Carbon, biodiversity & ecosystem services: exploring co-benefits

Tanzania

UN-REDD PROGRAMME

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Introduction

The maintenance and enhancement of natural carbon stocks is now considered a key climate change mitigation measure. Emissions from land use change, mainly tropical forest loss, contribute an estimated 17.4% of total anthropogenic greenhouse gas emissions (IPCC 2007a), equivalent to around 5.8 Gigatonnes (Gt) of carbon dioxide (CO_2) per year.

Co-benefits, often called multiple benefits, are the positive impacts of Reducing Emissions from Deforestation and Forest Degradation (REDD) that are additional to emissions reductions. These include ecosystem and social benefits such as biodiversity and non-timber forest products. Potential co-benefits from REDD are widely relevant in Tanzania, where forests and woodlands support the livelihoods of 87% of the rural poor (Milledge *et al*. 2007). Conserving biodiversity also promotes the continued provision of these benefits under environmental change (Campbell *et al*. 2009), thus increasing resilience to climate change.

Depending on where REDD action is taken, the co-benefits delivered will vary. Simple mapping tools can help identify how carbon, other services and pressures such as fire are distributed and relate to each other.

Here, we map the distribution of carbon stocks in relation to the possible co-benefits of REDD, alongside other relevant factors. A new map of carbon in Tanzania's ecosystems has been produced for this analysis.

Forests and REDD in Tanzania

Status of forests

The United Republic of Tanzania is the largest country in East Africa, covering an area of approximately 945 000 km^2. Nearly two fifths of the land area is covered by forest (FAO 2006). This includes seasonal coastal forests and thickets, mangroves, wet montane forests, wet lowland forests around the shores of Lake Victoria, seasonal miombo woodland in the south and east and seasonal acacia savanna to the east of Mount Kilimanjaro and along the Kenyan border (Burgess *et al*. 2004).

Between 1990 and 2005 it is estimated that forest cover decreased by about 1% per year, with an annual average loss of 4 122 km^2 (FAO 2006). Over 5 000 km^2 of forest are degraded annually (National Forest Programme 2001).

Tanzania had a population of more than 34 million people at the last census in 2002, which may have exceeded 40 million by 2009 (UNSD 2009). The rising population has contributed to the expansion of smallholder agriculture and increased demand for forest products such as charcoal. Pastoralists and smallholders use fire to clear land, harvest honey, eradicate tsetse fly and induce fresh growth (FOSA 2000); when these fires spread there can be substantial carbon losses (SJP 2009). Forests provide over 90% of the national energy supply through fuelwood and charcoal, and 75% of construction materials (Milledge *et al*. 2007). Other drivers of forest carbon loss include complex and insecure land tenure systems and illegal logging (SJP 2009).

Several policies to support forest management have been put in place since 2000, seeking to reduce unplanned deforestation, limit forest degradation and implement sustainable forest management (SJP 2009). These include regulations, guidelines and policies on forest management through the Forest Act No. 14 (2002) and the National Forest Programme (NFP 2001-2010), which operationalize the 1988 Forest Policy 1988 (SJP 2009).

The NFP aims to: promote stakeholder participation in forest resource management; strengthen institutional capacity, research and regulation; and enhance forest industry development. For example, there are increased efforts to involve communities in Participatory Forest Management schemes.

UN-REDD Programme

The UN-REDD Programme in Tanzania seeks to be fully aligned with the NFP. The Programme's proposed outcomes include strengthening the national governance framework and institutional capacities; increasing capacity for including REDD elements in Monitoring, Reporting and Verification (MRV) systems; improving capacity to manage REDD and provide other forest ecosystem services at district and local levels; and gaining broad stakeholder support for REDD (SJP 2009).

Here, we present the results of an initial mapping exercise for carbon and co-benefits.

Mapping carbon in Tanzania

A new map of carbon stocks in Tanzania's terrestrial ecosystems has been developed, combining estimates of above- and below-ground biomass and soil organic carbon to 1 metre depth (Map 1). Whilst there is still scope to improve it, we are confident that this is better than pre-existing maps. The methods and data sources are detailed in the Annex.

