How much carbon does community forest management save? The results of K:TGAL´s field measurements

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K:TGAL project

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This paper summarises data on carbon stock change in the 39 research sites that were included in the KTGAL project. Most of these sites were forests that were under community forest management, although a few were unmanaged forests have been included for comparison (control sites). The purpose of the analysis is to assess the effectiveness of community forest management in conserving and building up stocks of carbon, and to provide quantitative evidence of this.

The measurements were of above ground tree biomass stock, and they were taken over a number of years in each site. We have made the assumption that 50% of the biomass is carbon.

The paper starts by clarifying how community forest management (CFM) might play a role under international policy on Reduced Emissions from Deforestation and Degradation in Developing countries, pointing out that the main effect is likely to be in reducing degradation and bringing about forest enhancement, rather than by halting deforestation.

It then explains the methodology we employed and presents the results.

Finally a discussion of the implications of these findings as regards carbon crediting is provided

1. How CFM could contribute to mitigation of climate change under REDD+ policy

1.1 The nature of CFM

Programmes promoting the management of forests by communities are usually designed to provide the communities with the forest products they require for their subsistence (firewood, fodder, etc) while maintaining this off-take at a sustainable level so that the natural regeneration processes of the forest enable it to remain healthy. In other words, the environmental aim is to halt degradation of the forest and promote forest restoration or enhancement, while the social aim is to supply the local needs. Although these two objectives may seem contradictory, many examples of community forest management indicate that they can be compatible.

When forests are protected from over-use, they start to be more productive, and produce much more than when they are in a degraded condition. People are aware of this, the problem is usually an organizational one: how to regulate the off-take, rather than how to stop off-take completely. Indeed without an arrangement that allows for local people to gather the products they need, they are likely to be hostile to the scheme and sabotage the effort. The art is to find a balance, to change what used to be a *de facto* open access resource regime in which everyone grabs as much as they can, into a true common property regime, in which it becomes in the interest of the community to uphold rules which ensure a fair share for all, as this can guarantee sustainable production in the long term. It seems that people can often be motivated to accept management plans of this kind if (1) their individual as well as their community rights to use the forest are recognized, (2) if they are given powers to exclude outsiders from using the forest, and (3) if they have sufficient trust in their own local institutions to organize the work involved, and the distribution of the benefits, fairly.

1.2 CFM is effective in reducing particular types of forest degradation, rather than deforestation.

CFM has a specific niche amongst the various instruments that can be used to control loss of forests. Most successful CFM programmes are carried out in forests which had become degraded over time as a result of over use of the resource by the communities themselves. The purpose of the CFM is to halt and reverse this. Degradation in this sense refers to loss of biomass from within the forest, a gradual reduction spread over large areas and a long period of time. Degradation may also occur as a result of outside forces, particularly in high value rainforest, where commercial companies come in (legally or illegal) to selectively fell timber. This kind of degradation is not gradual but sporadic both in time and in space. CFM is not generally an instrument which is capable of preventing this type of degradation, because the profits from such logging are very high. These market forces are very hard to resist, and villagers may be co-opted. Government authorities have limited capacity to control it and villagers may have even less. Similarly, CFM is not usually very effective in preventing deforestation (wholesale clearance of forest), which again is in most cases the result of strong commercial forces. Where individuals in rural communities can greatly improve their economic situation by clearing the forests for alternative uses, or by selling the forest so that other can do this, CFM will probably not be able to stem the tide.

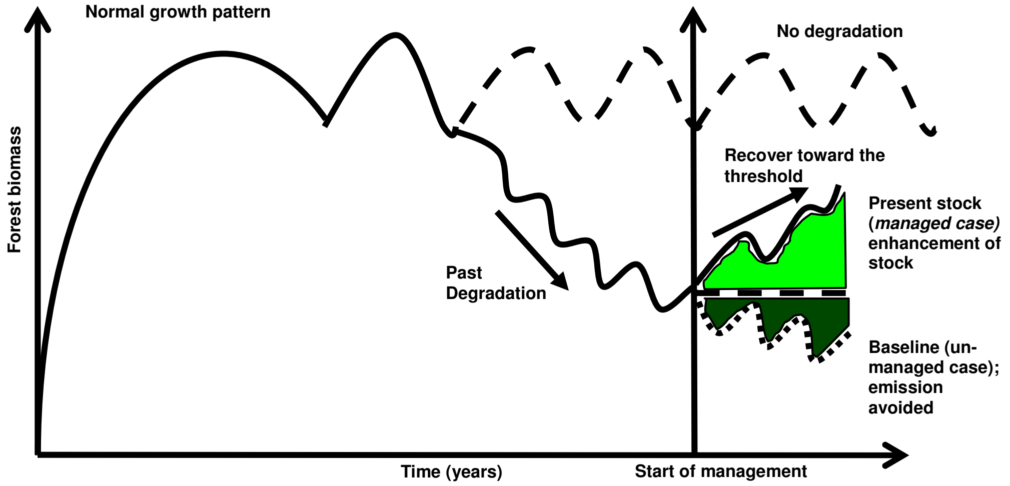
The primary utility of CFM is in the sphere of improved management of forests which are degrading as a result of uncontrolled community uses. The success of CFM in countries such as Nepal, India and Tanzania is based on the recognition of the communities that controlled management results in a better supply of the forest products they need.

1.3 The potential climate change impacts of CFM

CFM could result in two effects as regards climate change: a reduction of the rate of degradation, and an increase in forest biomass due to increasing sequestration (Figure 1). The first would be expected to precede the second.

In terms of crediting, the business as usual case (or reference scenario) would reflect the pre-CFM situation in which degradation (loss of forest biomass from within the forest) would continue unchecked. Any reductions in the rate of degradation would in principle be eligible for crediting. In addition, increased stocks represent forest enhancement which would also be eligible for crediting under REDD+.

Figure 1



2. Methodology used in the research

The KTGAL programme did not itself develop or introduce CFM projects, but selected sites in which such management plans had been operating for some time with reasonable success, and used these as its laboratory. The majority of these are in areas of forest earlier degraded by community uses, and most are not much threatened by outside market demands for timber, although some were earlier supplying charcoal for sale beyond the community. The exception to this are the sites in Papua New Guinea, which are all under pressure from logging companies, and which are being managed by the communities in part for timber products under FSC certification.

The sample of sites was made to reflect as broad a range of ecological and management conditions as possible given constraints on accessibility and reach of the research partners, who were responsible to their selection. In Nepal, the three sites represent forests at three different altitudes. In India, all the sites are clustered in one area (Himalayan temperate forests) but different strata of forest (different tree mixes) are represented, as well as different management conditions. In Tanzania the sites range from dry savanna woodlands to evergreen montane forests. In West Africa the sites distinguish a variety of savanna conditions. In Papua New Guinea the sites are all of tropical rainforest. Details of the site conditions is given in the document Site Dossiers.

Measurements of biomass stock were made by local people involved in the CFM, who were trained to monitor the forest using standard forest inventory procedures. Training was done by the research partner or an intermediary organization, and in the first years the forest monitors were supervised rather carefully by this same organization, although in later years they were able to carry out the measurements unaided.

