Quantifying carbon stocks for REDD+ implementation in Kilwa District

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Forest Inventory Report

Introduction

This document describes and details the work completed to date by MCDI and the University of Edinburgh (UoE) on generating baseline carbon stock estimates against which future changes in carbon stocks will be measured, and possibly credited under one of the proposed REDD frameworks. To achieve these objectives, the study is utilising a network of 150 forest inventory plots that have been set up using a nested sampling design at 25 locations across the district. The project activities were broken down into three stages: 1) forest area pre-assessment to locate potential plot locations, 2) the undertaking of field measurements of carbon stocks from a representative sample of the project area, and 3) the extrapolation of carbon stocks across the district and monitoring changes over the project lifetime. The methodologies employed in this study build upon previous work carried out as part of the Nhambita Community Carbon Project in Central Mozambique (Ryan *et al*., 2011). By using this information to inform current strategies, the project is pioneering new scientifically robust and efficient methods of carbon assessment. To set the context for this work, the document will first introduce the background to the goals and motivations of the project and its part in contributing to the REDD readiness of MCDI and the selected local communities of Kilwa District. Following this, the document will give a brief overview of the methodology employed by the project, detail our progress to date and provide some preliminary results based on the data collected.

Background

Quantifying the vegetation carbon stocks of forest ecosystems and how they change over time is extremely important for understanding current trends in the global carbon cycle. This issue has taken on added significance due to the recent adoption of REDD+ as there is now an urgent need to assess and produce data on forest carbon stocks and forest carbon stock changes. Tanzania, which is estimated to have lost 7% of its coastal forest and 13% of its miombo woodlands between 1990 and 2000 (Burgess *et al*., 2010), is one of nine countries targeted for REDD+ pilot projects. As methods for mapping land cover change improve with advances in remote sensing technologies, the key remaining challenge for the successful implementation of the REDD+ mechanism is the accurate and consistent estimation of both above and below ground carbon stocks and how they change over time. Procuring such accurate and consistent carbon stock estimates for the most extensive semi-arid to sub-humid woodland formation in southern and Eastern Africa however, represents a formidable scientific and technical challenge. These inherent difficulties derive partly from the spatial variability in forest biomass as caused by site specific variables such as rainfall, soil and disturbance history. This project seeks to address these needs by providing estimates of landscape carbon stocks in an area of Africa where there remains a paucity of such data.

Objectives

The establishment of the Permanent Sample Plots is designed to address several goals of the project:

1) An estimation of the mean carbon density for each land cover type along with an assessment of the spatial variability and uncertainties propagating through our biomass estimates
2) Estimates of the growth rates, recruitment rates and mortality rates of trees in each land cover type
3) Calibration of remote sensing estimates of above ground carbon stocks, particularly from the ALOS sensor

Plot locations

The first and most important activity for any REDD project is deciding how to account for the high degree of variation in C stocks across the area. The standard approach, and the one used in this project, is to stratify the project area into broad vegetation types with similar carbon stocks to ensure that the major variation in landscape C stocks has been adequately captured (Gibbs et al., 2007; Maniatis and Mollicone, 2011). Stratifying the project area by vegetation type and sampling from targeted locations within these strata has the additional benefit of increasing project efficiency by creating a means to infer carbon stocks for an entire vegetation class while measuring only a fraction of the total area. By using ground truth points obtained in June 2010 as a guide for satellite remote sensing data from LANDSAT, we divided the district into four land cover types:

- Tropical Woodland. Open canopy woodland typically characterised by the dominant *Miombo* species, including *Brachystegia boehmii, Brachystegia speciformis, Julbernardia globiflora* and *Spirostachys africana*. This broad land cover type also includes degraded and secondary woodlands which add further variability to the carbon stocks and species composition found in this stratum.
- Riverine or Coastal Forest. Closed canopy forest, although tending towards a thicket at ground level with lianas and climbers sometimes present. Species composition differs from the surrounding *Miombo* woodland with a number of very large, buttressed trees. Dense woodland plots were observed to have been included in this category.
- Savanna. Characterised by the co-existence of grasses and scattered trees, the latter of which is dominated by species of the genera *Acacia* and *Combretum*.
- Agricultural areas. Croplands, although some large trees remain due to the effort required removing them during clearance. See below for details on how these areas were sampled

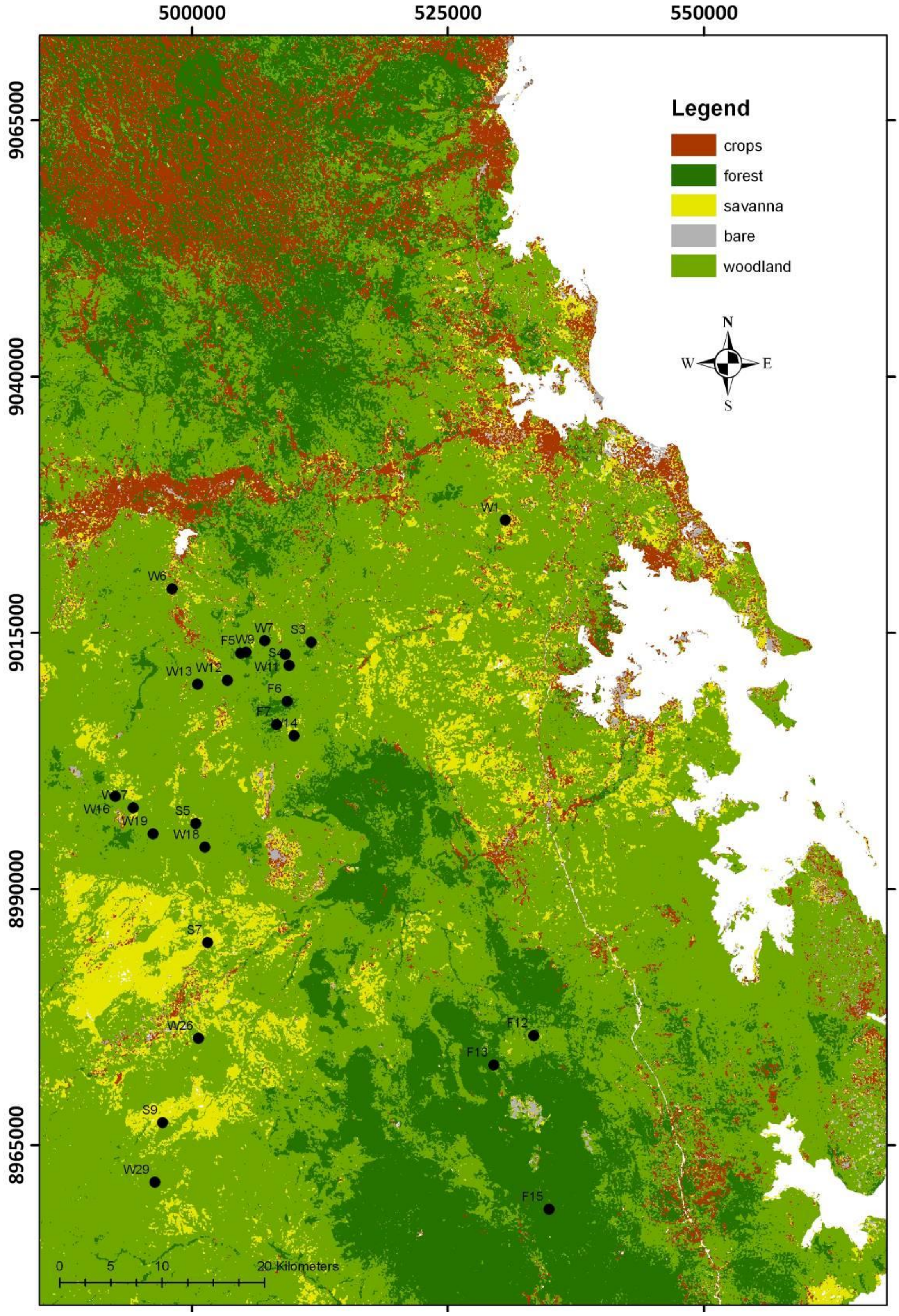

Figure 1. Locations of the PSP's sampled within Kilwa district. The map was created via a supervised classification that linked visual interpretations of ground cover 300 round reference points to reflectance values from LandSat which expanded the classification to the rest of the image.