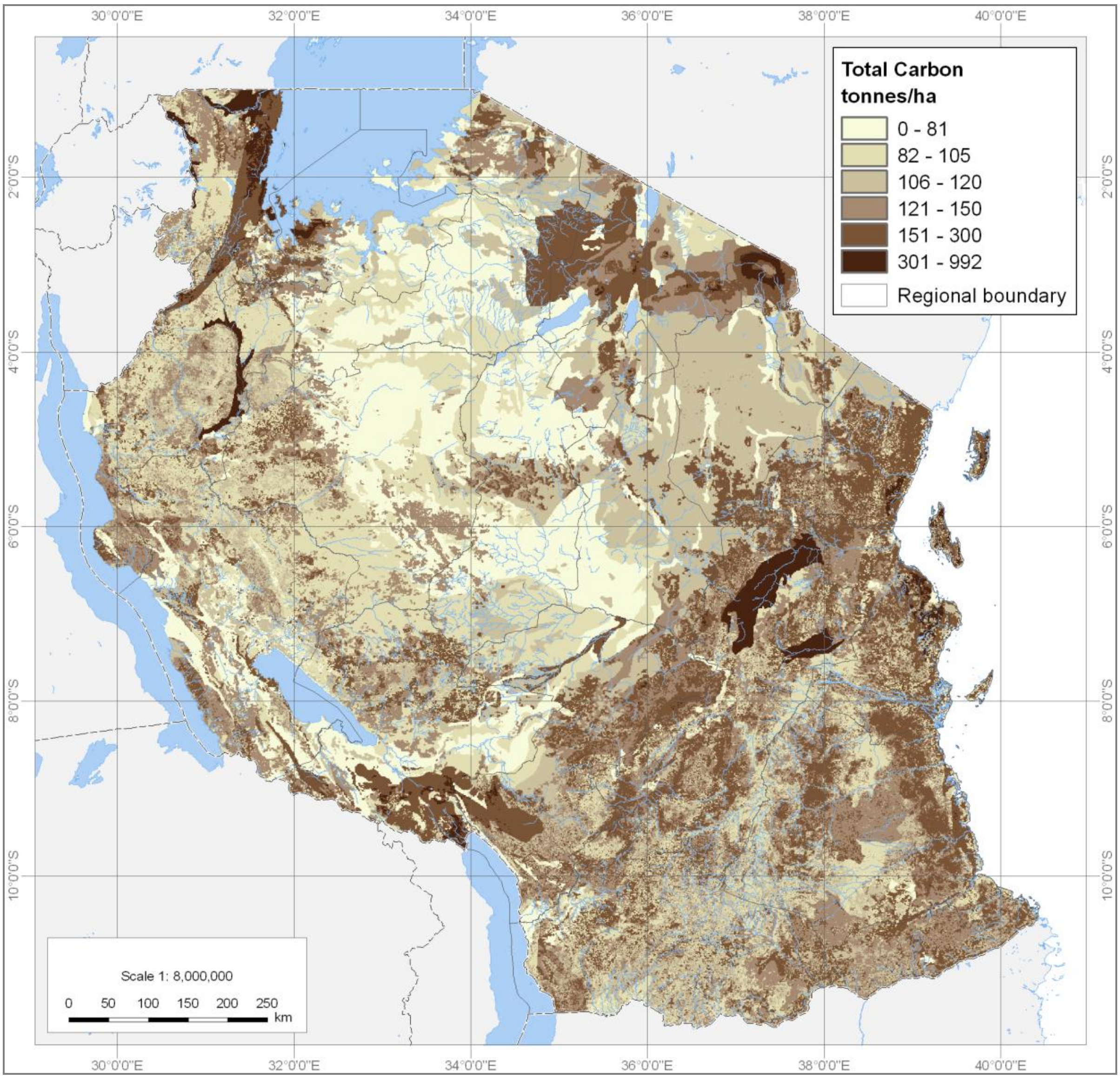
Total terrestrial carbon stock in Tanzania is estimated at 11.4 Gt, with a mean carbon density of about 143 t/ha. Lindi region has the greatest total stock, and Kilimanjaro the highest density. Table 1 summarises the area, carbon density and total carbon stock of different regions of Tanzania. The estimates exclude carbon in water bodies.

Table 1: Carbon density and stock of Tanzania's regions

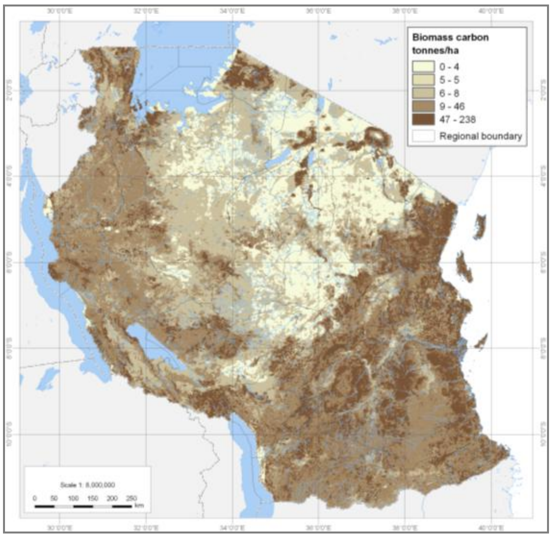
Region	Area (1 000 km^2)	Mean carbon density (t/ha)	Carbon stock (Gt)
Arusha	39 134	179	0.04
Dar Es Salaam	1 578	150	0.00
Dodoma	42 472	120	0.04
Iringa	61 035	147	0.06
Kagera	39 929	198	0.04
Kigoma	46 550	131	0.05
Kilimanjaro	13 333	359	0.01
Lindi	66 537	138	0.07
Manyara	45 781	134	0.05
Mara	30 199	106	0.03
Mbeya	58 369	132	0.06
Morogoro	68 993	156	0.07
Mtwara	17 633	132	0.02
Mwanza	34 451	113	0.03
Pemba South	853	127	0.00
Pwani	31 503	138	0.03
Rukwa	75 350	105	0.08
Ruvuma	64 177	125	0.06
Shinyanga	50 606	128	0.05
Singida	49 366	105	0.05
Tabora	76 815	105	0.08
Tanga	28 161	138	0.03
Unguja North	1 490	143	0.00

When soil carbon counts

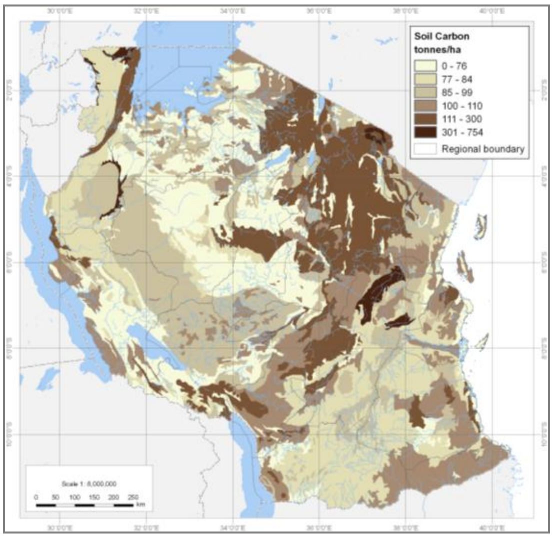
Soil organic carbon can make up a significant proportion of total carbon in terrestrial ecosystems (Maps 1-3). It is particularly noticeable that soil organic carbon is high over a large area in the northeast of the country where biomass carbon is low. The highest category in Map 1 (total carbon stock) is strongly influenced by soil organic carbon. However, it is not always appropriate to make decisions based on the total carbon stock. It is more difficult to predict the impacts of land use change on soil carbon than on biomass carbon. For example, the impact of deforestation on soil carbon depends on the land clearance practices and subsequent land use. In addition, the biomass carbon data are more accurate than the soil carbon data. From a REDD perspective, the total carbon maps should be viewed with these caveats in mind.



