Earth Observation datasets help determine REDD+ baselines of carbon emissions from deforestation in least developed countries

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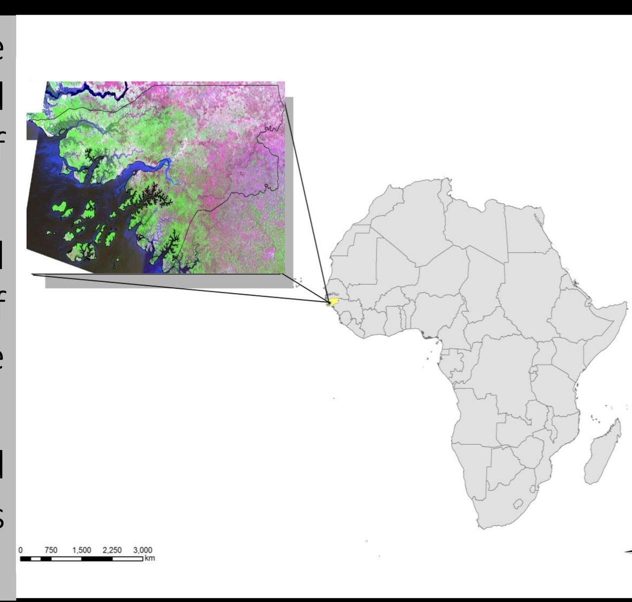
:background

For implementing REDD+ under the UNFCCC and accessing results-based payments, countries are required to generate baselines of carbon emissions. However, the majority of least developed countries lack the expertise, resources, technical capacity and support to generate this type of information.

Guinea-Bissau, on the Western Coast of the Guineo-Congolio-Sudanian ecoregion, is mostly covered with woodlands and mangroves, with some patches of tropical dense forests in the southern part of the country. It is also one of the world's poorest countries, ranking 177th out of 187 countries on the 2014 Human Development Index.

The objective of this analysis was to compare currently available global datasets against in-situ and national datasets and products that follow IPCC guidelines and VCS methodologies to deliver estimates of forest cover and carbon emissions from deforestation.



:in house data

- generated in the scope of several projects and used here to produce a prospective national reference level (emission factors x activity data).
- a preliminary version of this dataset was used in the 2nd national communication to the UNFCCC, where the country reported on their actions to address climate change
- a subset of this dataset was used for the validation of a sub-national VCS REDD project in two protected areas

emission factors

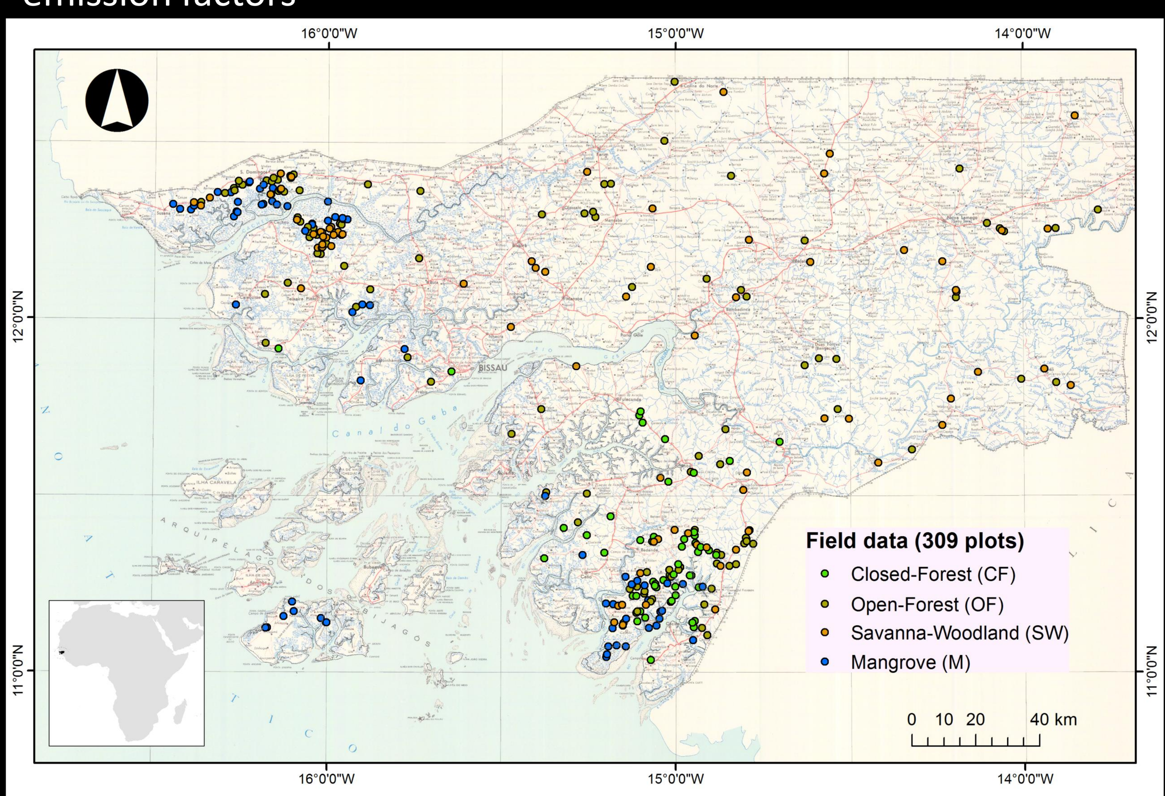
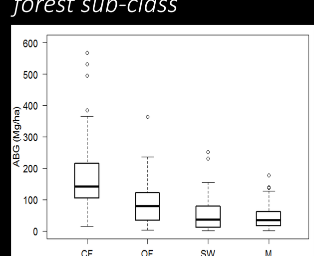


