Supplementary material – (.pdf 722 Kb)

This Supplementary provides details on the scenario development framework; the baseline maps for carbon and non-carbon benefits assessment, along with caveats and potential sources of error in datasets manipulation; and, the biodiversity richness and rarity index.

1.1 Scenarios development framework

Our scenario development framework aimed to tackle the challenges of translating qualitative narratives into quantitative scenarios incorporating indigenous and local knowledge. Following a mixed participatory and modelling framework (Table S1), our approach allows translation of stakeholders' developed qualitative and semi-quantitative scenarios trajectories and land use and land cover change patterns into quantitative and spatially explicit information.

Table S1. Steps of the participatory scenario development framework

Step 1 Scenarios definitions	Business as usual: policy framework, demand for commodities, and implementation of REDD+ follow the current development trajectory. Green economy: shift toward sustainable practices for agriculture, forestry and energy sectors supported by governance enforcement, effective REDD+ implementation, and enhanced productivity.
Step 2 Scenarios development by stakeholders	a) Development of qualitative and semi-quantitative socio-economic and environmental trajectories of change and relative drivers by main livelihood sectors identified at regional level by multiple stakeholders. b) Identification of specific spatial patterns of land use and land cover changes (LULCC) related to expected trajectories and drivers of change (e.g. "*high likelihood of conversion from closed woodland to*

	grassland due to charcoal production near roads and in districts where governance is weak in region X”).
Step 3 Modeling	a) Quantification of demand for cultivated land and wood biomass according to secondary data[1] and expected trajectories. In this study, the business as usual scenario refers to the BAU2 quantitative scenario detailed in Capitani et al. (2016; Appendix 2). Business as usual: 30% expansion for both cultivated and mixed cultivated-wooded land; pro-capita annual wood volume demand = 0.87 m^3. Green economy: 10% increase in crop productivity no expansion of shifting cultivation; 50% reduction of wood biomass harvesting exceeding available sustainable cut. b) Spatial allocation of LULCC based on scalar composite indicators of likelihood of change calculated for different types of LULCC following the stakeholders’ assessment and calculated from global and national reference datasets (corrected through locally obtained information when necessary)[1] according to the formula: $$SI_{lulcc} = (sp_1 + sp_2 + sp_3) \times m \times pas$$ SI_{lulcc}, composite indicators of likelihood of each specific LULCC; reclassified and standardized spatial datasets affecting LULCC likelihood (sp_n); m = 0/1 masking factor derived from crop suitability and slope to mask out unsuitable areas for cultivation expansion; pas, protected areas mask used to limit LULCC likelihood according to the rules: likelihood of LULCC occurring within protected areas decreasing

	with the distance from protected areas border in the BAU scenario (pas decreasing from 1 to 0); LULCC not occurring within protected areas in the GE scenario (pas = 0). Demand for land and for biomass is allocated through specific LULCC from the pixels with the highest likelihood of change until demand is fulfilled.
Step 4 Iteration	Validation of preliminary results, feedback and synthesis workshop with regional and national stakeholders; model and outputs refinement.

[1] See Appendix 2 Capitani et al. 2016.

1.2 Scenarios and baseline maps

The scenario outputs (Fig. S1) were generated with a spatial resolution of ca. 100 m, in agreement with the population density dataset (WorldPop, Tatem 2017[i]), representing one of the major driving forces of land changes in our scenarios. Impacts from land use and land cover change scenarios in Tanzania on carbon, biodiversity and water yield were calculated using datasets derived from different inputs, at different resolution and with different methods (Fig. S2).