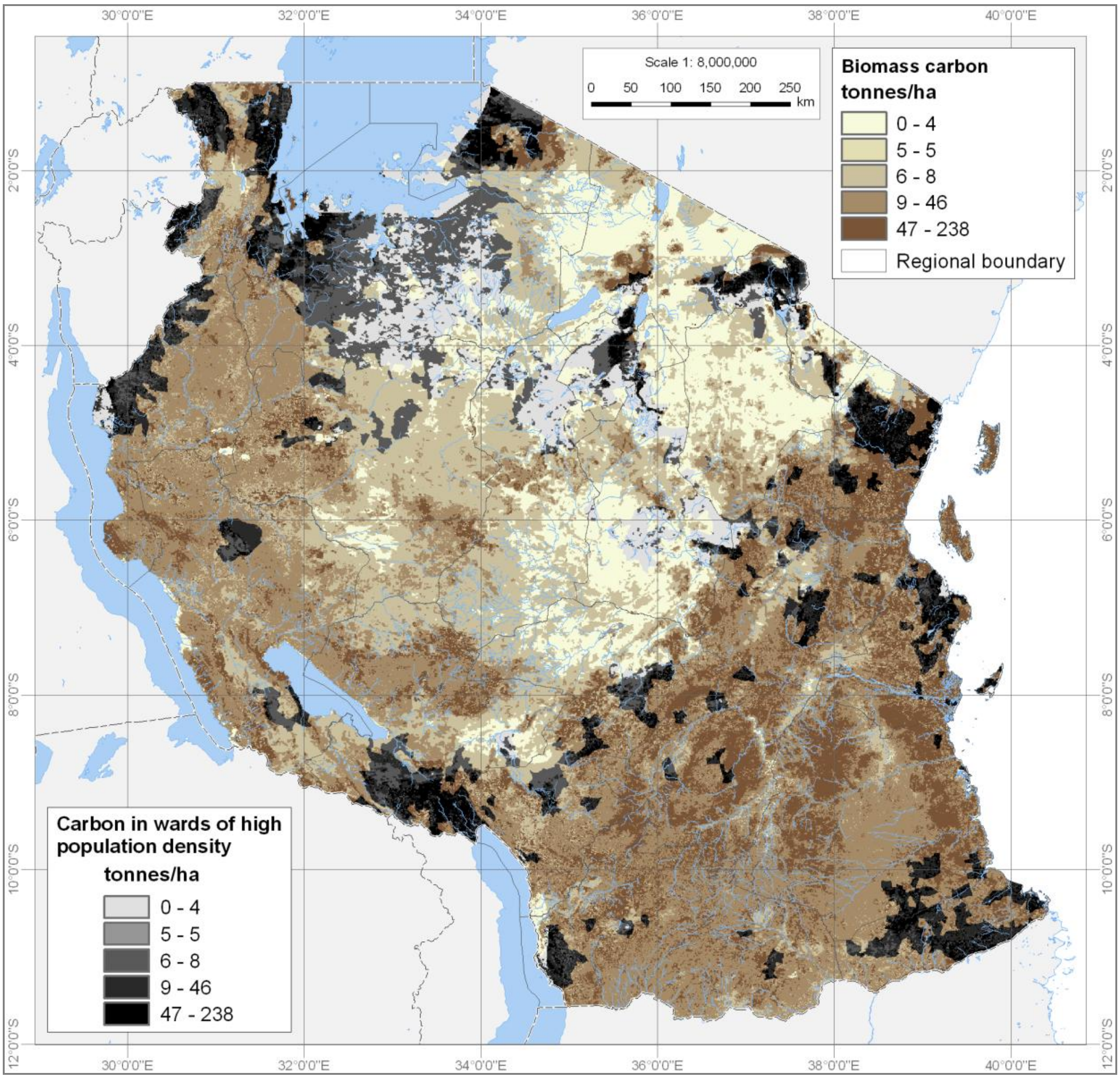
Map 1: Total carbon density (above ground biomass + below ground biomass + organic soil carbon to 1m depth)



Map 2: Biomass carbon (data sources in Annex)



Map 3: Soil organic carbon (data sources in Annex)



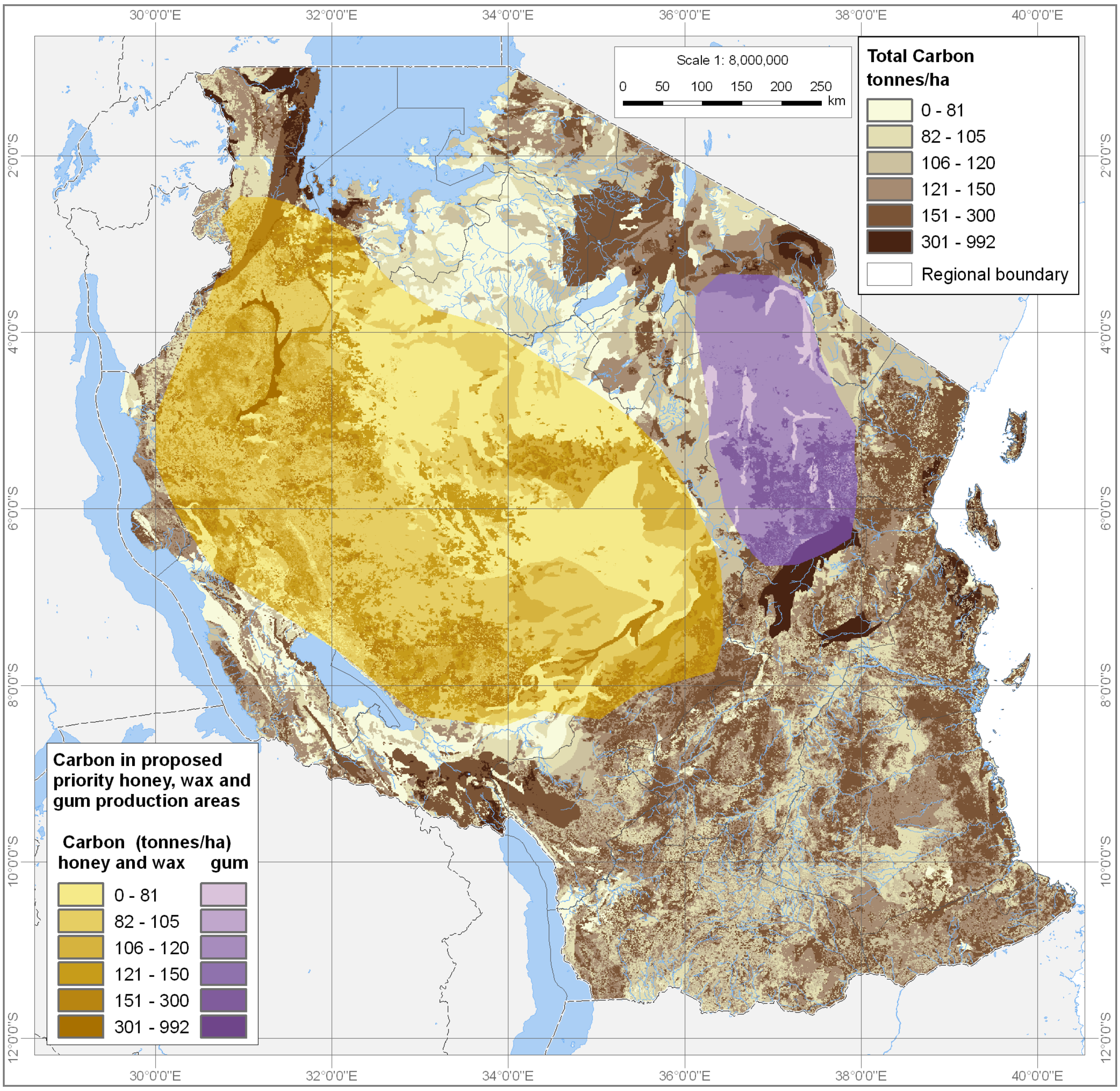
Map 4: Wards with high population density (Tanzanian Bureau of Statistics 2002), with biomass carbon density

