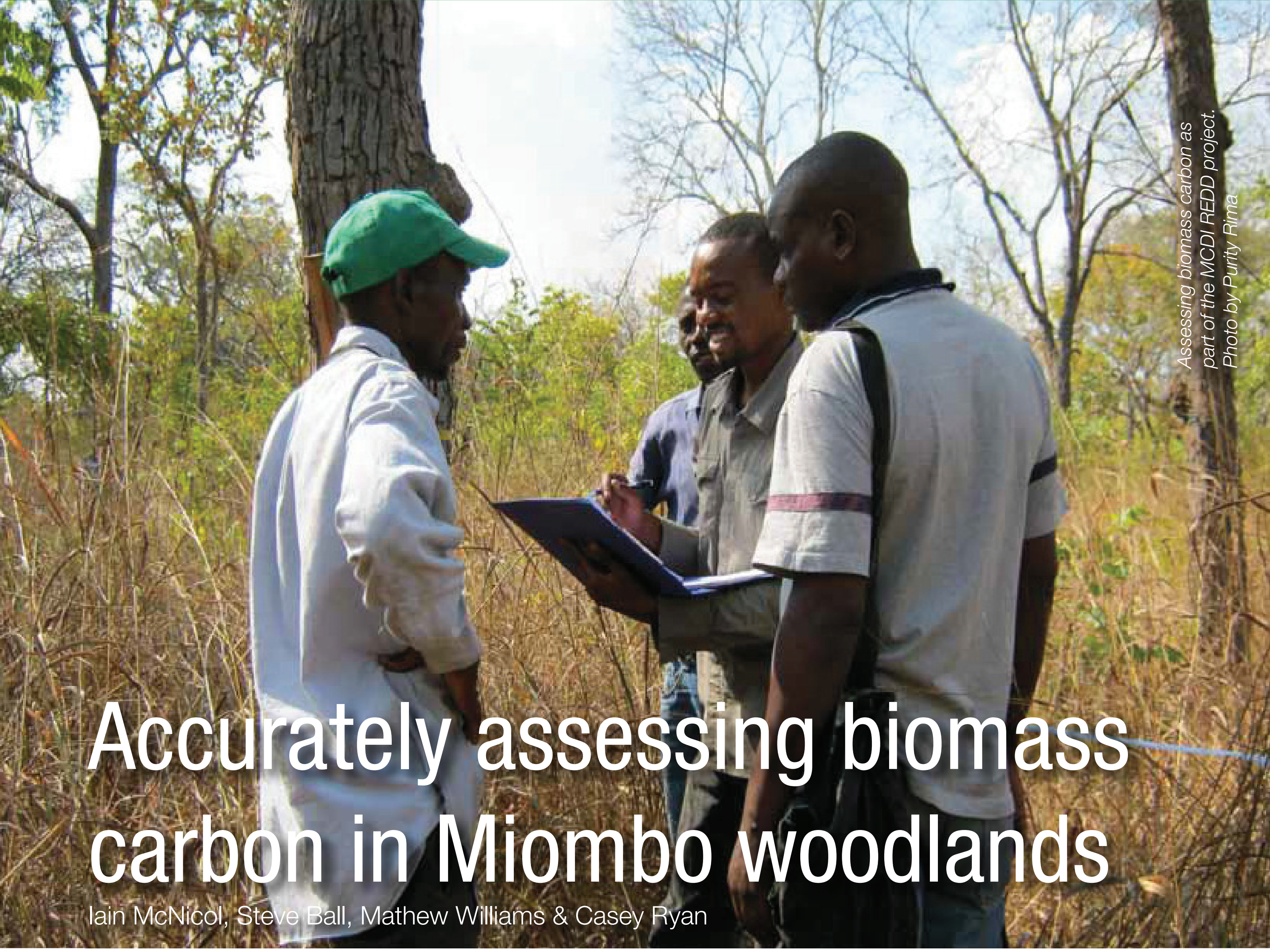

Assessing biomass carbon as part of the MCDI REDD project. Photo by Purity Rima

Accurately assessing biomass carbon in Miombo woodlands

Iain McNicol, Steve Ball, Mathew Williams & Casey Ryan

The Mpingo Conservation and Development Initiative's (MCDI) REDD pilot project is unusual. Most REDD projects assume a static area of forest. However, MCDI are more interested in the timber values of the forests in Kilwa in south-east Tanzania (a patchwork of Miombo Woodlands and East African Coastal Forest), which, we calculate, could yield substantially higher revenues than carbon, so long as the timber can be properly differentiated in the market which forest certification does.