The number of years of measurement varies from site to site, since not all sites were initiated at the same time, and in one or two cases a year was missed (e.g. due to heavy snowfall in Nepal which made access to the site impossible). The annual measurements at each site were taken at the same time of the year to avoid errors due to seasonal changes.

2.1. Estimating reduction in degradation

Estimating reduction in rates of degradation is counterfactual. It cannot be measured directly, since the earlier rate of degradation in forests which are now under management is unknown: that stage has been passed. A historical baseline would be needed, but this is difficult to construct *ex post*. Baselines could be based either on estimates of rates of degradation in control sites (unmanaged forests) close to the areas that are under management, or on estimates of degradation at a regional or biome level, from secondary data. We recognize that both of these methods are very rough and neither may yield very reliable baselines. In any case control sites were not available in all our study areas, for example in Nepal, where all the forest around the study areas was also under CFM. We have used both types of data where available and used a conservative approach, preferring to underestimate past degradation rates rather than to overestimate them.

2.2 **Estimating forest enhancement**

In contrast, measuring forest enhancement is relatively easy since it simply requires a time series of measurements after the start of the CFM. The methods we used drew on standard forest inventory technique as suggested by the IPCC Good Practice Guidance for Land Use, Land use Change and Forestry and Winrock`s Field Manual. This method rests on the establishment of permanent sampling plots, within which all trees greater than a given diameter at breast height are regularly (in our case, annually) measured (dbh and height). This data is entered into allometric equations which estimate the amount of above ground biomass in each tree, and the carbon content is taken at approximately 50% of this; carbon dioxide is calculated by multiplying the carbon value by 3.6. Expansion equations may be used to estimate the carbon content of the roots. Though in some of our sites we also measured the biomass of the herb and litter layers, and the carbon content of the soil, this was not done uniformly and these carbon pools have been omitted from our general reporting. Data is expressed per hectare.

3. Results of field measurements at the research sites (forest enhancement)

Table 1 presents the data on change in biomass over the years in which measurements were made. These are measurements of forest increment or enhancement, not of avoided degradation, which is estimated separately (see below).

Table 1 Above ground biomass stock changes as measured in the project sites

Country and site no.	Location/ community	Type of forest	Span of years measured	No. of annual measurements	Biomass stock in first year measured (tons/ha)	Biomass stock in final year measured (tons/ha)	Average annual change in biomass (tons/ha/year)[1]	% annual change on starting stock	Annual CO2 equivalent (tons C02)
Ind 1.1	Dhaili	Even aged banj oak	6	6	253.0	279.9	5.2	2.1	9.36
Ind 1.2	Dhaili	Dense mixed banj oak	6	6	386.3	426.4	7.9	2.0	14.22
Ind 1.3	Dhaili	Degraded oak forest	6	6	29.3	38.1	1.7	5.8	3.06
Ind 2.1	Toli	Chir pine with bushy banj	6	6	100.6	116.3	3.0	3.0	5.40
Ind 2.2	Toli	Young pure pine	6	6	114.6	143.6	5.6	4.8	10.08
Ind 2.3	Toli	Young banj oak with chir	6	6	246.4	280.11	6.7	2.7	12.06
Ind 3.1	Guna	Mixed banj oak	5	5	226.4	253.6	6.8	3.0	12.24
Ind 3.2	Guna	Young pure chir pine	5	5	16.4	31.3	3.6	21.0	6.48
Ind 3.3	Guna Private	Private mgt.,banj oak	5	5	275.6	290.8	3.5	1.3	6.30
Ind 4.1[2]	*Asota*	*Sacred, mixed banj oak*	*3*	*3*	*239.3*	*245.7*	*6.4*	*2.7*	*11.52*
Nep 1[3]	Ilam	Mixed subtrop, broad leaf	5	4	na	na	Na	na	na
Nep 2	Lamatar	Mixed temp. broad leaf	5	5	90.5	104.4	3.1	3.4	5.58
Nep 3	Manang	Temp. conifer	5	4	55.0	47.5	- 3.6	- 6.5	- 6.48
Tan 1.1	Kimunyu	Miombo	4	4	40.5	39.8	- 0.7	-1.7	- 1.26
Tan 1.2	SUATF	Miombo	4	4	35.2	42.2	2.8	7.9	5.04
Tan 1.3	*Kim/SUA*	*Miombo*	*3*	*3*	*8.48*	*7.59*	*-0.2*	*-2.4*	*-0.36*
Tan 2.1	Mangala	Lowland	4	4	151.1	177.9	8.8	5.8	15.84
Tan 2.2	*Mangala*	*Lowland*	*3*	*3*	*1.01*	*1.02*	*0.0*	*0.0*	*0.0*
Tan 3.1	Handei	Sub-montaine evergreen	4	4	151.5	173.9	7.1	4.7	12.78

Tan 3.2	*Handei*	*Sub-montaine evergreen*	*3*	*3*	*121.59*	*121.65*	*-0.1*	*0.0*	*0.18*
Tan 4.1	Warib	Miombo re-growth	3	3	31.7	36	2.2	6.9	3.96
Tan 4.2	Haitemba	Miombo old growth	3	3	73.4	75.4	1.0	1.3	1.8
Mal 1.1	Safecoro	Savanne arboree	3	3	26.18	35.08	4.4	16.9	7.92
Sen 1.1	Tomboroconto	Foret Claire	4	3	71.09	65.0	-3.1	-4.3	- 5.58
Sen 1.2	Tomboroconto	Savanne boisée	4	3	38.0	53.0	7.5	19.7	13.50
Sen 1.3	Tomboroconto	Savanne arboree	4	3	40.3	42.5	1.1	2.7	1.98
Sen 1.5	Tomboroconto	Savanne arbustive	4	3	19.6	21.0	0.7	3.6	1.26
GBs 1.1	Djalicunda	Savanne arboree	3	3	176.4	183.4	3.5	2.0	6.30
GBs 1.2	Buro	Savanne arboree	3	3	114.8	138.1	11.6	10.1	20.88
GBs 1.3	Ga Quebo	Savanne arboree	3	3	127.8	132.1	2.1	1.7	3.78
GBs 1.4	Sitato	Savanne arboree	3	3	72.9	85.6	6.3	8.6	11.34
GBs 1.5	*Djalicunda*	*Savanne arboree*	*2*	*2*	*60.2*				
GBs 1.6	*Buro*	*Savanne arboree*	*2*	*2*	*81.5*				
GBs 1.7	*Ga Quebo*	*Savanne arboree*	*2*	*2*	*85.6*				
GB 2.1	Djalocunda	Savanne arboree	2	2	154.9	159.8	4.8	3.1	8.64
PNG 1.1	Minda	Lowland rainforest	2	2	389.6	400.1	10.5	2.7	18.90
PNG 2.1	Baikakea[4]	Lowland rainforest	2	2		171.7			
PNG 3.1	Tavola primary	Lowland + low montane	2	2	287.0	301.8	14.5	5.0	26.1
PNG 3.2	Tavola sec.	Lowland + low montane	2	2	233.2	251.0	17.8	7.6	32.04
Average annual biomass increase per hectare, excluding control sites							4.9		8.8

Notes to table:

1. The average annual increment in biomass is the slope of the best fit regression line on the mean biomass measured per year.
2. Entries in italics refer to control sites (areas of unmanaged forest in the vicinity of the CFM sites). The purpose of including these was to estimate the underlying rate of degradation.
3. During analysis some irregularities (exceptionally high and apparently inconsistent readings in some years) were found in the database for this site so it has been left out of the results for the time being until we are able to determine the reason.
4. At Baikakea measurement was only taken in one year so growth figures cannot be calculated

The results are also presented graphically country by country (Figures 3 to 9). In these graphs we present the mean biomass per year with its 90% confidence interval. An analysis of variance for repeated measures (ANOVA) was performed to test for differences on biomass among years in 14 of the 32 sites from Nepal, Tanzania and India, where the data sets fulfilled the requirements for the analysis. Regression lines have been plotted indicating the trend of biomass change over time, the slope of the regression indicates average annual change on tons of biomass per hectare per year. Even though differences in terms of change between individual years may not always be significant, the overall trends generally are, as significant increase in biomass usually between data more than two years apart. This is the case for Manang and Lamatar from Nepal, and Haitemba from Tanzania. In all sites from India the overall increment of biomass was higher than zero. For these sites, the increment of biomass was significant from one year to the next, consistently. Control sites are included next to the managed site to which they are related, so that comparisons can be easily made.

In the vast majority of the sites which were under community management (32 in total), a positive gain in biomass (and hence carbon stocks) was registered, indicating that CFM in these areas was effective in increasing the carbon sink. There were a few (3) exceptions to this, however, which will be considered below. Leaving aside the negative cases (and the control sites), the gain in terms of tons biomass per hectare ranged from a low of 1 ton in some of the badly degraded savanna sites to 17 tons in one of the PNG rainforest cases, distributed as shown in Figure 2. The average growth over all the managed sites, including those that lost carbon, was just under 5 tons biomass per hectare per year, or 8.8 tons CO_2 per hectare per year.

Figure 2 Distribution of sites by growth rate

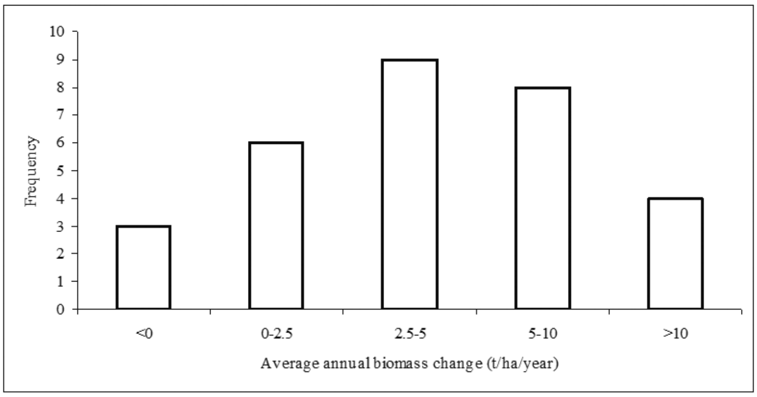
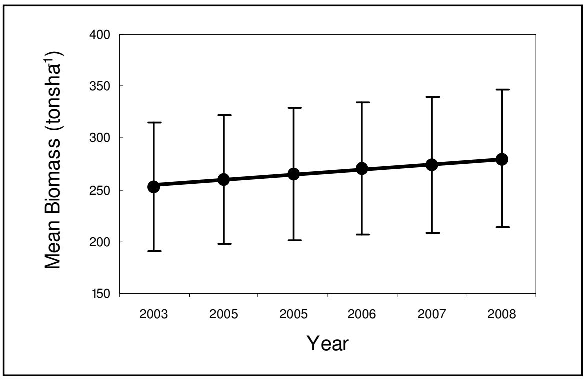
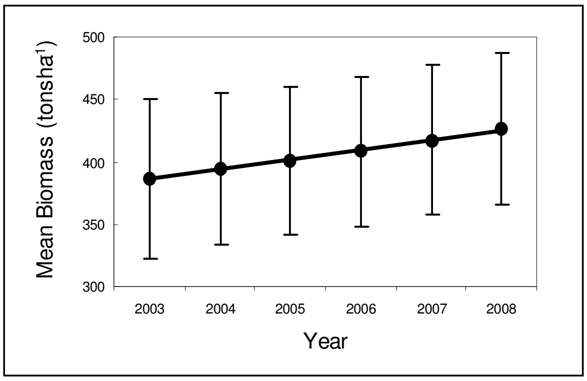


Figure 3: Indian sites, biomass change 2003-2008

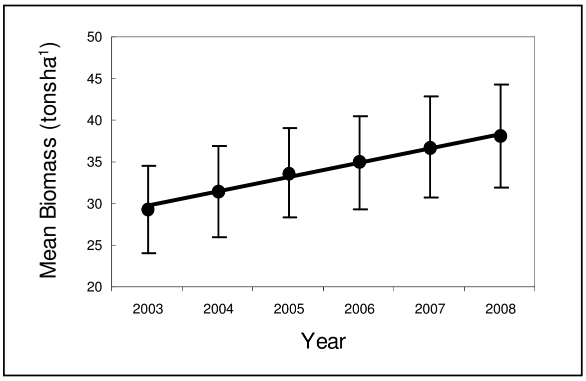
Even aged banj oak forest, Dhaili, Uttarkhand, India
Average biomass increase: 5.2 tonsha-^{1}year-^{1}



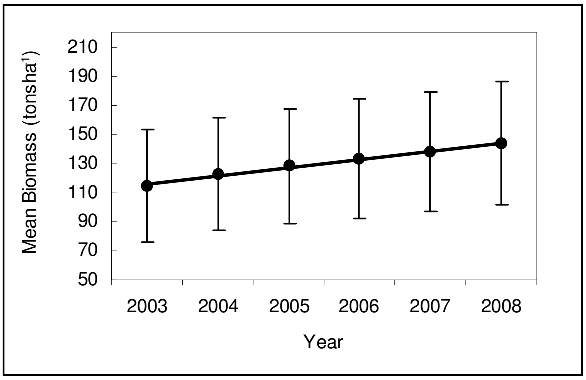
Dense mixed banj oak forest, Dhaili, Uttarkhand, India
Average biomass increase: 7.9 tonsha-^{1}year-^{1}



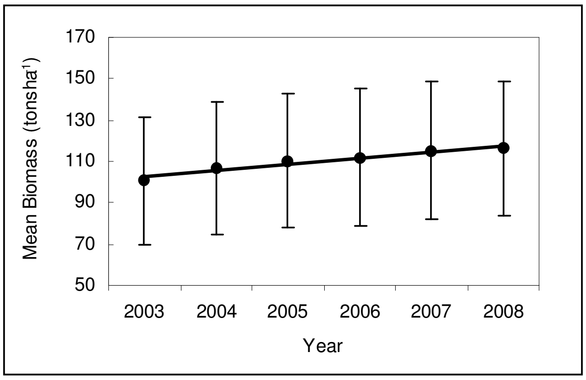
Degraded oak forest, Dhaili, Uttarkhand, India
Average biomass increase: 1.7 tonsha-^{1}year-^{1}