Exploring co-benefits

Carbon and population density

Map 4 depicts the distribution of biomass carbon stocks in wards of high population density (>5 136 people per hectare in 2002), in shades of grey, with biomass carbon in the remainder of the country shown in brown. Biomass carbon has been chosen for this map because wards with high population and high biomass are likely to be under greater pressure for charcoal production. It should be recognised that this is a simple picture, excluding factors such as consumption patterns, transport, access to markets and intensity of land use.

Nonetheless, the map reflects areas of potential population pressure, which at the same time are areas where there is a large population potentially affected by REDD action. Depending on how REDD is implemented, people may be affected positively (through retention of forest ecosystem services and possible carbon payments) and/or negatively (through loss of access to forest resources such as charcoal).



Map 5: Priority areas for production of honey, beeswax and gum arabic (Tanzania National Land Use Planning Commission 2006), with total carbon density

Carbon and non-timber forest products: honey, wax and gum

These priority areas for the production of honey, beeswax and gum arabic were identified as part of a national land use planning exercise. These non-timber forest products are also sometimes produced in relatively low-biomass ecosystems such as savanna. A large percentage of the carbon stock found in the priority areas is therefore in low to medium carbon density classes (Figure 1), perhaps not a REDD priority.

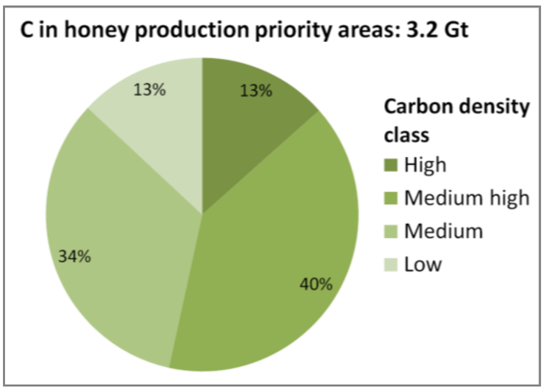
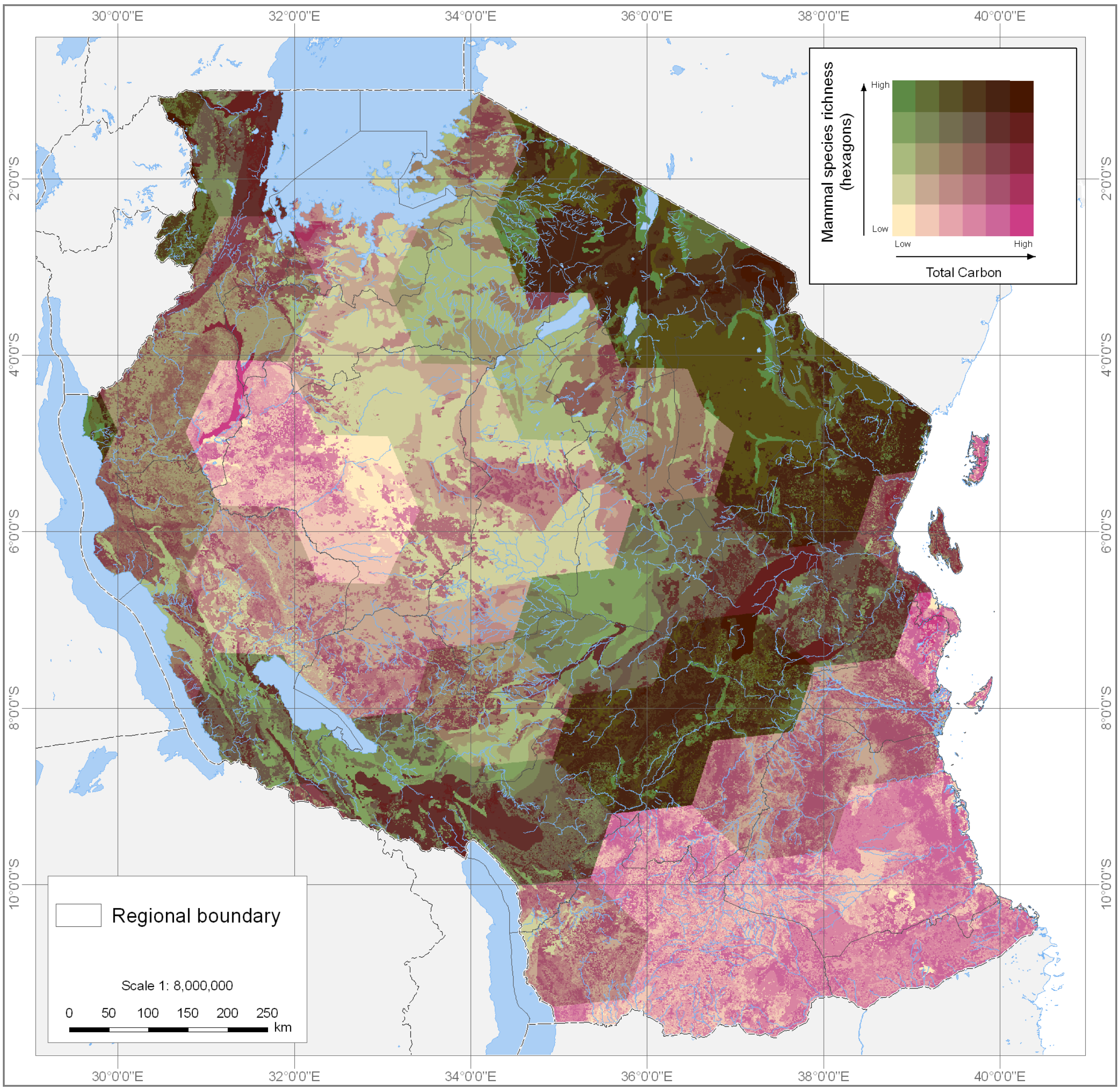