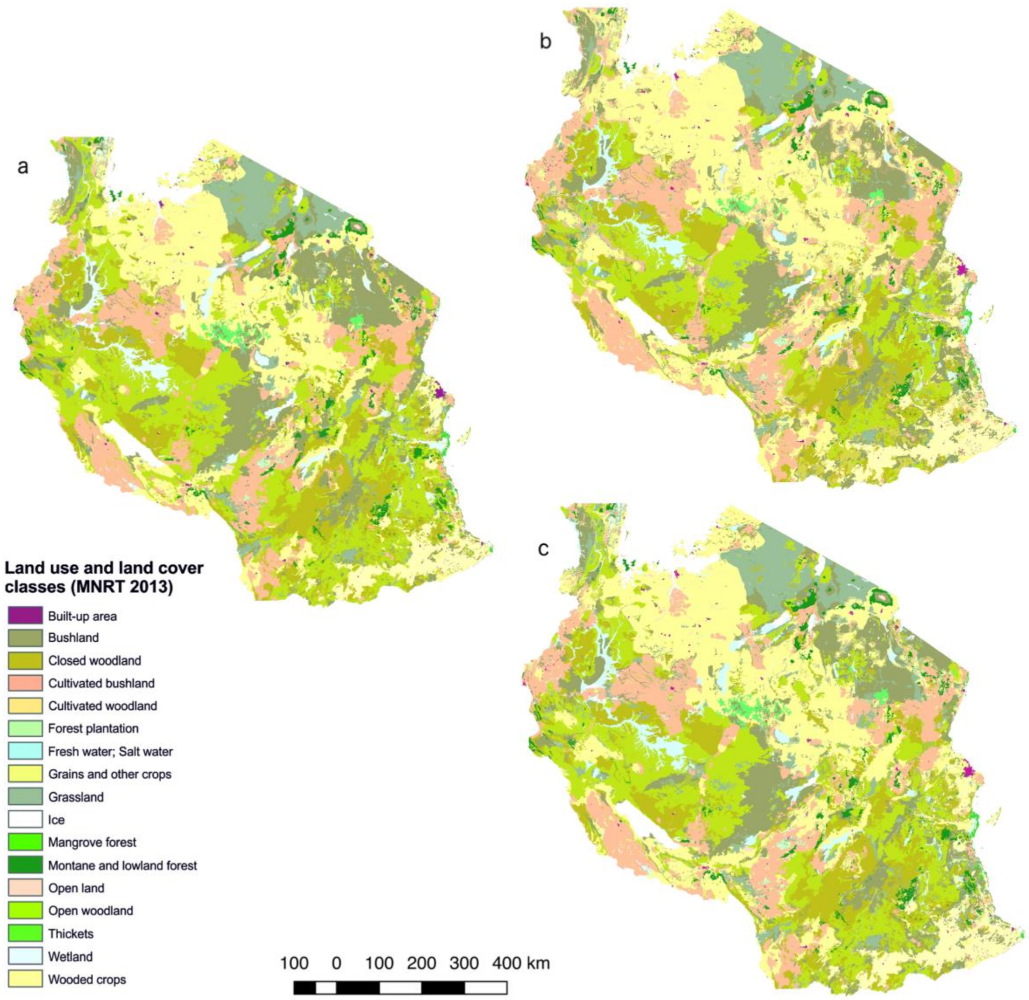

Figure S1. Land use and land cover reference map for 2010 (a, MNRT 2013) and for b) the business as usual and c) the green economy scenarios. Scenario output maps can be obtained upon request from the authors.