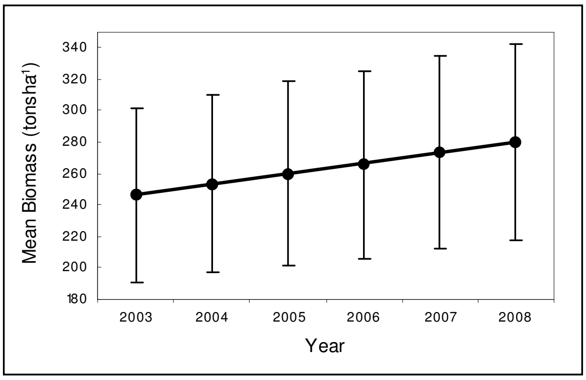
Young pure pine forest, Toli, India
Average biomass increase: 5.6 tonsha-^{1}year-^{1}



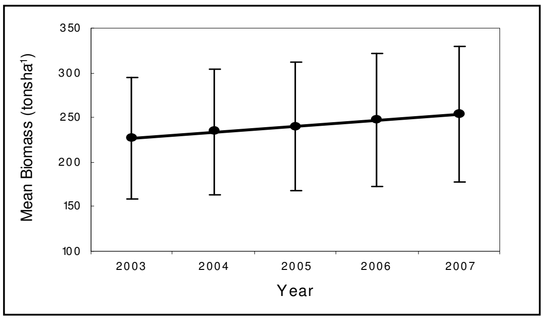
Chir pine with bushy banj forest, Toli, India
Average biomass increase: 3.0 tonsha-^{1}year-^{1}



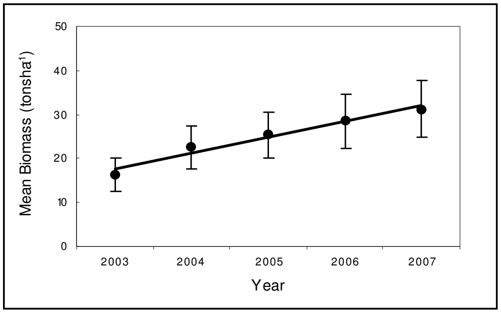
Young banj oak with chir pine forest, Toli, India
Average biomass increase: 6.7 tonsha-^{1}year-^{1}



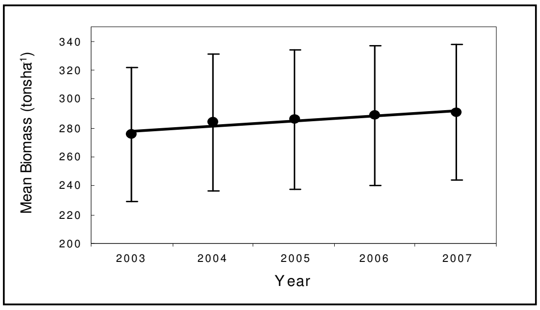
Mixed banj oak forest, Guna, India
Av biomass increase: 6.8 tonsha-^{1}year-^{1}



Young pure chir pine forest, Guna, India
Av biomass increase: 3.6 tonsha-^{1}year-^{1}



Mixed kail pine, Private, India
Av biomass increase: 3.5 tonsha-^{1}year-^{1}



Mix banj oak,sacred forest, Asota, India
Av biomass increase: 6.4 tonsha-^{1}year-^{1}

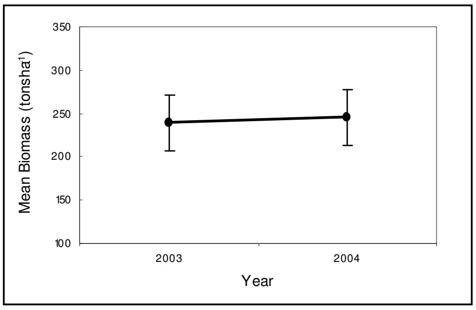


Figure 4: Nepalese sites, biomass change 2004-2009

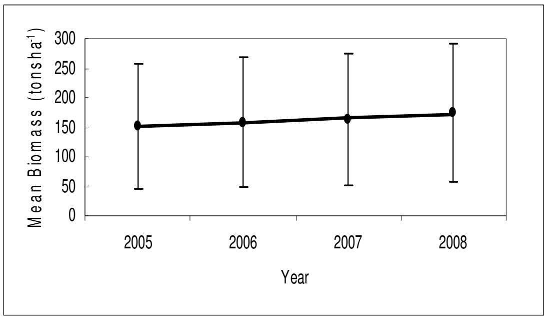
Mixted temperate broad leafed forest, Lamatar, Nepal
Av biomass increase: 3.1 tonsha^{-1}year^{-1}

Temperate conifer forest, Manang, Nepal
Av biomass increase: -3.6 tonsha^{-1}year^{-1}

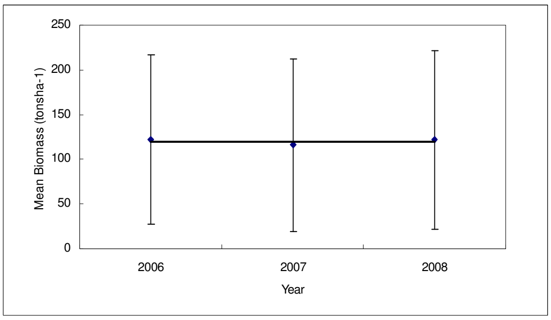
Note: data for the site at Ilam is under review

Figure 5: Tanzanian sites and *control sites:* biomass change, 2005-2008

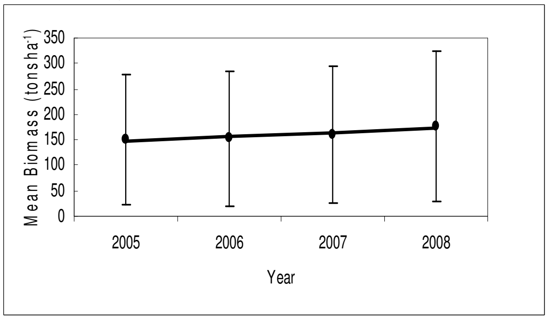
Sub-montane evergreen , Handei, Tanzania
Average biomass increase: 7.1 tonsha-^{1}year-^{1}



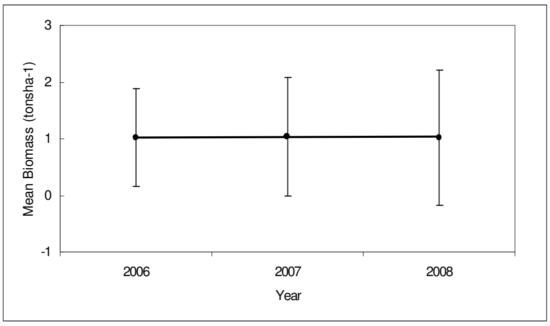
Control: Sub-montane evergreen , Handei, Tanzania. Av biomass increase: -0.1 tonsha-^{1}year-^{1}