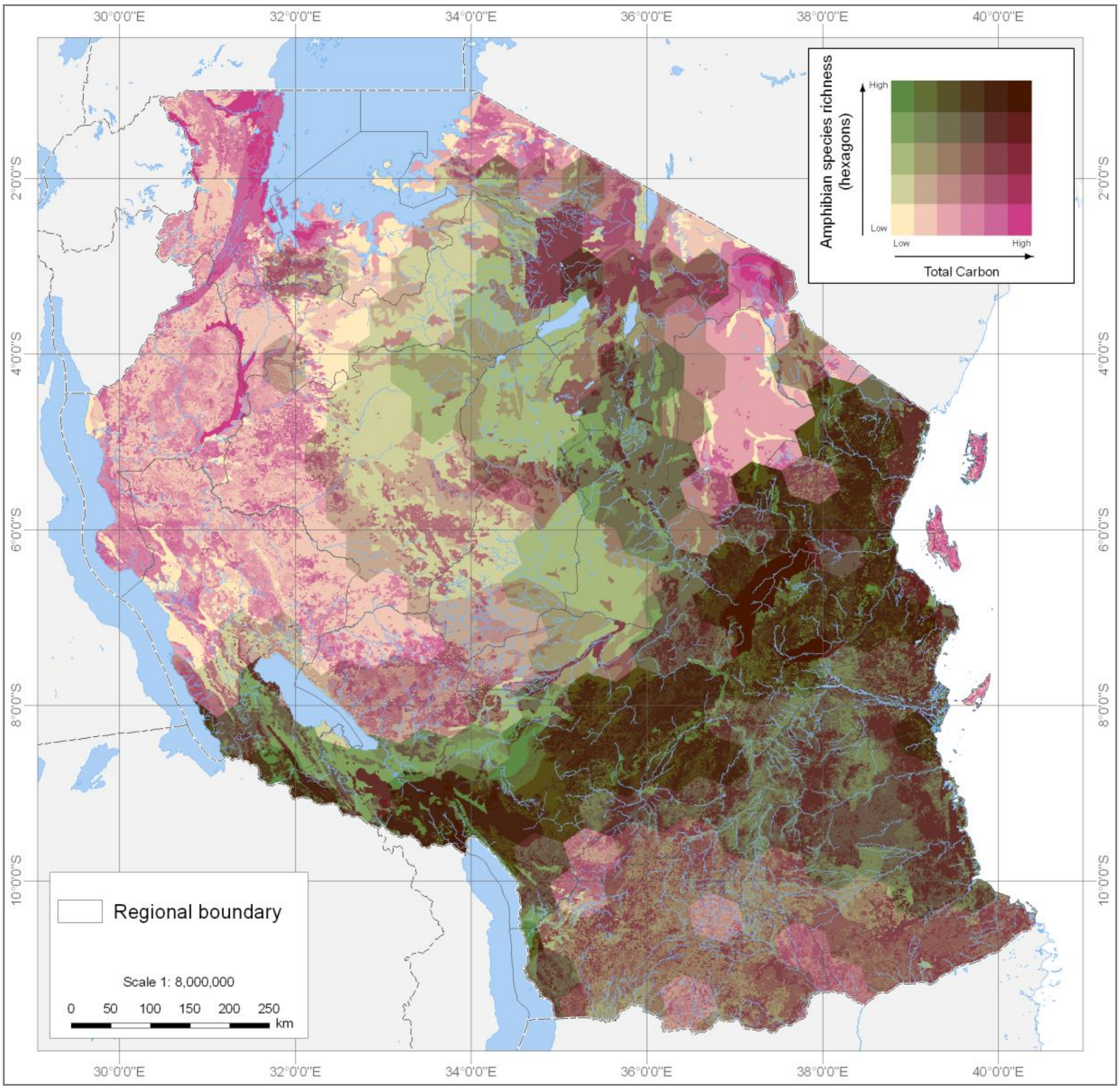
Figure 1: Variation in the density of carbon found within priority areas for honey production



Map 6: Maximum mammal species richness (hexagons, IUCN 2009) and total carbon density

Carbon and biodiversity – mammals

There are 359 mammal species in Tanzania. Map 6 compares maximum mammal species richness (based on species range data) with total carbon density. Both the carbon and mammal species richness classes used are based on quintiles of land area – so the top row in the legend key represents the top 20% of the species richness polygons. Bright green areas have high mammal species richness but low carbon density; bright pink areas have low mammal species richness but high carbon density; and the darkest areas are high in both these values. The richest hexagon contains up to 246 mammal species.