MCDI holds the first and so far only certificate from the Forest Stewardship Council for community-managed natural forest in the whole of Africa. However, MCDI needs to expand the area of certified forest in order to achieve the economies of scale which will make the certification scheme self-sufficient in the long run. MCDI has found it hard to raise from donors all the funds it needs to do this. In the language of the carbon markets, MCDI faces an 'investment barrier' to expanding a proven, effective means of sustainable forest management, and if carbon savings can be demonstrated, then carbon offsets can be generated using a REDD+ model, and sold on the global market to cover the costs of expanding PFM and FSC certification.

In the remote forests in which MCDI is working, there are relatively few pressures from the traditional drivers of deforestation in Tanzania: agriculture and charcoal production. Uncontrolled timber extraction is a problem, but is highly selective and thus the carbon losses are relatively low. MCDI is thus focusing on the degradation caused by regular bush fires. These often occur during the middle of the dry season, when farmers are clearing new land, but also the windiest time of year. The combination of high winds and abundant dry grasses lead to hot, extensive fires. MCDI aims to reduce the damage this causes the forest by embarking upon an ambitious programme of early burning in partnership with the communities with whom it is working. This improved fire management is expected to lead to annual carbon savings of the order of $0.5tCha^{-1}$ or about 2.5% of above-ground biomass. These small changes require an extremely effective monitoring regime to detect.
In collaboration with the University of Edinburgh, MCDI is therefore pioneering new methods of carbon assessment in order to provide scientifically

robust estimates of both above and below ground carbon stocks, and monitoring their change over time. To achieve this objective, MRV activities have been broken down into three stages:

1) Forest area pre-assessment to locate potential plot locations and to assess spatial variability,
2) Field measurements from a representative sample of the project area, and
3) Extrapolation of carbon stocks across the district and monitoring changes over the project lifetime.

Viewed at a project level scale, Miombo woodlands are spatially extremely heterogeneous, encompassing open grassland areas (*dambos*), savannah woodland and thicker riparian forest. Stratification is the usual solution to land cover heterogeneity, but the scale at which Miombo varies is too small to be accurately determined by analysis of satellite imagery. Thus instead we need a solution which manages extremely localised variation; large plot size is one answer. Previous fieldwork by the University of Edinburgh in Mozambique shows sample plots need to be at least 1ha in size if the resulting data set is to be approximately Normal (required for most statistical analyses) (Ryan *et al*., 2011).

We adopted a nested 'super' plot design, not dissimilar to the cluster plots used by NAFORMA. Thus our sample plots consist of 1 x 1ha Permanent Sample Plot (PSP), 1 x 9ha Large Sample Plot (LSP) and 4 x 0.2ha circle plots (one at each corner of the LSP). A large fraction of Miombo biomass is found in large trees. This fact allows us to increase the efficiency of surveying such large plots; only stems >40cm DBH are surveyed in the LSP (except where it overlaps with the smaller sub-plots). Nonetheless this survey design requires a lot of effort per plot, so the total sample size must be reduced; in our case to 25 super plots. For the circle plots plus PSPs, however, that delivers an *n* of 225. So long as the plots are not biased in their location, the width of the confidence interval on carbon stocks will primarily be driven by the number of trees measured and area surveyed. We surveyed a total of 225ha which compares very well with an expected project size of approx. 30,000ha.