In order to calculate and optimise the number of plots that needed to be measured in each stratum for the inventory, plots were proportionally allocated to different strata based on their spatial extent to ensure the preferential sampling of the more dominant communities. Following this strategy, twenty-five cluster plots - 14 in Woodland, 6 in Forest and 5 in

Savanna - were located and established from October 2010 – October 2011 in randomly stratified locations across the landscape using the initial survey of land cover as a basis (Figure 1). Pragmatism naturally played a role in site selection as it is easier to survey sites close to the road network; however a 1km buffer from the road was required in order to reduce the effects of disturbance (Williams et al., 2008). An additional 43 plots, 0.2ha in size, were also set up across the district between June and July 2011, encompassing a chronosequence of active and abandoned farmland (0-40 years abandoned) which has been used to quantify losses associated with conversion to agriculture and to analyse the rate of recovery over time. Given the obvious problems with setting up permanent sample plots in agricultural systems that employ traditional shifting cultivation, the active agricultural fields sampled as part of the chronosequence have been used to quantify the mean carbon density of the 'crops' land cover type (Figure 6).

Sampling strategy

Permanent Sample Plots

The sampling methodology employed in this project builds upon previous research in Mozambique as part of the Nhambita Community Carbon Project (Williams *et al*., 2008; Ryan *et al*., 2011). The statistical distribution of biomass estimates across the Mozambican sample plots provided us with useful information on the spatial variability of biomass which helped to inform current sampling strategies. One of the most striking discoveries in the Mozambican inventory was that the majority of carbon in natural woodland can be stored in the few trees of the largest diameter class (i.e. stems >40cm). Indeed, it was observed that the top 3% largest trees contributed 50% of the total biomass, and the top third of trees found to contribute 91% of the total biomass. To account for this, at each sample location monitoring in being undertaken using a nested sampling design that takes into account the spatial distribution of large stems in the landscape (Figure 2). This involved the use of a large 9 ha permanent sample plot in which all trees with a stem diameter ≥40cm were recorded and geo-located. For a more detailed analysis of population dynamics (i.e. growth, recruitment and mortality rates), we utilised a standard 1 ha sized Permanent Sample Plot in which all trees with a stem diameter ≥5cm were recorded and geo-located. For both plots, all trees were tagged with a metal label bearing a serial number which will allow the project to rapidly re-measure individual stems in future. In addition, four x 0.2ha circle plots, the size of which was selected to include an adequate number of stems for statistical analysis, were set up at each corner of the LPSP, within which all stems ≥10cm were measured but *not* tagged or geo-located. Plots <0.2ha in size were avoided as they tend to sample large stems ineffectively, generating problematic biomass distributions (Chave *et al*., 2004, Ryan *et al*., 2009). Stem carbon stocks were then able to be estimated from these measurements using a regionally derived allometric equation produced by Ryan *et al*. (2011a), using destructive harvest data collected in Mozambique.

[1] $$\log(\text{biomass}_{\text{stem}}) = 2.601 \log(\text{dbh}) - 3.629$$

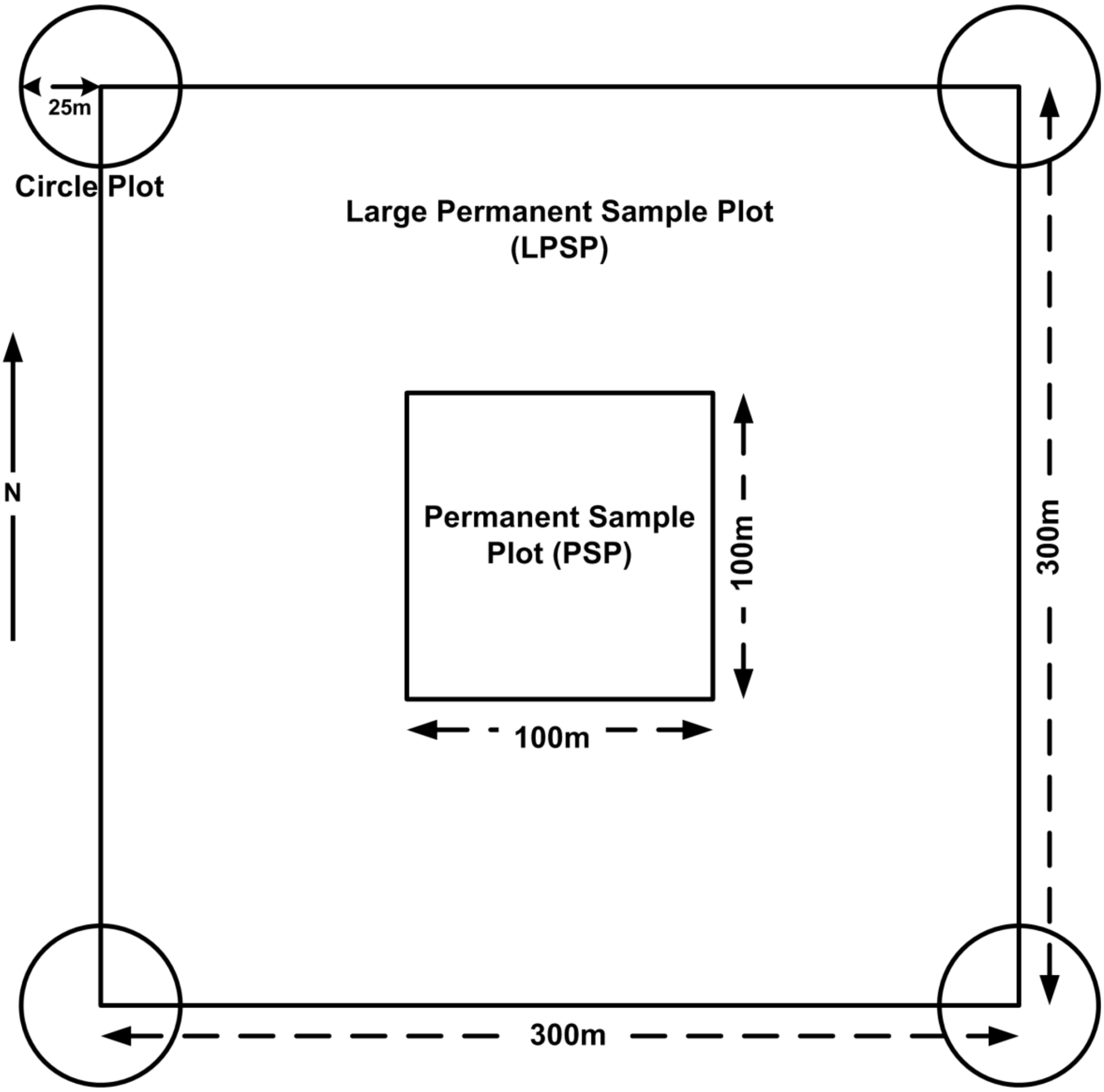

Figure 2. An example of the sampling strategy employed at each sample location.