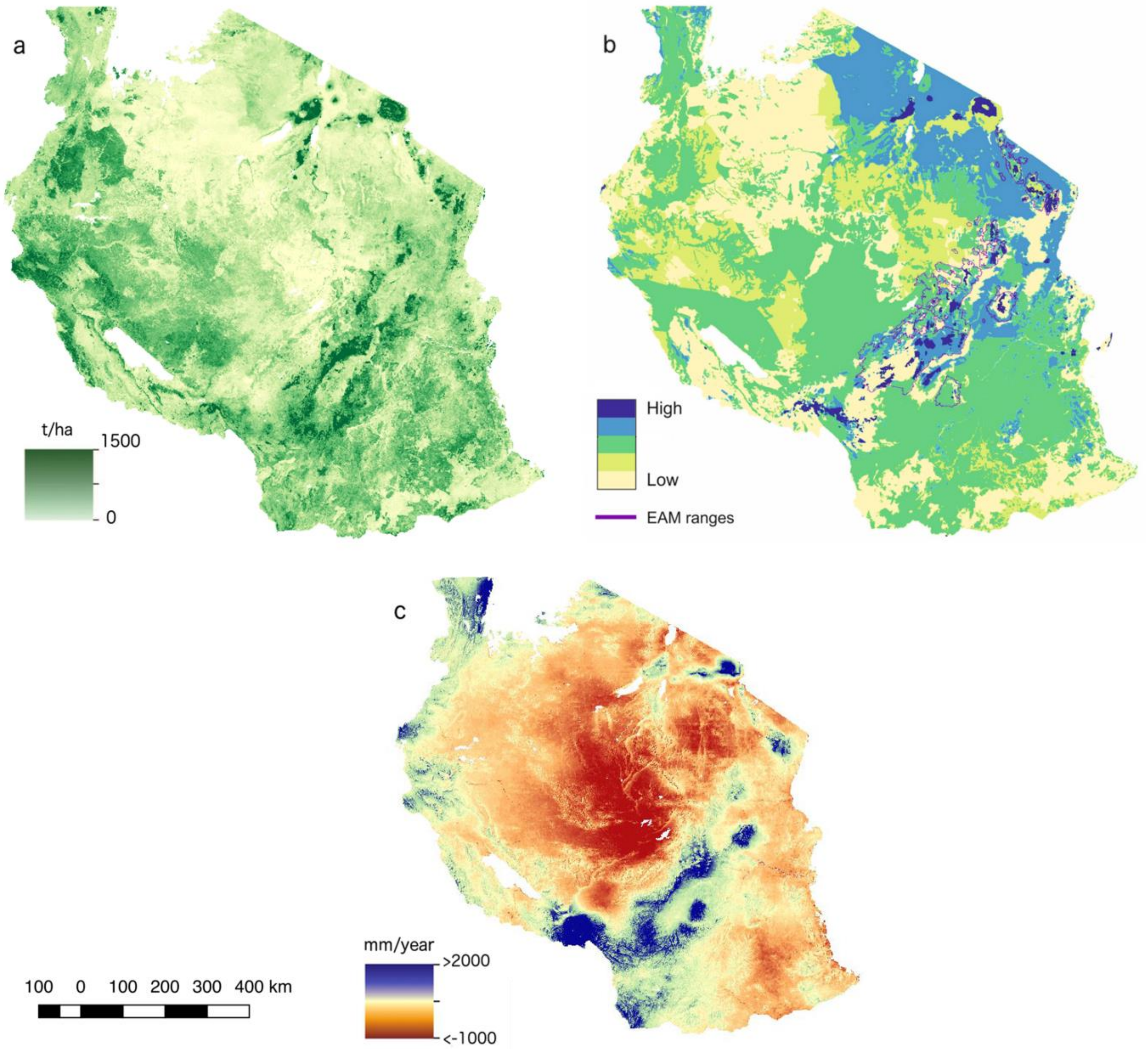

Figure S2 - Baseline maps for total carbon stock (a, ton ha^{-1}), biodiversity richness and rarity index of terrestrial vertebrates (b, range between 0 and 0.89) and water yield (c, mm $year^{-1}$) in Tanzania mainland. In b) the Eastern Arc Mountains biodiversity hotspot boundaries are represented by the purple line.