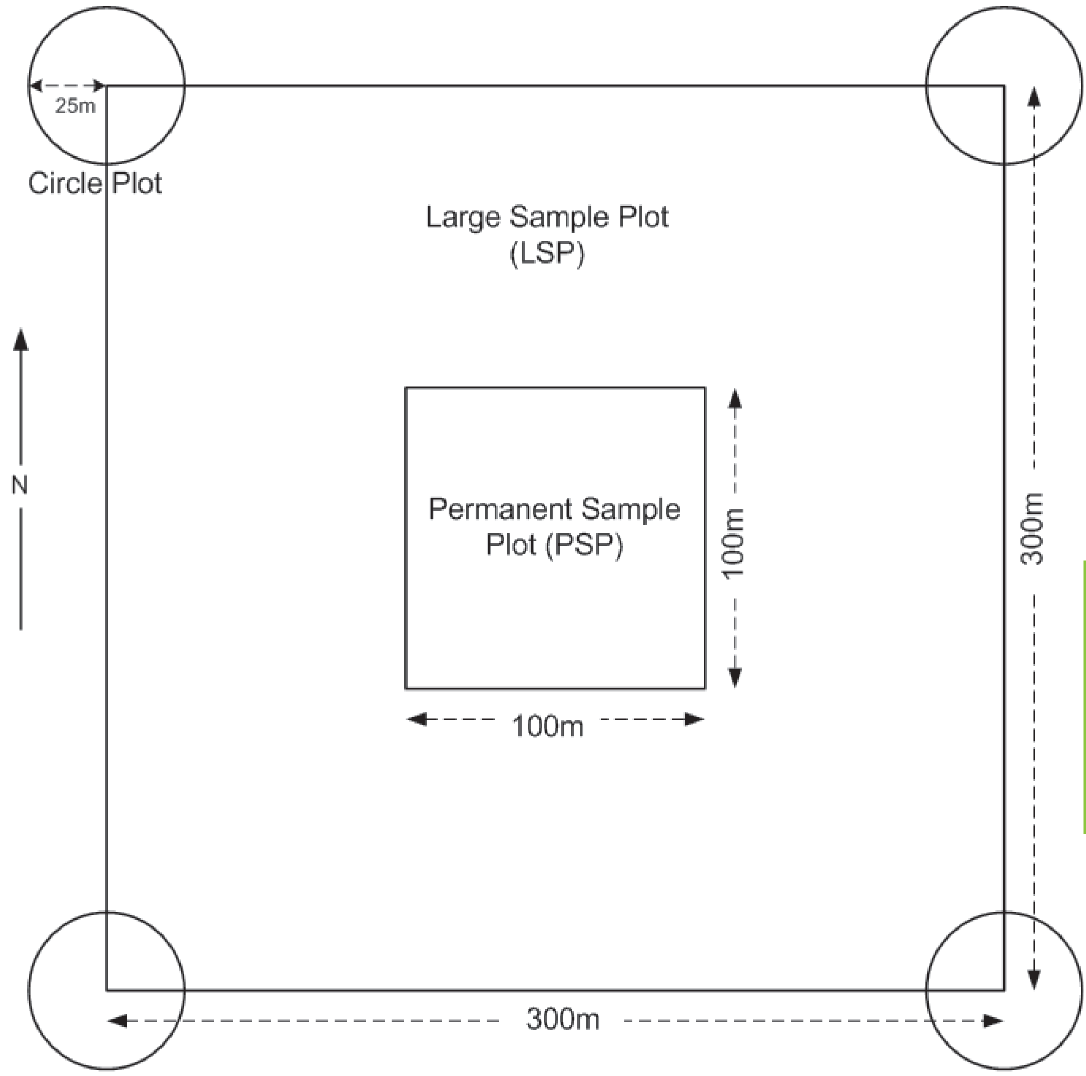

Figure 1. Plot layout showing arrangement of permanent, large and circle plots.

Super plots were located through an initial (experimental) stratification of the landscape based on LandSat imagery. Three discrete strata – Forest, Woodland and Savanna – were mapped based on >100 ground reference points. To maximise surveying efficiency we preferentially sampled the spatially dominant communities. Thus of the 25 sample locations, 14 were situated in woodland, 6 in forest and 5 in savannah. Pragmatism naturally played a role in site selection as it is easier to survey sites close to the road network; however a minimum 1km buffer from the road was implemented in order to reduce the effects of disturbance (as per Williams *et al.*, 2008).

The 25 super plots were established and subject to baseline surveys from October 2010 to October 2011. These were complemented with an additional 43 plots (0.2ha each) that were set up across the district, encompassing a chronosequence of active and abandoned farmland which is being used to quantify losses associated with conversion to agriculture and to analyse how the woodlands recover over time.

To estimate biomass carbon stocks we used the standard approach for a forest inventory, determining the species, and the diameter at breast height (DBH) for each stem using specified DBH thresholds for each plot type. The project employed local guides knowledgeable in botany to assist MCDI field technicians with species identification and to take DBH measurements. To convert DBH into aboveground biomass, the project used a new regionally derived allometric model, obtained from the destructive harvest of 29 trees in Mozambique, which relates tree diameter to stem and root biomass (Ryan *et al.*, 2011a).