Chronosequence

Forty-three plots, 0.2 ha in size, were sampled during the summer of 2011, including 9 agricultural fields active from 0 – 5 years (to highlight the effect of deforestation on carbon stocks), 23 secondary forests ranging from 1 – 39 years abandoned, and 11 mature forest plots which acted as reference plots against which the effect of deforestation and rate of recovery were measured. Sites were chosen based on their accessibility and the availability of suitable reference sites in the local area. Criteria for site selection included proximity (all reference site were within 2km of either an active field or a re-growing plot), soil texture (sandy to loamy textures), topographic relief (related to soil texture) and cropping strategy, as determined through site observations and interviews with local land holders. Sites where Cashew was cultivated were excluded from the analysis as they have markedly different cropping strategies (a form of agroforestry and not slash and burn). Circular plots were considered ‘optimal’ for this study as they have the smallest periphery in relation to area and consequently the lowest number of borderline trees but are also extremely fast and simple to set up.

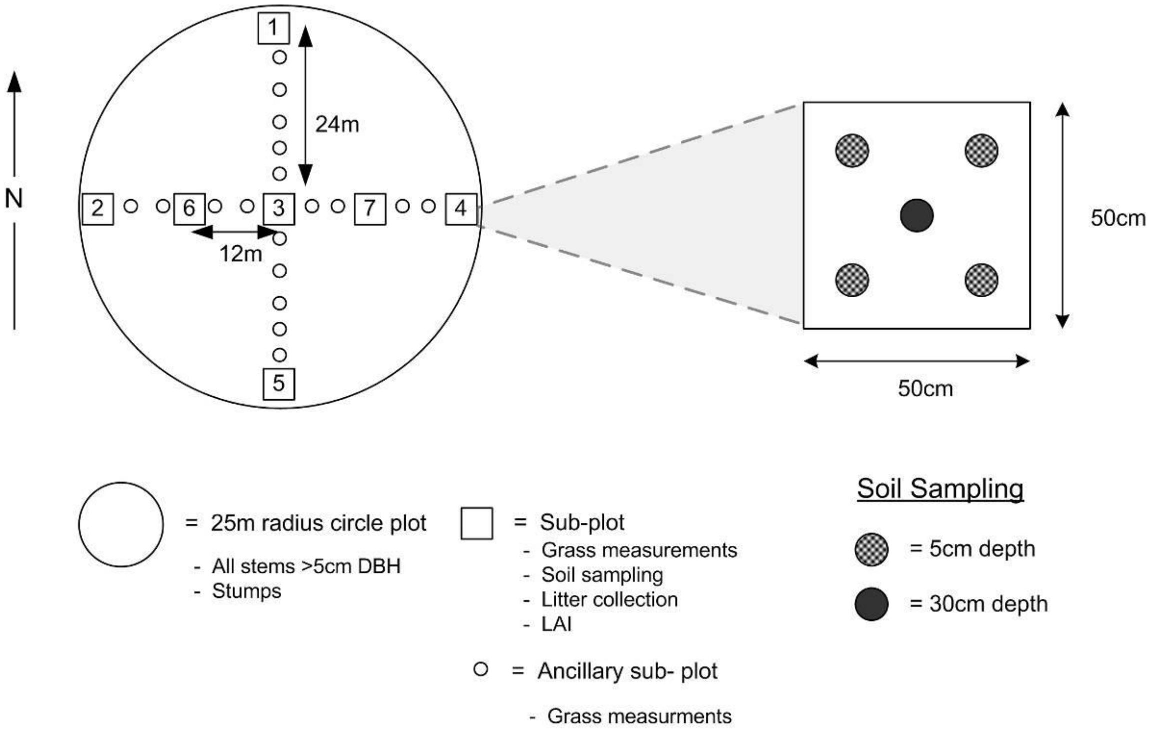

Figure 3. An example of the sampling strategy employed at each site sampled during the chronosequence study. Ancillary measurements of Grass biomass, Litter and Leaf Area Index (LAI) were collected in order to compare above to below ground carbon pools.

Results

Large stem data

Given the higher DBH threshold used to calculate C stocks in the LPSP, a significant number of stems will have been missed and therefore before analysing the data we need to first account for this 'missing' biomass in order to allow comparable estimates of carbon stock across all sampling scales to be obtained (Figure 4). To do this we compared the contribution of biomass from all the trees >40 in all 25 PSPs to the total biomass carbon stock (all stems >5cm). Based on the regression equation in Figure 4, taking the ratio of large stem biomass to total biomass of 0.4309, we were able to predict the total woody biomass for each of the 9 ha plots (Appendix 1).

Carbon stock estimates

Using the predicted biomass values for the LPSP, the 150 plots surveyed ranged in above-ground biomass from less than 2 tC ha^{-1} in some savanna and degraded woodland plots to 70 tC ha^{-1} in one of the forest plots (Table 1 and Figure 6). The distribution of plot-level carbon stocks within each strata was tested for normality using the Anderson-Darling test for the Woodland, Forest and Savanna data sets and the Shapiro-Wilk test for the Crops dataset. The AD test was chosen as it is ideally suited for sample sizes >25 while the Shapiro-Wilk is better suited to sample sizes <30.