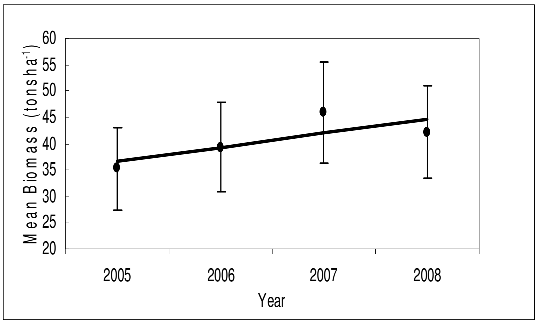
Lowland , Mangala, Tanzania
Average biomass increase: 8.8 tonsha-^{1}year-^{1}



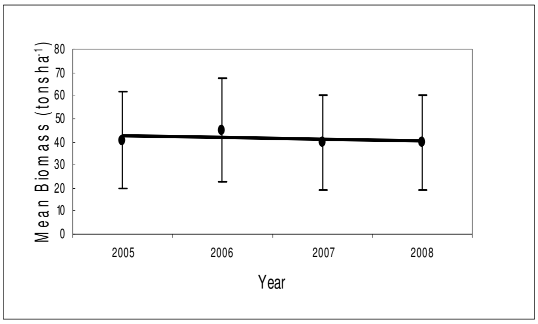
Control: Lowland , Mangala, Tanzania
Average biomass increase: 0.0 tonsha-^{1}year-^{1}



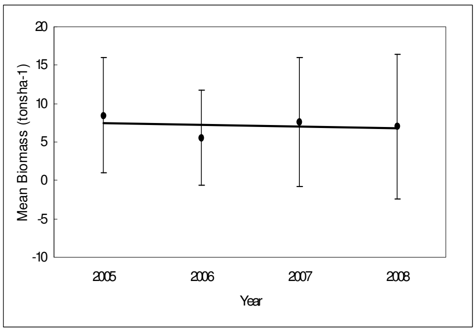
Miombo forest, SUAFT, Tanzania
Average biomass increase: 2.8 tonsha-^{1}year-^{1}



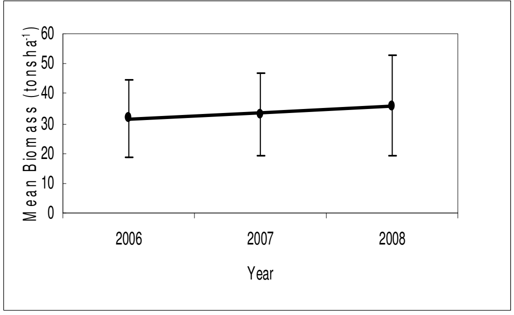
Miombo forest, Kimunyu, Tanzania
Average biomass increase: -0.7 tonsha-^{1}year-^{1}



Control: Miombo, Kim/SUA, Tanzania
Av biomass increase: -0.2 tonsha-^{1}year-^{1}



Miombo re-growth forest, Warib, Tanzania
Average biomass increase: 2.2 tonsha-^{1}year-^{1}



Miombo old growth forest, Haitemba, Tanzania
Average biomass increase: 1.0 tonsha-^{1}year-^{1}

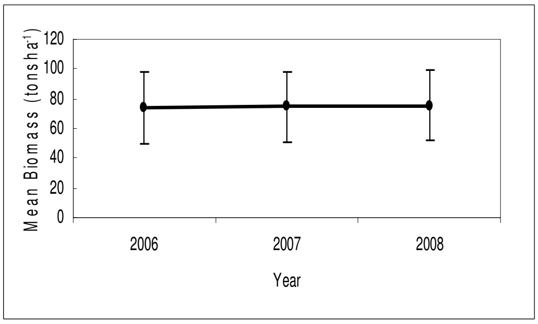
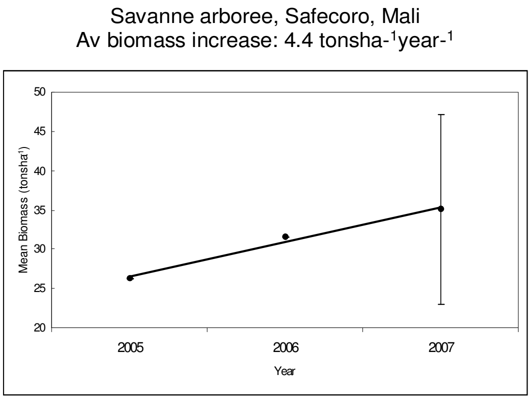


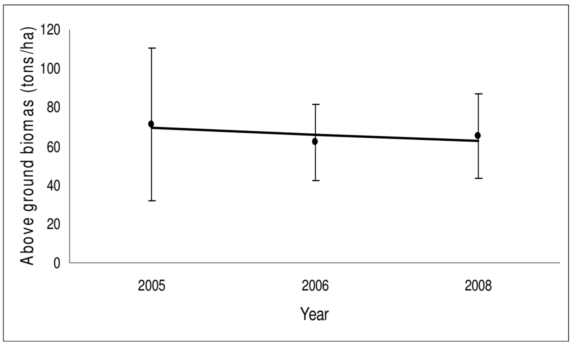
Figure 6: Malian site, biomass change 2004-2008



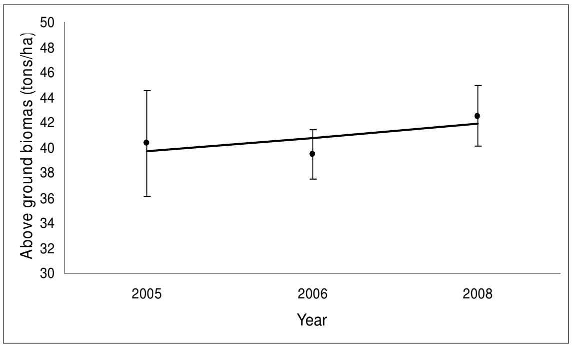
Savanne arboree, Safecoro, Mali
Av biomass increase: 4.4 tonsha-^{1}year-^{1}

Figure 7: Senegalese sites, biomass change 2005-2008

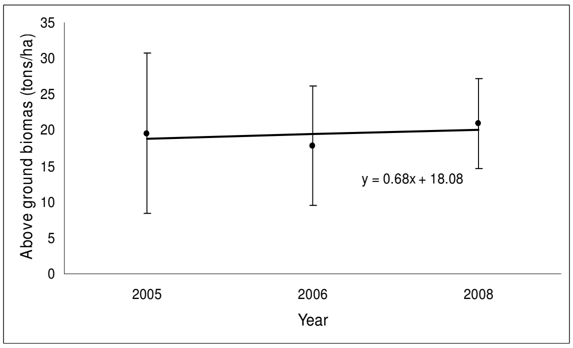
Foret Claire, Tomboroco, Senegal
Average biomass increase: -3.1 tonsha-^{1}year-^{1}



Savanne arboree, Tomboroco, Senegal
Average biomass increase: 1.1 tonsha-^{1}year-^{1}



Savanne arbustive, Tomboroco, Senegal
Average biomass increase: 0.7 tonsha-^{1}year-^{1}



Savanne boise, Tomboroco, Senegal
Average biomass increase: 7.5 tonsha-^{1}year-^{1}