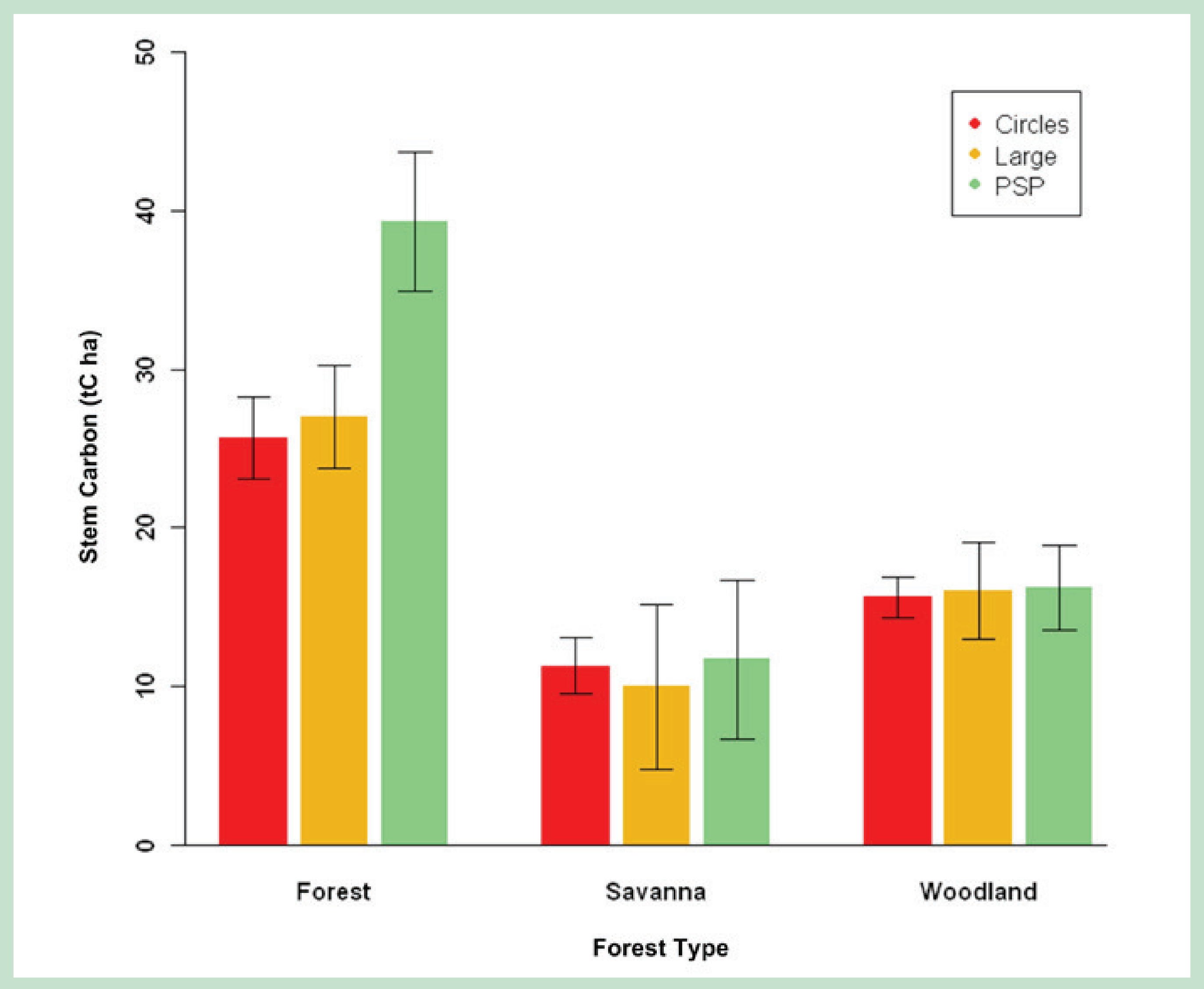

Figure 2. Mean carbon density (tC ha^{-1}) of each land cover type separated by plot typeError bars indicate standard error of the mean (SEM)

The results of the baseline were further processed to align the data from the three different plot types. This showed that across the central Kilwa Landscape the following carbon densities apply:

	Mean stem C density (t ha^{-1})	*Area (000 ha)*	*Total stem C (000 tonnes)*
Forest	28.4	428	12,155
Woodland	15.7	824	12,937
Savannah	11.5	262	3,013
Farmland	9.4	236	2,218
TOTAL		1,750	30,323

Analysis, also showed that, as expected, the biomass figures for the smaller circle plots, and even the 1ha PSPs, were non-Normal, the data for the LSPs are indeed normally distributed.

The final steps in MRV will be to extrapolate the ground based measurement across the project area and to monitor changes over time. Repeat inventories of the 1 and 9ha plots only are scheduled for 2013 and will allow the project to record and monitor natural and anthropogenic changes in C stocks at a high spatial resolution and with careful error assessment.

However, due to constraints on time, effort and resources, it is not possible to directly sample a sufficient number of plots across the district in order to be able to use ground based data alone to directly estimate relatively small changes in carbon stocks. Instead remote sensing data will be used to extrapolate the plot data across the landscape. By combining the field based inventory data with information derived from ALOS PALSAR, an L-Band radar satellite sensor, the project will generate carbon density maps at 25m resolution using the method of Ryan et al. (2011b). The ability to combine the plot based measures with more extensive EO data will ultimately enhance our understanding of the carbon balance of the district as a whole. The inclusion of both relatively undisturbed as well as degraded areas in the sampling strategy will provide extra calibration and validation capacity for the remote sensing data.

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