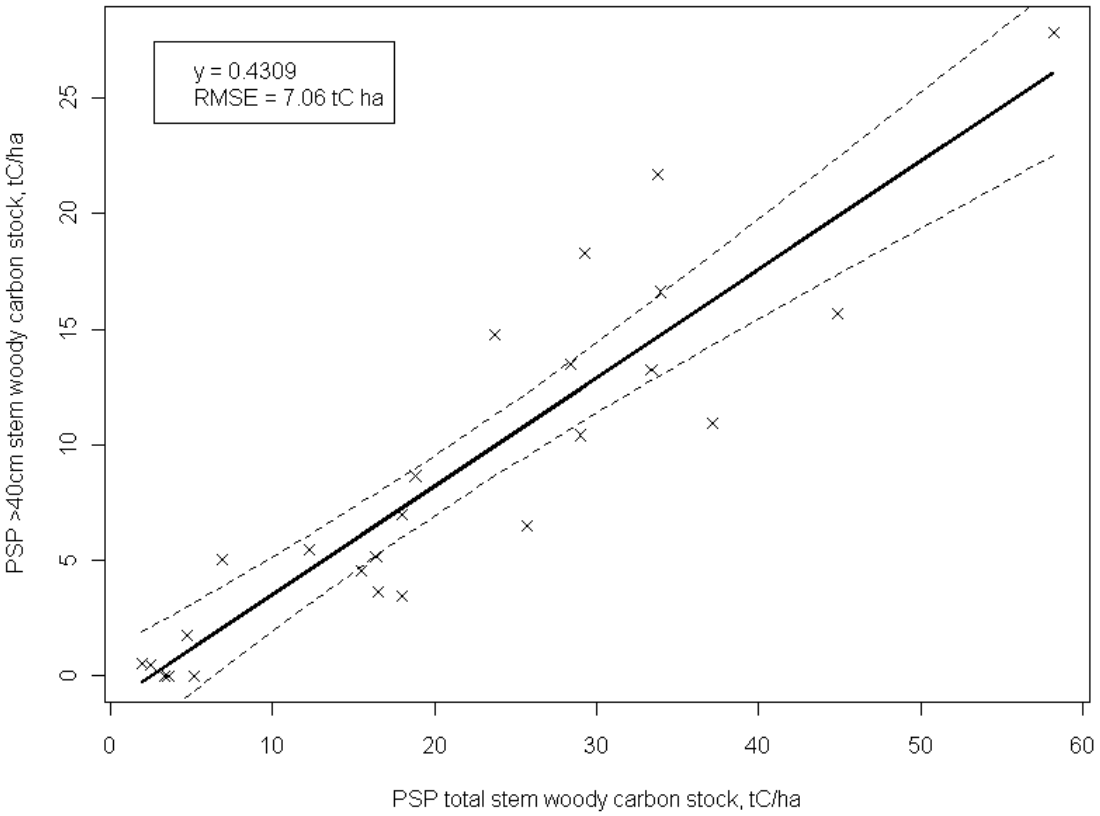

Figure 4. Relationship between large stem biomass (≥40cm stems only) and total stem biomass (all stems ≥5cm) for all 25 PSPs. A linear regression forced through zero resulted in equation y = 0.4309, R^2 = 0.82. Plotting the Woodland, Forest and Savanna datasets separately and fitting the line did not change the result therefore we applied the same ratio to all of the data. The dotted line indicates the 95% confidence interval

Stem C stocks were found to be normally distributed for the savanna dataset (*P* = 0.10), however both the Woodland and the Forest datasets showed a skewed distribution for above-ground carbon, with the forest strata in particular exhibiting a long 'tail' of biomass which reaches 70 tC ha^{-1}. As a result, stem C stocks in the Woodland and Forest (*P* = 0.03 and *P* = 0.02, respectively), were found to be non-normally distributed reflecting the highly heterogeneous forest cover within these strata (Figure 6). The non-normality of our data, particularly in the spatially dominant Woodland strata, is a cause for concern when it comes to upscaling our measurements as it means we are not able to use our mean C stock value with any confidence. Methods on how to account for the non-normality are discussed in the final section (remark 2).

Table 1 – Statistical summary of aboveground stem carbon stocks in each of the three land cover classes separated by plot type. All values are expressed in tC ha^{-1}

	Forest			**Woodland**			**Savanna**		
	Circles	**Large**	**PSP**	**Circles**	**Large**	**PSP**	**Circles**	**Large**	**PSP**
Mean	25.6	27.0	39.3	15.6	16.0	16.2	11.3	9.9	11.7
Median	21.9	27.4	35.4	13.2	13.3	17.3	11.9	5.2	6.9
St. dev	12.5	7.9	10.7	9.8	11.3	9.9	7.7	11.6	11.1
St. error	2.6	3.2	4.4	1.3	3.0	2.7	1.7	5.2	5.0
Max	69.2	36.2	58.2	39.9	35.6	29.3	20.9	28.6	29.1
Min	15.5	12.6	28.4	0	0.2	1.9	0.1	0.9	2.5
Num. of plots	24	6	6	56	14	14	20	5	5

Between strata variability in C stocks was also found to be significant (*P* = <0.001, Kruskal Wallis test, 3 way comparison) highlighting the success of the original stratification procedure in accounting for the major variability in C stocks across the project area. Despite the obvious similarities between the Woodland and Savannah systems, conducting a similar test just on the woodland and savannah datasets highlights that there is indeed a significant difference in carbon stocks between the two strata (*P* = 0.04, T-test). The result contests, to a certain degree, the suggestion in the LTS report that the Woodland and Savannah could be considered a single stratum in terms of C density and it is expected that this difference will be accentuated in any future re-stratification, however the weak significance of the difference means we cannot ignore that there is a relatively strong continuum between the two strata. Breaking the results down further and looking at the contribution of the individual plot types to the carbon stocks of each strata, we can see that of the three sampling scales used to generate our estimates (Figure 5), the values obtained using the PSPs and circle plots provided statistically similar estimates total stem carbon stocks for the woodland and savanna categories (*P* = <0.001). The circle plots and the larger plots in the Forest strata, however, produced markedly different estimates (Figure 5).

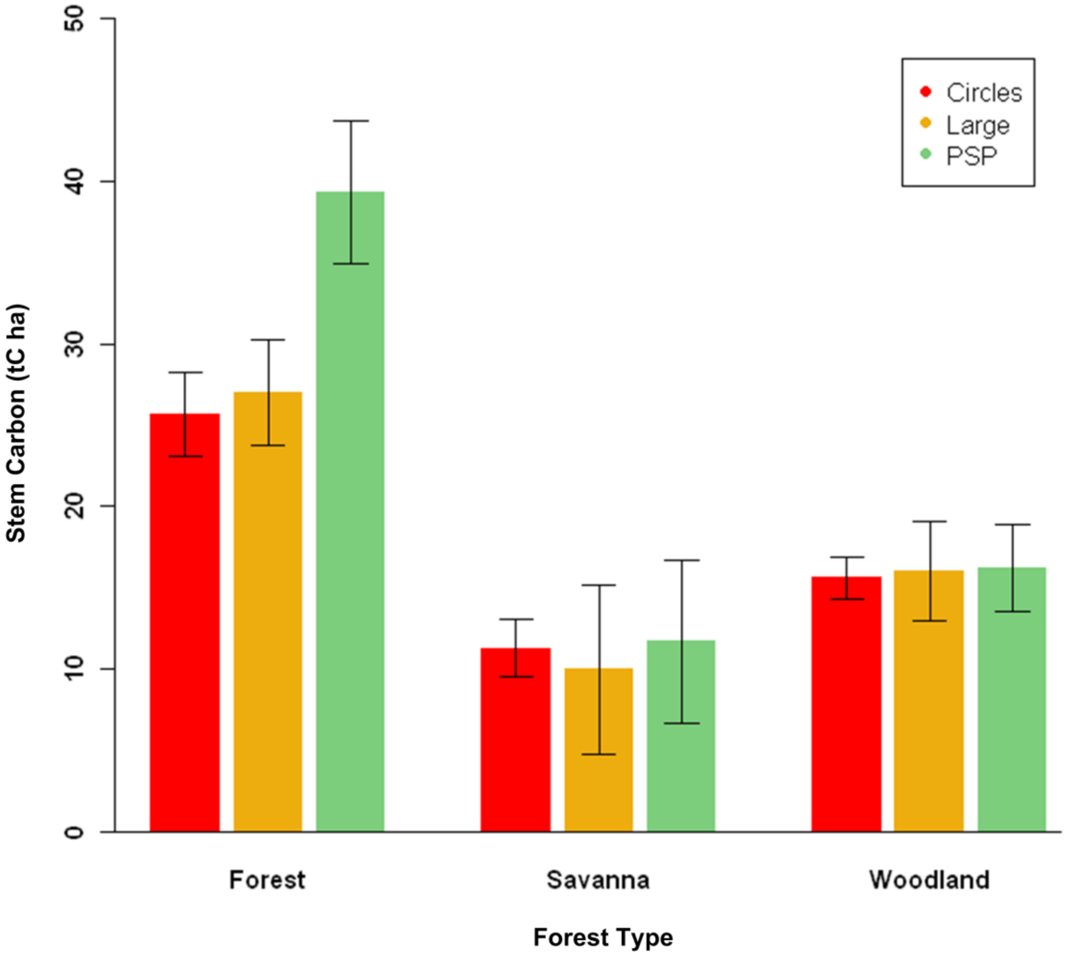

Figure 5. Mean carbon density (tC ha^{-1}) of each land cover type separated by plot type. Error bars indicate standard error of the mean (SEM)

There are two hypotheses as to why this occurred; the first possibility is that the scale at which the Forest varies in terms of biomass is smaller than in the Savannas and Woodlands, and therefore the circle plots at the corner of the LPSP are sampling different patches of

Forest. The other possibility is that the circle plots are ineffective at sampling large stems in dense forest leading to an underestimation of C stocks compared to the PSPs. To test our hypotheses we will simulate the sampling of 25 circle plots at random locations within each of the 6 Forest PSPs using the stem locations (x,y co-ordinates) in each of the PSP's as a guide. More work is required to test these hypotheses and will be made available in due course. By combining the PSP, LPSP and circle plot data, the mean carbon density (tC ha^{-1}) was averaged to 15.77 ± 2.44 tC ha^{-1} for the woodlands, 28.38 ± 4.76 tC ha^{-1} for the forests, 11.5 ± 2.08 tC ha^{-1} for the savannas, and based on the plots surveyed during the chronosequence study, 9.44 ± 4.46 tC ha^{-1} for the croplands (Figure 6 and Table 2).