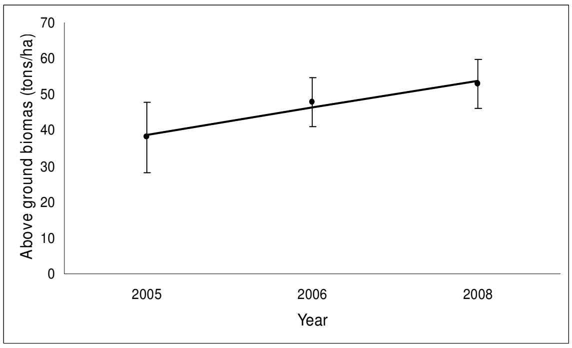
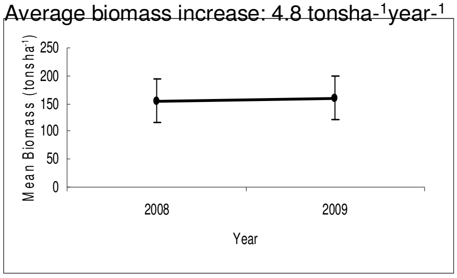
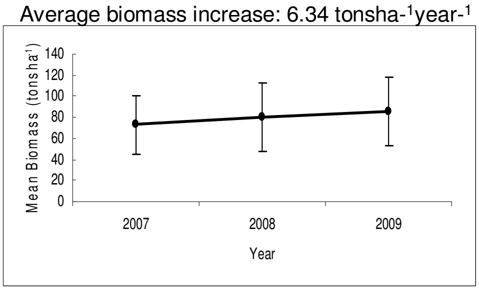


Figure 8: Guinea Bissau sites, biomass change 2007-2009

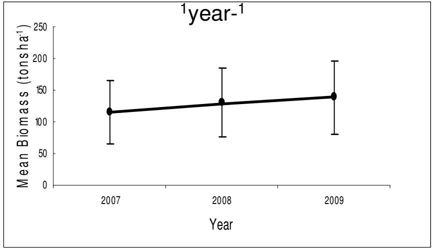
Savanne arboree, Djalocunda, Guinea Bissau
Average biomass increase: 4.8 tonsha-^{1}year-^{1}



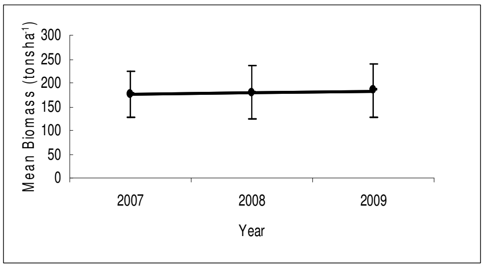
Savanne arboree, Sitato, Guinea Bissau
Average biomass increase: 6.34 tonsha-^{1}year-^{1}



Savanne arboree, Buro, Guinea Bissau
Average biomass increase: 11.6 tonsha-^{1}year-^{1}



Savanne arboree, Djalicunda, Guinea Bissau
Average biomass increase: 3.5 tonsha-^{1}year-^{1}



Savanne arboree, Ga Quebo, Guinea Bissau
Average biomass increase: 2.15 tonsha-^{1}year-^{1}

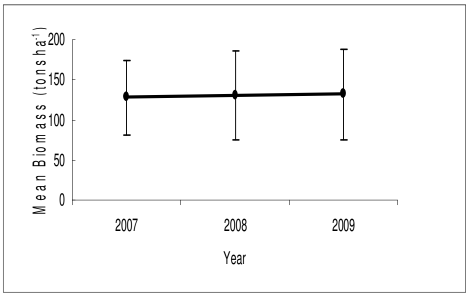


Figure 9: Papua New Guinea sites biomass change

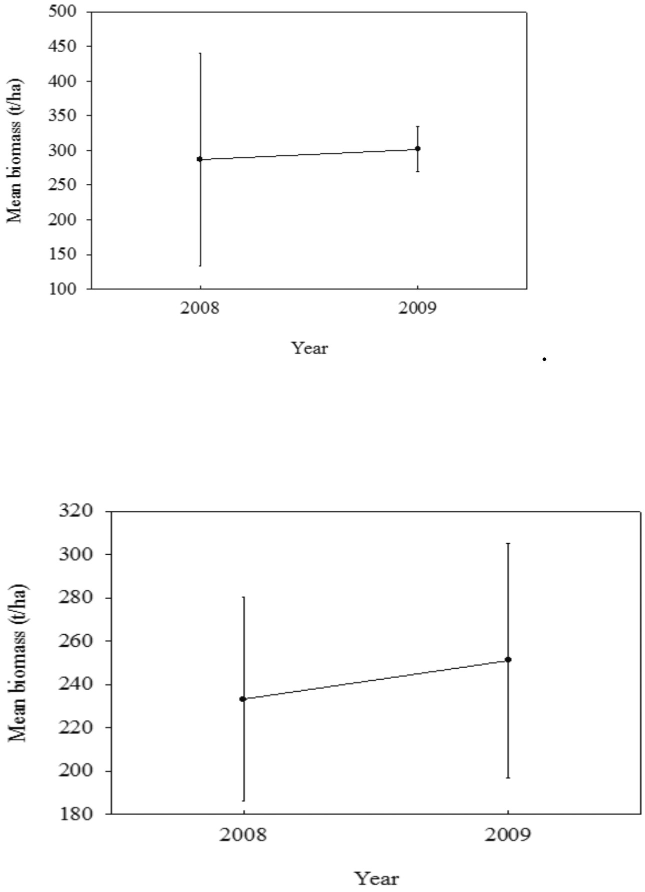


Tavola primary forest (upper graph): biomass increment 14.5 tons/ha/year
Tavola secondary forest (lower graph): biomass increment 17.8 tons/ha/year

Minda (not shown as graph): biomass increment 10.5 tons/ha/year

Baikakea: measurements taken in one year only, no growth calculations made.

3.2 Explanations for differences observed

It is noticeable that when growth is considered in percentage terms, the fastest increases are found in sites with rather low levels of vegetation, because in these places, regeneration is taking place at a rapid rate, under management. This is entirely to be expected. The rates of increase are asymptotic and will slow down as the total biomass present at the site increases.

Further, the sites can be roughly divided into three ecological types: temperate mountain forests, savanna forests and wet tropical, subtropical and lowland forests, as illustrated in Tables 2, 3 and 4. It is clear that growth rates in managed degraded forests are slightly lower (3.1 tons per ha per annum, equivalent to about 5.5 tons CO_2) in the dry savanna than in the temperate mountain forests in the Himalayas (4.3 tons per ha per annum, equivalent to about 7.5 tons CO_2) while growth rates in tropical rainforests are considerably higher (11.7 tons per ha per annum, 21 tons CO_2). This is also not an unexpected finding. Water availability and length of growing season are the key limitation to plant growth.

3.3 Why some sites lost carbon

Three sites (out of the 32 that were managed) lost carbon. In two of the three cases (Kumunyu in Tanzania and Manang in Nepal), the reason was observed. Part of the community forest in these two locations was encroached by a private individual from outside the community, meaning that the average biomass density for the whole area was greatly affected. It has been mentioned earlier that CFM is not an instrument that is strong in reducing deforestation, and these are good example of that. What is interesting however that both before and after the incident, the biomass levels in the forest are rising, indicating that is functional as regards encouraging forest enhancement (Figure 10). At the third site, the Foret Claire in Tomboroconto, we were not able to establish the reason for the loss, but most probably it was due to extraction of timber by people from within or outside the community. This represents a failure of CFM, and inability of the community of completely control use of the area, although the three other strata in that area all increased their biomass density throughout the period.