The high resolution adopted for the scenario analysis was helpful in incorporating local knowledge collected during the regional workshops, e.g. for simulating local patterns of small forest patches encroachment. To transfer the local representativeness of change pressures into the national scale impacts assessment on carbon and non-carbon benefits, we altered the spatial resolution of the layers used to calculate carbon stock, biodiversity and water yield change, in order to match the ca. 100-m scenario resolution. Then we generalised the results at 1-km resolution. This double resampling process has determined a loss of accuracy in the analysis.

For biodiversity and water yield, the downscaling of the original input datasets at the scenario resolution was applied to match the reference habitat types and land cover classes with those used for the scenario analysis. Then the biodiversity and the water yield indices and their changes were calculated at 1-km resolution.

For carbon stock, the biomass and soil carbon stock layers were downscaled from ca. 250 to ca. 100 m resolution, to apply the change pressure on biomass and land determined by the specific land change expected in the scenarios (e.g. form forest to cultivated land, from closed woodland to bushland). Then changes were aggregate at 1-km resolution. The total amount of carbon biomass removed is upper limited by land and biomass demand set for the scenarios. However, the pixel-base allocation for the carbon stock change is influenced by the pixel-base carbon density, particularly for soil stock, and therefore is affected by the resampling process.

1.3 Biodiversity richness and rarity index

The Biodiversity richness and rarity index in the baseline $BRRI_{gt_0}$ was calculated for each grid-cell (g) by the formula:

$$BRRI_{gt_0} = \sum_{1}^{i} \left(\frac{ESH_{igt_0}}{ESH_{it_0}} \times R_i\right)$$

with ESH_{igt_0} the extent of suitable habitat of the *i* species in each pixel g, ESH_{it_0} the total extent of suitable habitat of the i species in Tanzania and R_i the ratio of the distribution range of the i species in Tanzania over the globe, at the time t_0.

Changes between the scenarios and the baseline where calculated for each pixel (g)

$$BRRI_g = \sum_{1}^{i} \left(\frac{ESH_{igt_1} - ESH_{igt_0}}{ESH_{it_0}} \times R_i\right)$$

with ESH_{igt} the extent of suitable habitat of the i species in each pixel g in the scenario (t_1) or in the baseline (t_0), ESH_{it_0} the total extent of suitable habitat of the i species in Tanzania in the baseline and R_i the ratio of the distribution range of the i species.

When calculating the BRRI changes in the future scenarios we assumed that:

- LULCC-sensitive species abandon habitats converted to cultivated land or degraded;

- non-LULCC-sensitive species lose habitat due to conversion to cultivated land (e.g species mainly associated with forest or closed canopy woodland or generalist species reported not to be tolerant to agriculture activities);

- non-LULCC-sensitive species mainly found in grassland can gain habitat following degradation of woodland and bushland, when degradation is above 15m^3 ha^{-1} wood biomass loss.

These rules are based on the reported habitat preference for the species[ii], on the reference land use and land cover classes, and on the biomass changes calculated for the scenarios; gains are considered only within the extent of occurrence of each species. We did not consider other factors than habitat that could affect species capacity of moving or adapting to changes.

The adopted biodiversity richness and rarity index (BRRI) has the advantages of being calculated from data relatively easy to obtain on a large scale, and of being directly sensitive to LULCC, compared to other quantitative indices (e.g. species abundance, richness, diversity). However, it doesn’t consider multiple aspect of biodiversity complexity, e.g. functional or taxonomic diversity, connectivity, complementarity, species adaptation capacity. In Tanzania the BRRI represents well the highly endemic montane forests and species-rich woodlands, and particularly emphasized the impacts of habitat changes on rare species. Using other indices, or other prioritisation approaches, different spatial pattern would emerge, e.g. weighting all species equally as in the species richness index.

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[i] Tatem, A. J. (2017) WorldPop, open data for spatial demography. Sci. Data 4:170004 doi: 10.1038/sdata.2017.4

[ii] IUCN 2016. The IUCN Red List of Threatened Species. Version 2016-3. Downloaded 05/2016. [www datset]. URL http://www.iucnredlist.org.