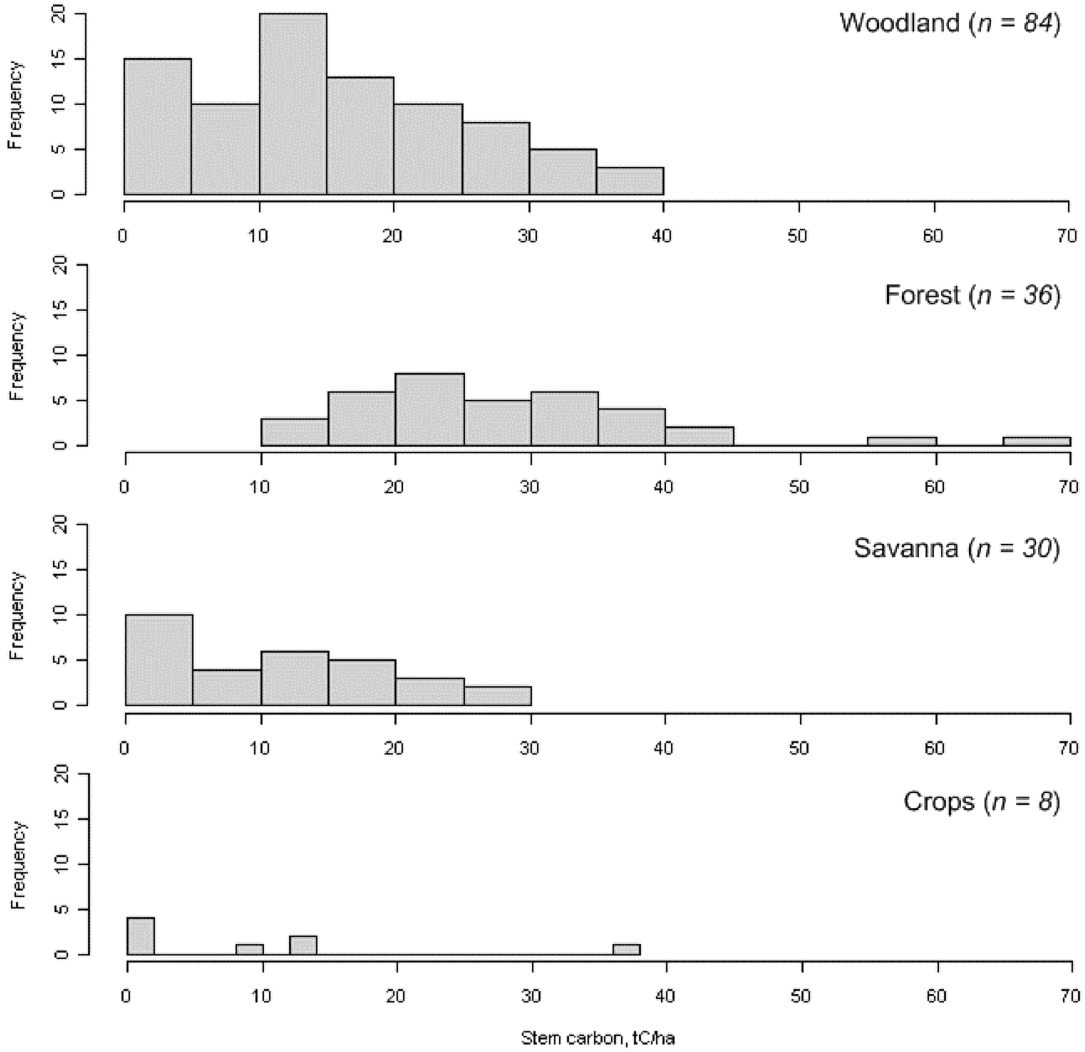

Figure 6. Frequency distribution of stem carbon (tC/ha) in each vegetation type using data for all sample plots

Recovery rates following land clearance

For the abandoned fields, there was a clear relationship between time since abandonment and increasing stem C stocks (Figure 6). A linear regression explained 32% of the observed variability and resulted in estimates of biomass accumulation rates of 0.84 tC/ha/yr. The mean estimated stem C stock for the oldest abandoned fields (>25 years) was 24.82 ± 2.19, ranging from 9.48 to 28.61 tC ha^{-1}, whilst the mean value for the mature woodland plots was 29.3 ± 1.70 tC ha^{-1}, ranging from 23.76 to 38.5 tC ha^{-1}. There was no significant difference in the woody stem C stock estimates between abandoned fields >20 years old (*P* = 0.06) or >25 years old (*P* = 0.12) and the woodlands (two-sample t-test) indicating that C stocks recover to pre-disturbance levels (assuming the land prior to conversion was mature woodland) after approximately 25 years of abandonment.