Temperate conifer forest, Manang, Nepal
Biomass increment for a managed forest before perturbation (a) and after perturbation (b)

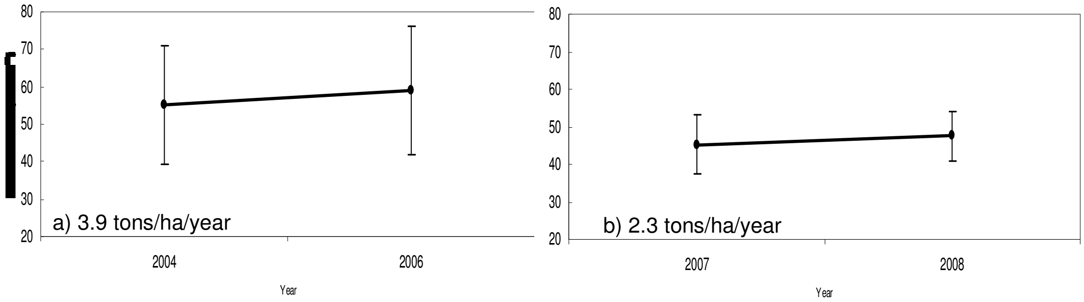


Figure 10: In Manang, the forest was partially encroached between 2006 and 2007 (see Figure 4). Both before and after this, biomass was increasing.

Table 2: Sites representing temperate mountain forest

Country and site no.	Location/ community	Type of forest	Span of years measured	No. of annual measure-ments	Biomass stock in first year measured (tons/ha)	Biomass stock in final year measured (tons/ha)	Average annual change in biomass (tons/ha)[1]
Ind 1.1	Dhaili	Even aged banj oak	6	6	253.0	279.9	5.2
Ind 1.2	Dhaili	Dense mixed banj oak	6	6	386.3	426.4	7.9
Ind 1.3	Dhaili	Degraded oak forest	6	6	29.3	38.1	1.7
Ind 2.1	Toli	Chir pine with bushy banj	6	6	100.6	116.3	3.0
Ind 2.2	Toli	Young pure pine	6	6	114.6	143.6	5.6
Ind 2.3	Toli	Young banj oak with chir	6	6	246.4	280.11	6.7
Ind 3.1	Guna	Mixed banj oak	5	5	226.4	253.6	6.8
Ind 3.2	Guna	Young pure chir pine	5	5	16.4	31.3	3.6
Ind 3.3	Guna Private	Private mgt.,banj oak	5	5	275.6	290.8	3.5
Ind 4.1[2]	*Asota*	*Sacred, mixed banj oak*	*3*	*3*	*239.3*	*245.7*	*6.4*
Nep 2	Lamatar	Mixed temp. broad leaf	5	5	90.5	104.4	3.1
Nep 3	Manang	Temp. conifer	5	4	55.0	47.5	- 3.6
Average annual change biomass increase per hectare, excluding control sites							4.3

Table 3: Sites representing savanna woodlands

Country and site no.	Location/ community	Type of forest	Span of years measured	No. of annual measure-ments	Biomass stock in first year measured (tons/ha)	Biomass stock in final year measured (tons/ha)	Average annual change in biomass (tons/ha)[1]
Tan 1.1	Kimunyu	Miombo	4	4	40.5	39.8	- 0.7
Tan 1.2	SUATF	Miombo	4	4	35.2	42.2	2.8
Tan 1.3	*Kim/SUA*	*Miombo*	*3*	*3*	*8.48*	*7.59*	*-0.2*
Tan 4.1	Warib	Miombo re-growth	3	3	31.7	36	2.2
Tan 4.2	Haitemba	Miombo old growth	3	3	73.4	75.4	1.0
Mal 1.1	Safecoro	Savanne arboree	3	3	26.18	35.08	4.4
Sen 1.1	Tomboroconto	Foret Claire	4	3	71.09	65.0	-3.1
Sen 1.2	Tomboroconto	Savanne boisée	4	3	38.0	53.0	7.5
Sen 1.3	Tomboroconto	Savanne arboree	4	3	40.3	42.5	1.1
Sen 1.5	Tomboroconto	Savanne arbustive	4	3	19.6	21.0	0.7
GBs 1.1	Djalicunda	Savanne arboree	3	3	176.4	183.4	3.5
GBs 1.2	Buro	Savanne arboree	3	3	114.8	138.1	11.6
GBs 1.3	Ga Quebo	Savanne arboree	3	3	127.8	132.1	2.1
GBs 1.4	Sitato	Savanne arboree	3	3	72.9	85.6	6.3
GBs 1.5	*Djalicunda*	*Savanne arboree*	*2*	*2*	*60.2*		
GBs 1.6	*Buro*	*Savanne arboree*	*2*	*2*	*81.5*		
GBs 1.7	*Ga Quebo*	*Savanne arboree*	*2*	*2*	*85.6*		
GB 2.1	Djalocunda	Savanne arboree	2	2	154.9	159.8	4.8
Average annual biomass increase per hectare, excluding control sites							3.1

Table 4. Sites representing wet tropical, subtropical and lowland forest

	Location/ community	Type of forest	Span of years measured	No. of annual measure-ments	Biomass stock in first year measured (tons/ha)	Biomass stock in final year measured (tons/ha)	Average annual change in biomass (tons/ha)[1]
Nep 1[3]	Ilam	Mixed subtrop, broad leaf	5	4	na	na	na
Tan 2.1	Mangala	Lowland	4	4	151.1	177.9	8.8
Tan 2.2	*Mangala*	*Lowland*	*3*	*3*	*1.01*	*1.02*	*0.0*
Tan 3.1	Handei	Sub-montaine evergreen	4	4	151.5	173.9	7.1
Tan 3.2	*Handei*	*Sub-montaine evergreen*	*3*	*3*	*121.59*	*121.65*	*-0.1*
PNG 1.1	Minda	Lowland rainforest	2	2	389.6	400.1	10.5
PNG 3.1	Tavola primary	Lowland + low montane	2	2	287.0	301.8	14.5
PNG 3.2	Tavola sec.	Lowland + low montane	2	2	233.2	251.0	17.8
Average annual biomass increase per hectare, excluding control sites							11.7

3.4 Estimating reduced degradation

Estimating the counterfactual presents some difficulties. In this research, our primary strategy was intended to be the use control sites in the vicinity of the primary research sites. These control sites would represent unmanaged forest, to compare the rate of stock change with that of managed forest. There have been a number of difficulties in this strategy however.

In many places it was not possible to find control sites. In Nepal, and India, all the area in the vicinity of the research sites was under community management, as was the case in Senegal. In a number of other areas, the villagers were not willing to take measurements in areas they considered to be ´outside their area´. Even where control sites were identified and measured, there is some doubt about whether the processes observed there really represent just the ´business as usual´ condition. At least in one site in Tanzania villagers from the managed site were observed to be taking some forest products from the control site for subsistence use: this means what was being measured was at least partly leakage, rather than business as usual (for discussion on leakage, see below, para 3.5). Moreover although unmanaged control sites were identified in Tanzania and Guinea Bissau, multiple measurements were made only in Tanzania. The data (see also Figure 5) are shown in Figure 5, and the results are not entirely unambiguous.