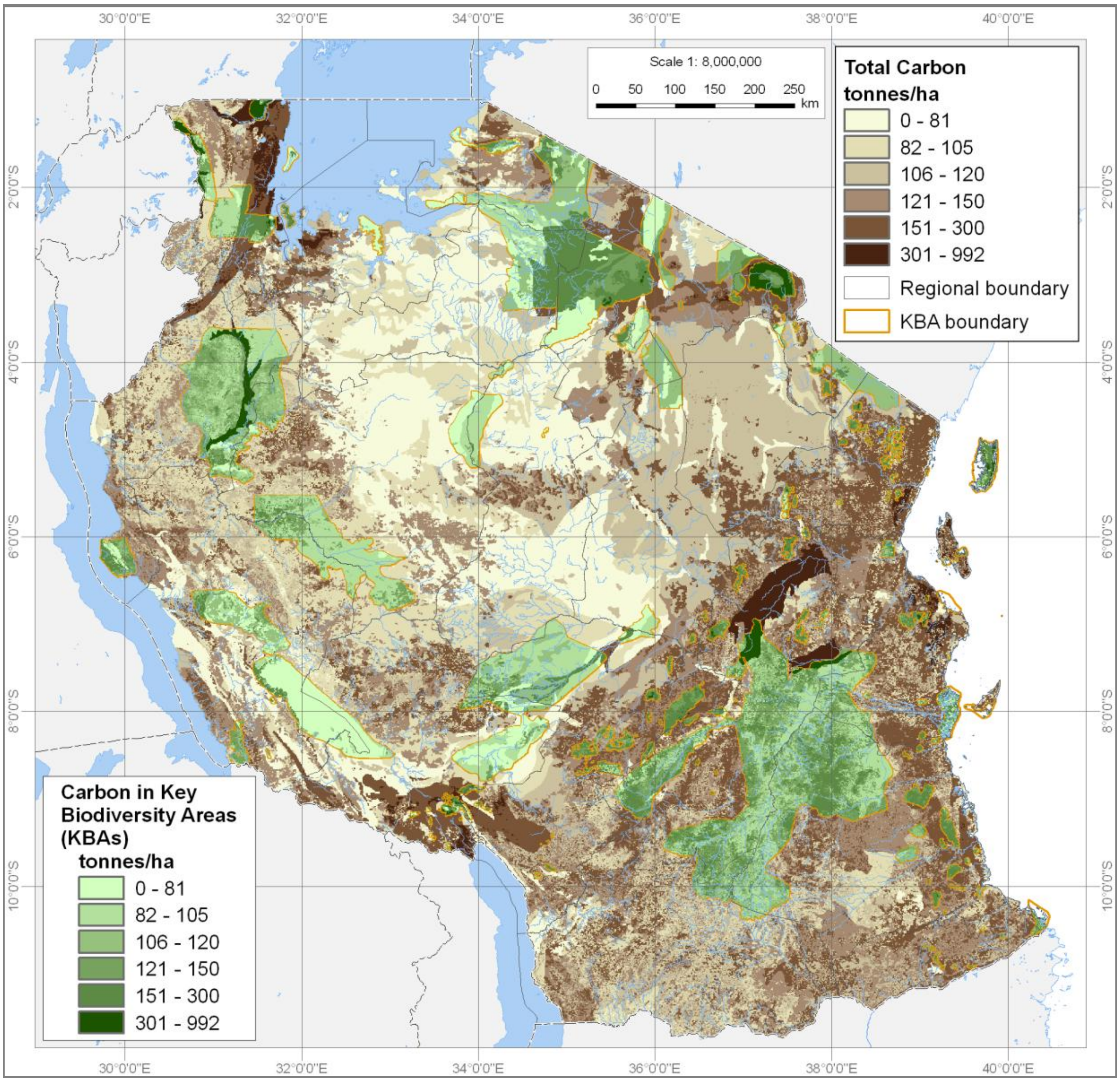
Map 7: Maximum amphibian species richness (hexagons, IUCN 2009) and total carbon density

Carbon and biodiversity – amphibians

Map 7 compares the maximum amphibian species richness with total carbon density, using the same type of legend as for mammal richness (Map 6), but on a finer grid. The richest hexagon contains up to 81 amphibian species, of a national total of 183 species.

Comparison with Map 7 illustrates the differences in distribution between areas rich in mammal species, and those rich in amphibian species. For example, there is an area of greater mammal diversity in the north, and greater amphibian diversity in the south. Richness of plants, invertebrates and other vertebrates may be differently distributed again. Comparison with Map 8 illustrates the difference in distribution between areas rich in all species, and areas rich only in the species of immediate conservation concern that have been used to identify Key Biodiversity Areas.

National and subnational conservation priorities will determine which type of map is most useful in any given area.



Map 8: Key Biodiversity Areas (Eken *et al*. 2004, Birdlife International 2009) and total carbon density

Carbon and biodiversity – key biodiversity areas

Key Biodiversity Areas (KBAs, Eken *et al*. 2004) are sites of global importance for biodiversity conservation, based on the vulnerability and irreplaceability of the species they contain. About 20% of the country's total carbon stock (2.3 Gt) is located within KBAs (Map 8). 43% of this is found in very high or high carbon density areas.

Much of the KBA network of Tanzania is already formally protected (Map 9).