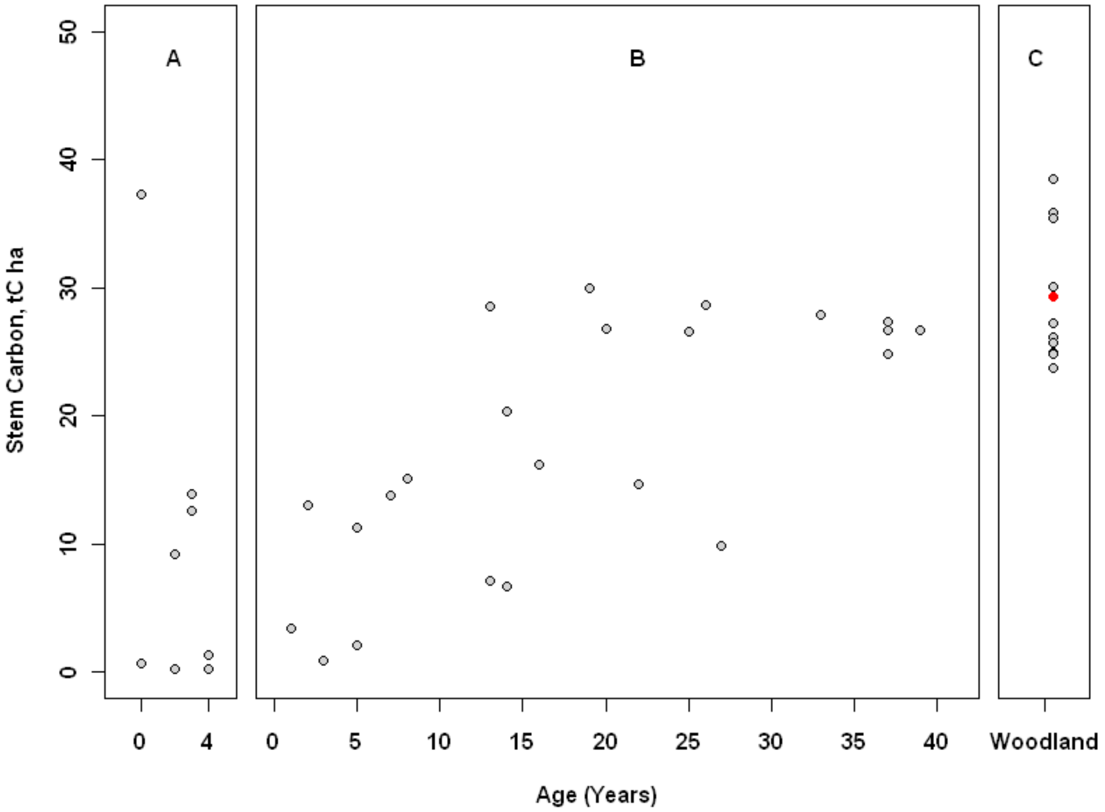

Figure 7. Stem carbon stocks plotted against age for the active fields (left panel - A), abandoned fields (central panel - B), and for mature woodland plots (right panel - C, red dot indicates mean). A linear regression forced through zero (not shown on graph) was applied to the data, y = 0.8428, R^2 = 0.32

Comparisons with other datasets

Our estimates of stem carbon stocks for the woodland sites are found to be considerably lower than that of the Ryan et al. (2011) average for Nhambita in Mozambique of 21.2 tC ha^{-1} and for Frost's (1996) 'average for dry miombo' in Zimbabwe and Zambia of 26 tC ha^{-1}. A likely reason for this discrepancy is that our forest inventory incorporates a significant number of degraded areas with low biomass values (e.g. plot W1). Sampling in both mature and degraded areas such as abandoned fields and sites logged for charcoal production naturally reduces the mean value of our C stock and increases the variability of our estimates as compared to sampling wholly in say, mature plots, however it can be argued that the strategy employed avoids 'majestic forest bias' and accounts for a greater proportion of the heterogeneity in landscape C stocks, particularly given that disturbance (agriculture, fire, humans) is key feature of miombo woodlands. Our estimates for crop standing are considerably higher than anticipated due to the presence of one particularly high biomass plot (37.3 tC ha^{-1}) which had recently (6 months previous) been cleared for maize cultivation. It was found that not all farmers completely remove all trees from their fields, particularly given the difficulties in removing large stems. Indeed, the majority of the biomass in the aforementioned plot was found in just one 107cm diameter tree which helps to highlight the role of large stems as major stores of carbon. Repeated annual/bi-annual burning of the plot was found to gradually reduce stem woody carbon stocks to almost zero after about 4-5 years of continual cultivation. Following abandonment, the mean annual increment of 0.84 tC/ha/yr in stem C stocks in old farms was found to be similar to the Mozambican estimate of 0.7 tC/ha/yr over 25 years, and also to other figures for the miombo of 0.9 tC/ha/yr over 35 years in Zambia (Chidumayo, 1997) and 0.5 tC/ha/yr over 16 years in coppiced woodland in northern Zambia (Stromgaard, 1985).

Project level carbon stocks

Given that the area of each land cover type and its mean carbon density have now been determined, the total project level C stock can be provisionally estimated by simply multiplying the two values for each cover type. The 'stratify and multiply' approach has obvious errors associated with it, particularly considering that the average value cannot adequately account for all the variation in an entire forest category, therefore the values presented in Table 2 should be used as a rough estimate only.

Table 2. Estimated total stem biomass (tC/ha) within each land cover class

	Mean C density (Stem carbon only)	*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
Crops	9.4	236	2,218
Total			30,323

Concluding remarks and future work

1. The forests and woodlands of Kilwa District are extremely heterogeneous, and as such, carbon stocks in above ground biomass have been shown to vary widely. For an initial conservative estimation of carbon in above-ground woody biomass based on the combined data from the PSPs, LPSPs and Circle plots, we may assume a carbon density (stem carbon only) of 15.7 ± 2.44 tC ha^{-1} in the woodlands, 28.4 ± 4.76 tC ha^{-1} in the forests and 11.5 ± 2.08 tC ha^{-1} in the savannas. Our estimates are subject to various uncertainties and therefore should only be treated as preliminary estimates.

2. Lack of normality in data distribution was always a concern, hence our use of unusually large sample plots. These concerns were realised as data from all the plots except the very largest were found to be non-normally distributed. Plotting the data from the large

plots alone, however, was found to produce normally distributed biomass estimates for all three strata, justifying our innovative sampling strategy.

Combining the data from all plots produced the non-normal distribution of biomass shown for the Woodland and Forest strata. This lack of normality, particularly in the spatially dominant Woodland strata, is a cause for concern when it comes to upscaling our measurements (Figure 6). The stratification procedure may have played a role in this due to potential errors in the initial cover classification by Landsat. Tropical woodlands often grade gently into savanna and the transition zone between the two can often be extremely difficult to demarcate, even while standing on the ground. This confusion undoubtedly led to some 'woodland' plots being characterised as savanna and vice versa in the initial classification which may have contributed to the non-normality (Figure 8). Methods on how to account for this will need to be discussed, although it is likely that a re-classification using the forest inventory data as ground truth points may be necessary in order to produce sampling estimates with a lower error or confidence interval for each stratum.

Another possibility which we will look into will be to sub-divide the large 9 ha sample plot into 1 ha parcels and predict woody stem biomass in each 'sub-plot'. The GPS data collected from each large plot will allow us to know which trees fall in to which parcel from which we can calculate, using the equation presented in Figure 4, total stem carbon stocks for each plot. This will increase our total *n* from 150 to 325 (182 in the Woodland, 78 in the Forest, 65 in Savanna) which should reduce the width of the confidence intervals on our estimates.

Figure 8. An example of two misclassifications in the initial classification by LANDSAT. Photograph A was classified as 'Woodland' (W19) whilst photograph B was identified as 'Savanna' (S5).

3. Repeat inventories of all recorded stems on the PSPs and large plots will be initiated in 2013 with the express aim of quantifying woody biomass accumulation rates, along with growth rates, mortality rates and recruitment rates at all sites. The re-measurement of the PSPs should give a good indication of natural magnitudes and directions of change in C stocks. IM has already quality controlled the first round of data and is also in the process of archiving the data in preparation for the repeat inventory. Once complete, the data will be maintained by the UoE and MCDI and will be made freely available to all relevant stakeholders.

4. Although permanent sample plots can provide accurate descriptions of natural processes of mortality, growth and recruitment, they are limited in their extent. 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 carbon stocks. Given the expected lifetime of the project, and the need to monitor regional changes in C stocks, the inventory data needs to be related to satellite remote sensing data so that the areas under management may be assessed rapidly and economically, and with minimum uncertainty. 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 backscatter recorded by the satellite instrument can be correlated to woody biomass using the ground plot data as a guide. The inclusion of both relatively undisturbed as well as degraded areas in the forest inventory will provide extra calibration and validation capacity for the remote sensing data. The ability to combine the plot based measurements with more extensive EO data will ultimately enhance our understanding of how carbons stocks vary across the landscape and how they change over time in response to both natural and anthropogenic processes.