Table 5 Comparison of rates of change of biomass stock, managed and control sites, Tanzania

Control site	Rate of biomass stock change in managed area Tons per ha per year	Rate of stock change in matched control site Tons per ha per year
Tan 1.3 Kimunyu/SUATF	-0.7, + 2.8,	-0.2
Tan 2.2 Mangala	+ 8.8	0.0
Tan 3.2 Handei	+7.1	-0.1

The first control site was designed to match the two sites at Kitalangalo, Kimunyu Village Reserve (CBM) and the SUA training forest (JFM), but these two sites present dramatically different outcomes, with Kimunyu being one of the managed sites where carbon was lost due to encroachment. If the control is compared to the JFM forest however there is a clear difference, of 3 tons per ha per annum. In the other sites, which are in wetter areas, there difference is even greater.

It is interesting that the control areas are not actually degrading at the moment, although it had been expected that they would be. Rather, the off take appears just to match the annual regeneration, so that there is no net increase. But the level of biomass is already very low, at least for the cases of Kimunyu and Mangala, such that there may be very little left to extract from the forest.

From the figures presented for Tanzania we would have to conclude that the underlying degradation rate is approximately.

Data was gathered from 3 control sites in Guinea Bissau, but only for one year (Table 1). This shows clearly that the level of biomass in the unmanaged sites is only about half that of the managed sites, but it is not possible to draw conclusions about the annual rate at which that degradation has been taking place.

The control site in India at Asota was of a different nature. Asota became is a sacred site around a shrine, since 2001, and is therefore not used at all for forest product off-take. Before 2001, it was quite degraded, Interesting however the growth rate in this site is very similar to that of the matched managed site (Guna mixed banj oak), Table 6.

Table 6 Comparison of rate of stock change, managed and control site, India

Site	Rate of stock change in matched managed forests (Guna mixed banj oak) Tons per ha per year	Rate of stock change at control site Tons per ha per year
Ind 4.1 Asota	+6.8	+6.4

What this shows is that the managed sites are improving as regards biomass stock at the maximum rate possible from a biological point of view when there is no human intervention (represented by Asota). In the long run, it will be very interesting to see whether the total biomass stock at Asota when it is fully recovered, reaches higher levels than that of the managed sites like Guna.

Our data is not strong enough to give a strongly conclusive figure on rates of degradation at each site individually in the absence of the CFM projects. So in addition, we have derived figures from the literature which give estimates of typical degradation rates in the countries in which our sites were located (Table 7). These figures are derived from the FAO Forest Resources Assessment 2005, the most recent global database available, from Table 12, which refers to growing stock changes. However these data not really reliable, in two sense. First of all, they are averages across whole countries and may not be in the least accurate for the particular locations we have studied. But secondly, the methodology used to obtain these figures for the FAO report is not reported, may vary from country to country, and is probably based on very small samples or on linear extrapolation from earlier data which was also based on very small samples.

Table 7 Rates of degradation, national level, from FAO FRA 2005

Country	Rate of degradation
India	+ 0.08
Nepal	Ns
Tanzania	- 0.04
Mali	Ns
Senegal	-0.01
Guinea Bissau	+0.02
Papua New Guinea	-0.01

Our conclusion is that it is extremely difficult to assess with any accuracy at all what the underlying degradation rates have been in areas which are now, because of management interventions, on the road to recovery. This is, in fact, likely to pose a major problem in the accounting for REDD+ in most countries. Even the assessment of on-going degradation rates in areas which have not yet been brought under management will cause problems, since in most countries there is no historical data on biomass/carbon density changes over time.

3.5 Leakage

When a forest comes under management, there is always risk of leakage if demand for wood is simply displaced to another source, near or far. We were not able to measure this accurately, although as the site dossiers indicate, in most cases, the management of the forest largely produces sufficient wood products to meet the needs of the communities. In India it was estimated that approximately 10% of firewood and fodder needs might be being sourced outside the community forest, in unmanaged government forests. In PNG, the forests clearly produced enough for local needs, and may have provided negative leakage by providing forest products for nearby communities whose forests were not under management but had been logged over by commercial companies. In Tanzania, particularly at the Kimunyu site, it was observed that villagers were deriving some of the household needs from areas outside the managed forest, but this was not quantified.

4 Discussion

4.1 **What should be credited**?

Most literature on international REDD has assumed that payments will be made primarily for reduced levels of deforestation: degradation was brought into the equation later. At national level, it is probable that reducing levels of deforestation will translate into large numbers of carbon credits, and assessing the quantities involved will not be very difficult since calculations will be built on area change multiplied by estimates of biomass/carbon density in each type of forest. But controlling deforestation is not likely to be achieved by CFM, which as noted above is much more suited to the control of degradation processes and for the stimulation of forest enhancement (increases in stock levels per hectare).

What our study has shown is that in the degraded forests which have been allocated to communities to look after under different CFM programmes, the underlying rate of degradation is probably approaching zero, because the forests are so degraded that there is not much left to take. Given the very great difficulty of establishing a reliable baseline or reference scenario for degradation, our recommendation is therefore that communities should not be rewarded for avoided degradation at all, but only for the positive increases in biomass stock which they can demonstrate through field measurements (i.e. for forest enhancement). If there is an underlying degradation rate which has been reversed as a result of CFM, this is an addition benefit as far as global climate change is concerned, but would not be credited.

This makes sense because imposing rules of off take and guarding against forest fires under CFM mainly has an effect on stimulating natural regeneration and thus causing forest enhancement. Forest enhancement is specifically acknowledged as a positive process in climate change mitigation under REDD+ and should also be eligible for carbon crediting.

Our estimates are that the average accumulation rate of carbon dioxide in community forests is around 5.5 tons per hectare per year in dry savanna forest, 7.5 in temperate mountain forests and 21 in tropical rainforests, subtropical forests and lowland forests.

It has been argued that growth of forest is natural not anthropogenic and that therefore communities should not be rewarded for stock increases. For example, Lewis et al (2009) have shown that untouched tropical rainforests grow at a rate of about 0.5 tons per hectare per year. However, our figures indicate that where the forest is not managed there is a considerably lower biomass stock and the growth rate of the stock also very low. Growth rates in response to community management are clearly well above this, and well above the ´natural´ growth rate determined e.g. by Lewis et al (2009).

4.2 Practical advantages of a payment system based on forest enhancement

One of the advantages of paying for forest enhancement rather than for avoided deforestation is that the effect is annual, meaning that the payments can be annual, creating an income stream as an incentive for continued positive forest management. Payment for not deforesting in contrast involves a promise that the forest will not be cut any time in the future; this type of contract is very difficult to enforce, for a variety of reasons.

Annual payment for forest enhancement is based on a transparent system which can easily be verified (either by remeasurement or by spot checks using high resolution remotely sensed images such as IKONOS) and does not require complicated preparation in the form of a baseline, which means that transaction costs will be minimized.

This kind of payment system is one that can relatively easily be implemented at national level to fit into existing and future plans for CFM.