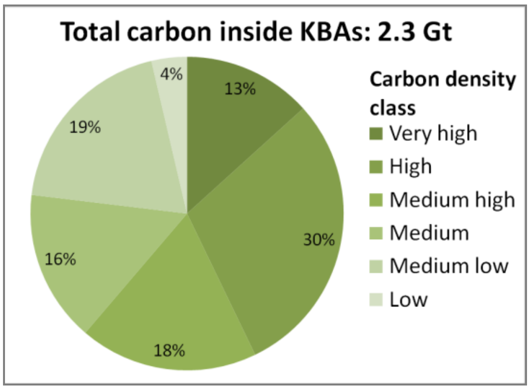
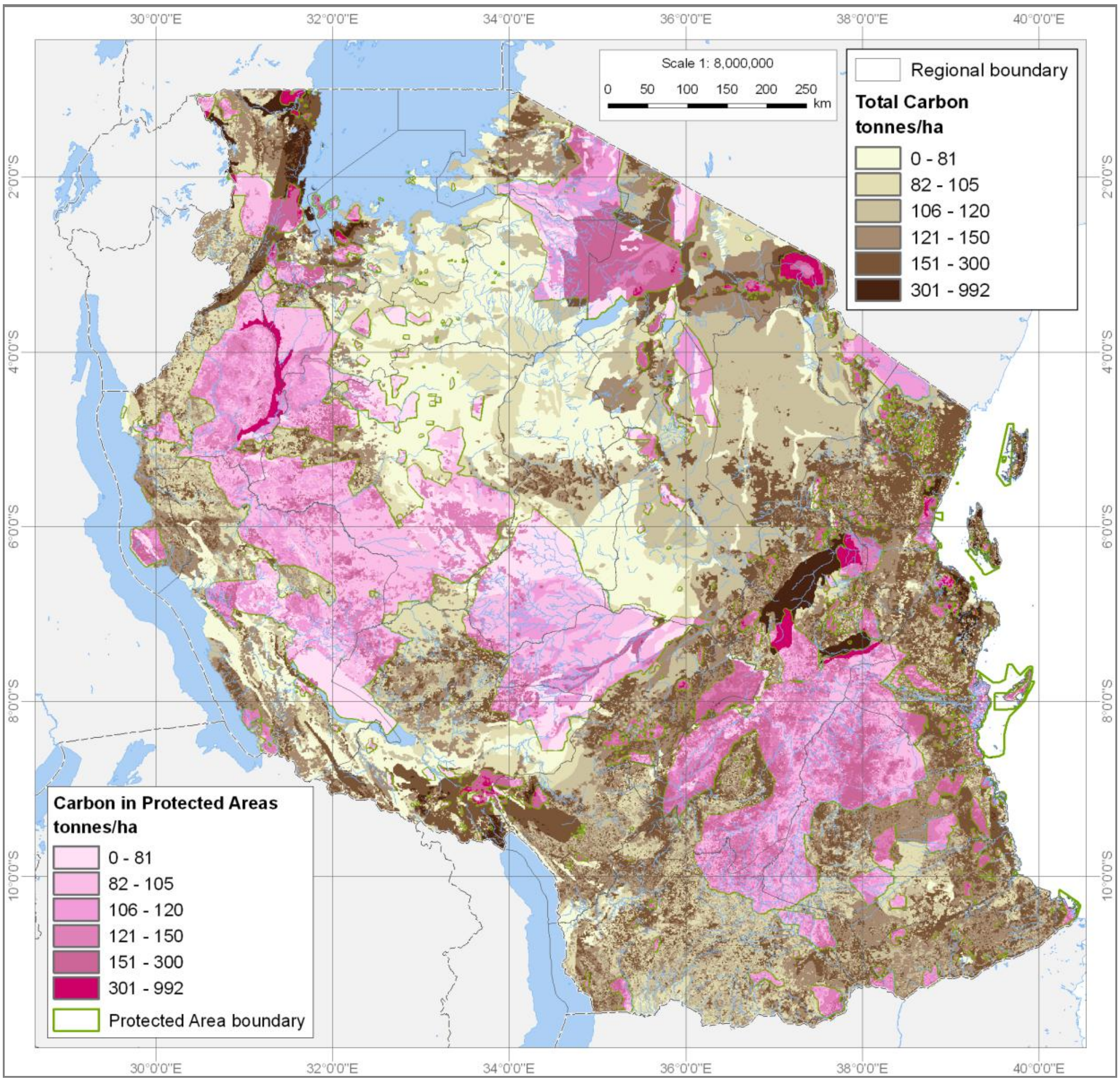


Figure 2: Variation in the density of carbon found within Key Biodiversity Areas



Map 9: Protected areas (UNEP/IUCN 2009; Wildlife Division, Tanzania 2009) and carbon density