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Appendix A – Plot level carbon stocks and structural characteristics

Plot number	Plot ID	Land cover type	Plot type	Plot size	Stocking density (ha)	Basal area (m^2/ha)	Stem carbon (tC/ha)	Stem carbon >40 only (tC/ha)	Stem carbon >10 only (tC/ha)	Predicted biomass - large plot only (tC/ha)
1	W1	Woodland	PSP	1	554	2.57	3.34	0.00	1.36	3.34
2	W6	Woodland	PSP	1	165	1.95	4.74	1.73	4.24	4.74
3	W7	Woodland	PSP	1	256	2.80	5.20	0.00	4.49	5.20
4	W9	Woodland	PSP	1	360	7.69	18.00	3.43	17.18	18.00
5	W11	Woodland	PSP	1	470	10.50	29.30	18.30	28.09	29.30
6	W12	Woodland	PSP	1	397	7.56	18.82	8.66	17.75	18.82
7	W13	Woodland	PSP	1	602	7.70	18.00	6.99	16.01	18.00
8	W14	Woodland	PSP	1	220	4.62	12.30	5.44	11.69	12.30
9	W16	Woodland	PSP	1	431	7.06	16.53	3.65	15.40	16.53
10	W17	Woodland	PSP	1	703	13.37	33.93	16.62	32.07	33.93
11	W18	Woodland	PSP	1	352	8.53	23.72	14.77	22.71	23.72
12	W19	Woodland	PSP	1	77	0.93	1.93	0.53	1.71	1.93
13	W26	Woodland	PSP	1	873	11.96	25.73	6.51	23.22	25.73
14	W29	Woodland	PSP	1	361	6.68	15.49	4.57	14.57	15.49
15	F5	Forest	PSP	1	1506	17.39	37.14	10.95	32.73	37.14
16	F6	Forest	PSP	1	450	12.39	33.40	13.27	32.45	33.40
17	F7	Forest	PSP	1	665	11.42	28.38	13.49	26.51	28.38
18	F12	Forest	PSP	1	270	11.12	33.81	21.69	33.32	33.81
19	F13	Forest	PSP	1	1511	19.66	44.87	15.70	40.14	44.87
20	F15	Forest	PSP	1	1185	21.35	58.21	27.84	54.84	58.21
21	S3	Savanna	PSP	1	536	2.74	3.56	0.00	1.67	3.56
22	S4	Savanna	PSP	1	72	1.98	6.90	5.02	6.73	6.90
23	S5	Savanna	PSP	1	610	11.64	29.04	10.42	27.40	29.04
24	S7	Savanna	PSP	1	206	1.48	2.47	0.46	1.78	2.47
25	S9	Savanna	PSP	1	275	6.63	16.39	5.16	15.91	16.39
26	W1	Woodland	large	9	0.22	0.03	0.10	0.10	0.10	0.24

27	W6	Woodland	large	9	4.11	0.88	3.33	3.33	3.33	7.73
28	W7	Woodland	large	9	5.78	1.08	3.89	3.89	3.89	9.02
29	W9	Woodland	large	9	5.78	0.99	3.41	3.41	3.41	7.92
30	W11	Woodland	large	9	18.33	4.03	15.35	15.35	15.35	35.63
31	W12	Woodland	large	9	10.33	1.98	7.15	7.15	7.15	16.59
32	W13	Woodland	large	9	12.00	2.51	9.28	9.28	9.28	21.54
33	W14	Woodland	large	9	6.33	1.20	4.44	4.44	4.44	10.31
34	W16	Woodland	large	9	5.78	1.15	4.20	4.20	4.20	9.75
35	W17	Woodland	large	9	23.56	4.21	14.76	14.76	14.76	34.25
36	W18	Woodland	large	9	20.89	3.93	14.02	14.02	14.02	32.55
37	W19	Woodland	large	9	2.89	0.53	1.87	1.87	1.87	4.34
38	W26	Woodland	large	9	11.00	2.13	7.69	7.69	7.69	17.84
39	W29	Woodland	large	9	11.00	1.99	7.01	7.01	7.01	16.27
40	F5	Forest	large	9	6.56	1.48	5.45	5.45	5.45	12.64
41	F6	Forest	large	9	12.67	3.04	11.99	11.99	11.99	27.81
42	F7	Forest	large	9	15.11	3.12	11.48	11.48	11.48	26.65
43	F12	Forest	large	9	17.00	3.64	13.72	13.72	13.72	31.84
44	F13	Forest	large	9	19.56	4.11	15.58	15.58	15.58	36.16
45	F15	Forest	large	9	14.22	3.05	11.60	11.60	11.60	26.93
46	S3	Savanna	large	9	0.89	0.15	0.51	0.51	0.51	1.17
47	S4	Savanna	large	9	6.44	1.52	5.98	5.98	5.98	13.88
48	S5	Savanna	large	9	18.00	3.44	12.31	12.31	12.31	28.56
49	S7	Savanna	large	9	0.78	0.12	0.41	0.41	0.41	0.96
50	S9	Savanna	large	9	2.67	0.59	2.24	2.24	2.24	5.19
51	W1	Woodland	circle	0.19635	122.23	1.49	2.34	0.00	2.34	2.34
52	W6	Woodland	circle	0.19635	0.00	0.00	0.00	0.00	0.00	0.00
53	W7	Woodland	circle	0.19635	224.09	8.58	7.21	1.52	7.21	7.21
54	W9	Woodland	circle	0.19635	397.25	12.25	29.68	1.61	29.68	29.68
55	W11	Woodland	circle	0.19635	229.18	12.03	36.34	4.92	36.34	36.34
56	W12	Woodland	circle	0.19635	35.65	1.96	9.47	0.00	9.47	9.47

57	W13	Woodland	circle	0.19635	112.04	5.21	14.68	1.73	14.68	14.68
58	W14	Woodland	circle	0.19635	66.21	4.43	13.33	1.70	13.33	13.33
59	W16	Woodland	circle	0.19635	152.79	7.21	18.73	0.61	18.73	18.73
60	W17	Woodland	circle	0.19635	224.09	9.96	26.88	2.71	26.88	26.88
61	W18	Woodland	circle	0.19635	193.53	11.11	39.95	5.21	39.95	39.95
62	W19	Woodland	circle	0.19635	178.25	5.19	12.12	0.53	12.12	12.12
63	W26	Woodland	circle	0.19635	346.32	10.03	23.47	1.13	23.47	23.47
64	W29	Woodland	circle	0.19635	137.51	6.87	19.15	1.25	19.15	19.15
65	F5	Forest	circle	0.19635	264.83	8.79	21.09	0.83	21.09	21.09
66	F6	Forest	circle	0.19635	178.25	7.89	22.46	2.67	22.46	22.46
67	F7	Forest	circle	0.19635	229.18	9.34	13.67	0.00	13.67	13.67
68	F12	Forest	circle	0.19635	162.97	7.74	21.53	2.07	21.53	21.53
69	F13	Forest	circle	0.19635	132.42	4.42	10.31	0.47	10.31	10.31
70	F15	Forest	circle	0.19635	366.69	7.99	15.98	0.00	15.98	15.98
71	S3	Savanna	circle	0.19635	40.74	0.57	0.93	0.00	0.93	0.93
72	S4	Savanna	circle	0.19635	117.14	6.41	21.71	3.00	21.71	21.71
73	S5	Savanna	circle	0.19635	198.62	6.10	15.59	1.12	15.59	15.59
74	S7	Savanna	circle	0.19635	112.04	4.90	13.54	1.25	13.54	13.54
75	S9	Savanna	circle	0.19635	122.23	4.48	12.66	1.67	12.66	12.66
76	W1	Woodland	circle	0.19635	0.00	0.00	0.00	0.00	0.00	0.00
77	W6	Woodland	circle	0.19635	71.30	1.38	2.66	0.00	2.66	2.66
78	W7	Woodland	circle	0.19635	96.77	5.30	4.84	1.78	4.84	4.84
79	W9	Woodland	circle	0.19635	112.04	4.03	9.80	0.43	9.80	9.80
80	W11	Woodland	circle	0.19635	264.83	11.24	33.15	3.80	33.15	33.15
81	W12	Woodland	circle	0.19635	76.39	4.56	22.75	1.93	22.75	22.75
82	W13	Woodland	circle	0.19635	61.12	4.11	12.20	1.61	12.20	12.20
83	W14	Woodland	circle	0.19635	132.42	5.47	13.99	0.59	13.99	13.99
84	W16	Woodland	circle	0.19635	259.74	6.28	13.52	0.46	13.52	13.52
85	W17	Woodland	circle	0.19635	208.81	5.10	10.44	0.00	10.44	10.44
86	W18	Woodland	circle	0.19635	86.58	9.06	29.78	4.89	29.78	29.78