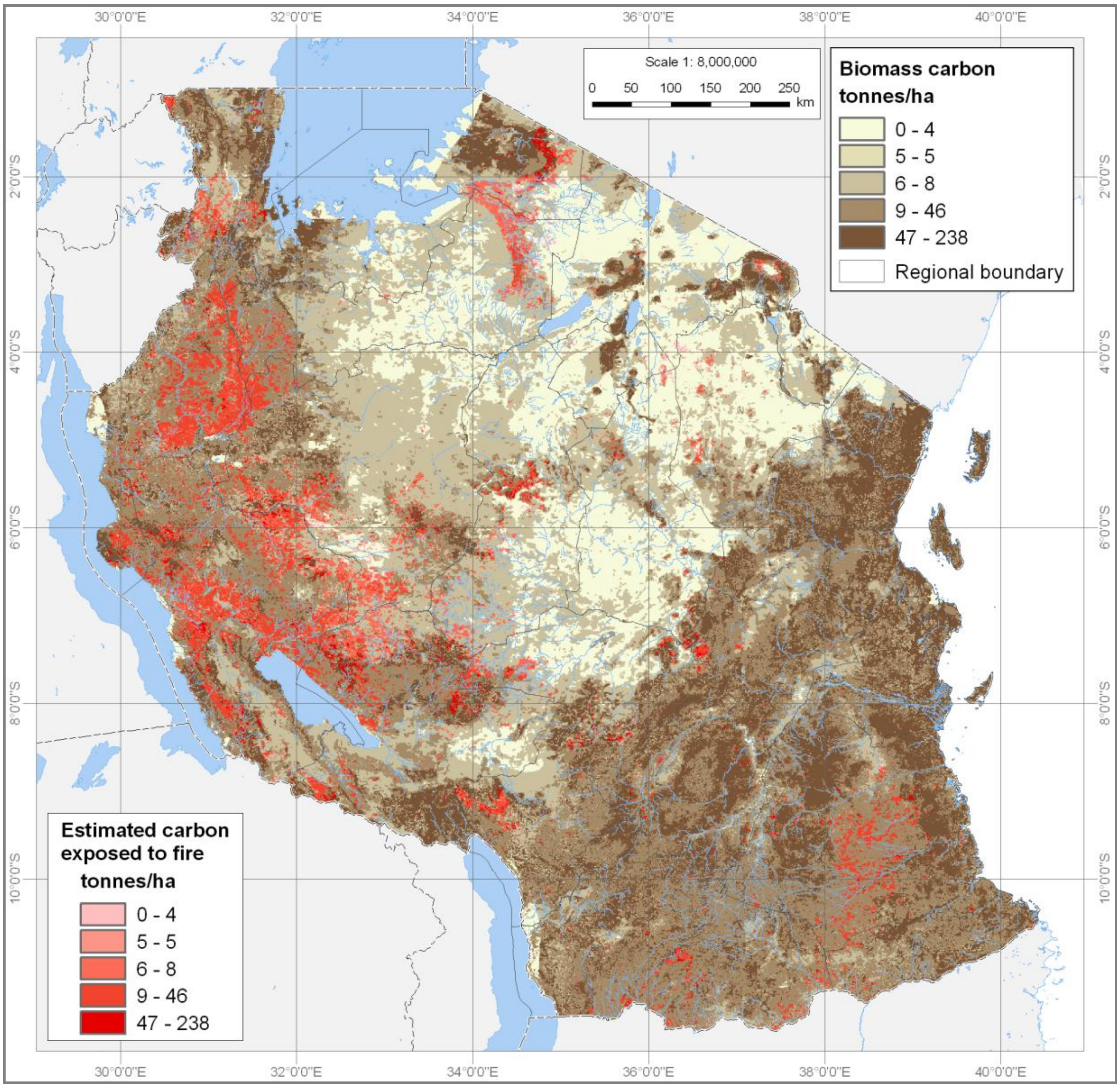
Protected areas and carbon

The national REDD plan for Tanzania may include some support to protected area management, as protected areas are not immune from forest degradation and loss. Forest reserves experience more loss of carbon stocks than other protected area types (SJP 2009).

About 32% of Tanzania's total carbon stock (3.7 Gt) is stored in its protected areas[1]. Of this, about 36% is found in high carbon density areas.

Almost one quarter of the country's total carbon (11.4 Gt) is found in high carbon density areas that are not formally protected.

[1] The best available protected areas dataset omits some Wildlife Management Areas, so this is an underestimate.



Map 10: Burnt areas (2006-7, Gregoire *et al*. 2007) and biomass carbon density

Exposure to fire

In certain ecosystems, including savanna, fire is a natural process that can contribute to regeneration and ecosystem health. However, anthropogenic fires are common in the dry season. Carbon losses will depend on the intensity of fire, type of vegetation and speed of regeneration. Of the 0.18 Gt of biomass carbon exposed to fire in 2006-7, 30% was in high carbon density areas, which are most likely to suffer long-term fire damage to carbon stocks.

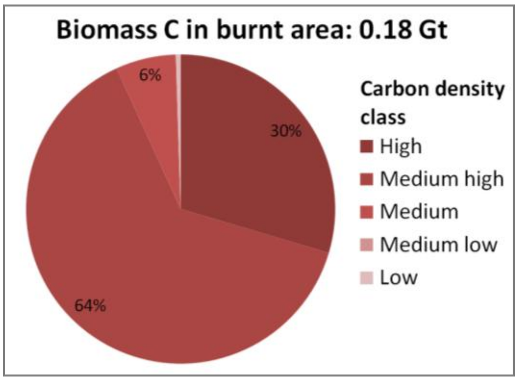


Figure 3: Variation in the density of carbon found within burnt areas

Conclusions

Carbon and co-benefits

There are clear differences in distribution between organic carbon stores in biomass and in soils. Soil organic carbon density is so great in some parts of the country that it is vital that emissions reduction estimates take the potential effects of REDD measures on soil carbon emissions into account.

The potential co-benefits of REDD are also distributed differently from one another. For example, priority areas for honey, wax and gum production (Map 5) with priorities for species conservation (Map 8) do have overlaps but each includes large areas where there is no overlap.

As the UN-REDD Programme in Tanzania develops, it will need to involve multiple stakeholders to consider trade-offs in the benefits delivered from prioritising different land areas for REDD.

Useful future analyses

These results are only the first step in exploring the co-benefits of carbon conservation under a REDD initiative in Tanzania. While some data on ecosystem services exist, especially for certain areas such as the Eastern Arc mountains, there is substantial scope to develop and improve maps at a national scale, at a resolution high enough to effectively support decision-making.

Questions still outstanding include:

How are carbon stocks distributed amongst different land uses and ecosystems? (Note that the carbon map presented here does not account for the distinctive ratio of above- and below-ground carbon stocks in mangroves).

Where are carbon stocks changing most rapidly, and how does this compare with the distribution of co-benefits?

How do carbon stocks compare with the distribution of other ecosystem services such as maintenance of watersheds and delivery of water to hydropower stations, soil erosion protection, other non-timber forest products, and cultural services?

How might future land use change pressures affect carbon and co-benefits under a business-as-usual scenario?

Annex: carbon mapping methods

Several data sources were brought together to generate a carbon map for Tanzania (Map 1), comprising above- and below-ground biomass, with soil carbon to 1 metre depth. The above-ground biomass was derived from a model for tropical Africa, which uses remotely-sensed MODIS NBAR data from 2000-2003 (Baccini *et al*. 2008). Ecosystem-specific conversion factors (IPCC 2006) were used to add below-ground biomass to this map, with the factors allocated to FAO ecological zones[2] (FAO 2001). The carbon mass of the resulting total was estimated as half the biomass (Gibbs & Brown 2007). There were no model data for zones with <9 tons of biomass per hectare. Values from a global biomass carbon map (Ruesch & Gibbs 2008) were substituted in these zones, giving a final map of biomass carbon (Map 2). Soil organic carbon to a depth of 1 metre (Map 3) was added from a new dataset (Scharlemann *et al*. 2009) based on the Harmonised World Soil Database (FAO *et al*. 2008), which for Tanzania relies on the SOTER database (Eschweiler 1998).

[2]Where an ecological zone was not listed in IPCC 2006, the tropical shrubland factor was used.

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When planning efforts to Reduce Emissions from Deforestation and Forest Degradation, the benefits could be increased by taking account of the distribution not only of carbon, but of other ecosystem services such as biodiversity or non-timber forest products. Here, we map the distribution of carbon stocks in relation to the distribution of these possible co-benefits of REDD. Other relevant factors such as protected area distribution and fire occurrence are also compared with carbon stocks. A new map of carbon in Tanzania's ecosystems has been produced for this analysis.

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