87	W19	Woodland	circle	0.19635	10.19	0.32	0.72	0.00	0.72	0.72
88	W26	Woodland	circle	0.19635	106.95	4.69	11.84	0.00	11.84	11.84
89	W29	Woodland	circle	0.19635	96.77	3.43	9.14	0.88	9.14	9.14
90	F5	Forest	circle	0.19635	269.93	6.97	15.48	0.42	15.48	15.48
91	F6	Forest	circle	0.19635	127.32	6.46	17.76	1.52	17.76	17.76
92	F7	Forest	circle	0.19635	264.83	7.84	20.54	1.96	20.54	20.54
93	F12	Forest	circle	0.19635	198.62	7.25	17.94	0.68	17.94	17.94
94	F13	Forest	circle	0.19635	529.67	16.09	44.36	4.10	44.36	44.36
95	F15	Forest	circle	0.19635	412.53	9.99	22.21	0.47	22.21	22.21
96	S3	Savanna	circle	0.19635	5.09	0.06	0.10	0.00	0.10	0.10
97	S4	Savanna	circle	0.19635	219.00	8.72	24.30	2.65	24.30	24.30
98	S5	Savanna	circle	0.19635	280.11	8.40	19.28	0.42	19.28	19.28
99	S7	Savanna	circle	0.19635	117.14	2.27	4.26	0.00	4.26	4.26
100	S9	Savanna	circle	0.19635	10.19	0.17	0.31	0.00	0.31	0.31
101	W1	Woodland	circle	0.19635	20.37	0.43	0.81	0.00	0.81	0.81
102	W6	Woodland	circle	0.19635	96.77	4.78	12.68	1.05	12.68	12.68
103	W7	Woodland	circle	0.19635	112.04	4.72	15.22	1.34	15.22	15.22
104	W9	Woodland	circle	0.19635	203.72	6.33	14.78	0.50	14.78	14.78
105	W11	Woodland	circle	0.19635	178.25	7.37	20.16	2.25	20.16	20.16
106	W12	Woodland	circle	0.19635	50.93	1.97	20.87	0.92	20.87	20.87
107	W13	Woodland	circle	0.19635	56.02	4.30	12.98	1.59	12.98	12.98
108	W14	Woodland	circle	0.19635	61.12	1.74	4.01	0.00	4.01	4.01
109	W16	Woodland	circle	0.19635	188.44	5.22	13.10	1.05	13.10	13.10
110	W17	Woodland	circle	0.19635	264.83	10.01	27.25	2.63	27.25	27.25
111	W18	Woodland	circle	0.19635	127.32	4.48	11.93	1.05	11.93	11.93
112	W19	Woodland	circle	0.19635	25.46	1.74	4.95	0.41	4.95	4.95
113	W26	Woodland	circle	0.19635	137.51	7.56	24.48	3.48	24.48	24.48
114	W29	Woodland	circle	0.19635	142.60	5.58	15.24	2.13	15.24	15.24
115	F5	Forest	circle	0.19635	300.48	7.82	20.31	1.64	20.31	20.31
116	F6	Forest	circle	0.19635	224.09	11.87	32.00	2.05	32.00	32.00

117	F7	Forest	circle	0.19635	208.81	3.93	23.84	2.51	23.84	23.84
118	F12	Forest	circle	0.19635	173.16	11.53	36.93	4.01	36.93	36.93
119	F13	Forest	circle	0.19635	371.79	12.16	31.64	3.24	31.64	31.64
120	F15	Forest	circle	0.19635	356.51	13.32	34.04	1.64	34.04	34.04
121	S3	Savanna	circle	0.19635	91.67	1.27	2.09	0.00	2.09	2.09
122	S4	Savanna	circle	0.19635	208.81	6.24	16.90	1.93	16.90	16.90
123	S5	Savanna	circle	0.19635	198.62	7.65	20.89	1.94	20.89	20.89
124	S7	Savanna	circle	0.19635	106.95	2.91	6.70	0.41	6.70	6.70
125	S9	Savanna	circle	0.19635	183.35	3.37	6.41	0.00	6.41	6.41
126	W1	Woodland	circle	0.19635	81.49	1.64	4.06	0.57	4.06	4.06
127	W6	Woodland	circle	0.19635	112.04	3.73	8.67	0.00	8.67	8.67
128	W7	Woodland	circle	0.19635	137.51	6.63	11.37	1.95	11.37	11.37
129	W9	Woodland	circle	0.19635	183.35	5.23	12.20	0.53	12.20	12.20
130	W11	Woodland	circle	0.19635	213.90	11.73	33.14	2.99	33.14	33.14
131	W12	Woodland	circle	0.19635	117.14	8.48	28.50	3.46	28.50	28.50
132	W13	Woodland	circle	0.19635	173.16	4.71	10.84	0.45	10.84	10.84
133	W14	Woodland	circle	0.19635	101.86	7.18	24.30	3.89	24.30	24.30
134	W16	Woodland	circle	0.19635	305.58	9.67	24.60	2.32	24.60	24.60
135	W17	Woodland	circle	0.19635	132.42	8.49	27.19	3.68	27.19	27.19
136	W18	Woodland	circle	0.19635	117.14	4.22	11.33	1.23	11.33	11.33
137	W19	Woodland	circle	0.19635	157.88	6.26	18.57	2.78	18.57	18.57
138	W26	Woodland	circle	0.19635	173.16	5.14	11.36	0.00	11.36	11.36
139	W29	Woodland	circle	0.19635	254.65	8.60	21.31	0.90	21.31	21.31
140	F5	Forest	circle	0.19635	437.99	20.50	69.23	8.54	69.23	69.23
141	F6	Forest	circle	0.19635	244.46	9.79	25.43	1.67	25.43	25.43
142	F7	Forest	circle	0.19635	198.62	6.16	18.62	1.18	18.62	18.62
143	F12	Forest	circle	0.19635	224.09	12.76	37.93	4.01	37.93	37.93
144	F13	Forest	circle	0.19635	173.16	6.90	18.40	1.69	18.40	18.40
145	F15	Forest	circle	0.19635	387.06	10.42	24.00	1.15	24.00	24.00
146	S3	Savanna	circle	0.19635	117.14	2.24	4.54	0.00	4.54	4.54

147	S4	Savanna	circle	0.19635	122.23	3.66	10.43	1.54	10.43	10.43
148	S5	Savanna	circle	0.19635	208.81	7.44	18.80	0.93	18.80	18.80
149	S7	Savanna	circle	0.19635	275.02	7.29	14.94	0.00	14.94	14.94
150	S9	Savanna	circle	0.19635	183.35	5.05	11.06	0.48	11.06	11.06