Figure 1. location of Guinea-Bissau in Africa, and a map of the country showing the location of the 309 measured plots in Closed-forest (CF, 49 plots), Open-forest (OF, 120 plots), Savanna-woodland (SW, 70 plots) and Mangrove (M, 70 plots) between 2007 and 2012.

Table 1. in-situ based mean AGB density (Mg ha^{-1})* and C stocks (Mt C) per forest sub-class Closed-Forest (CF), Open-Forest (OF), Savanna-Woodland (SW) and Mangrove (M). Spread of sampling distribution for 95% confidence (±MoE) per forest sub-class and combined error (%).

Strata	Area (ha)	Sample size	AGB* (Mg ha^{-1})	(±MoE)	Total C stock (Mt C)		Combined Error (%)
CF	37,712	49	180.5	(±34.7)	3.2	86.9	13.1
OF	777,971	120	86.3	(±11.3)	31.5		
SW	1,823,418	70	53.2	(±12.2)	45.6		
M	307,727	70	45.6	(±9.1)	6.6		

Figure 2. distribution of AGB (Mg ha^{-1}) values by forest sub-class



activity data

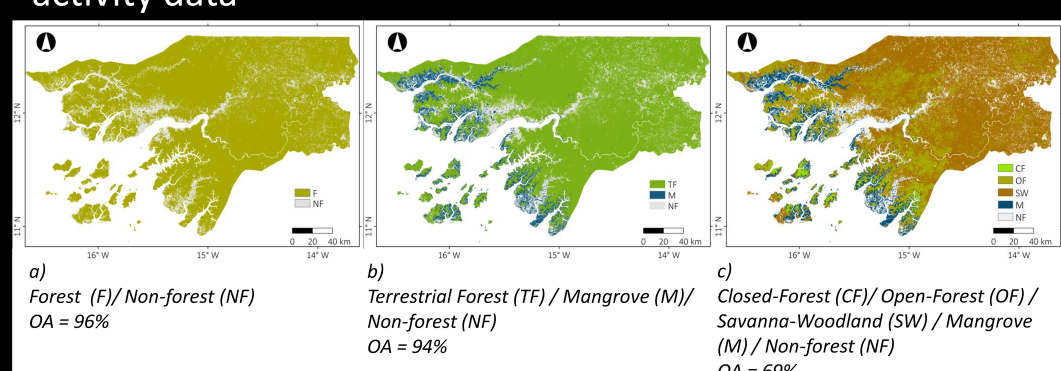


Figure 3. a) two-class b) three-class and c) five-class Landsat TM and ETM+ based land cover maps for 2010. Overall accuracy (OA) is also given. The same information was also produced for 2002 and 2007 (Vasconcelos et al., 2014).

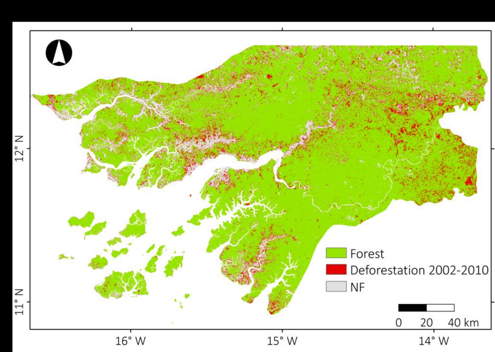


Figure 4. gross deforestation in the reference period 2002-2010. The same information was produced for the sub-periods 2002-2007 and 2007-2010 and for the disaggregated forest classes

Table 2. gross annual deforestation (ha yr^{-1} and total) for the reference period 2002-2010

Land Cover transition	Gross deforestation (ha yr^{-1})	(ha)
F --> NF	39,463	315,700
CF --> NF	64	510
OF --> NF	4,278	34,226
SW --> NF	31,293	250,343
M --> NF	3,828	30,621

activity data
x
emission factor*

reference emission level

Table 3. reference emission level (in Mt C yr^{-1})

Fluxes (Mt C yr^{-1})	Combined Error (%)
1.04	17.5

*emission factor is an estimate of the change in C stocks in all carbon pools. In this study, only the AGB pool is considered and the post-deforestation C stock is assumed to be equal to zero. Therefore the emission factor of each forest sub-class estimated with the in-house dataset is given in Table 1 in Mg ha^{-1} (95% CI)

:highlights

Forest area estimates obtained for 2010 are similar between in-house and Hansen et al. (2013) datasets. Much lower values were obtained from Shimada et al. (2014) using JAXA's ALOS PALSAR data.

Deforestation rates are noticeably different between in-house data (38,702 ha yr^{-1}) and Hansen et al. (2013) (6,282 ha yr^{-1}) for the period 2002-2010. The differences are even more striking between Shimada et al. (2014) and the former two datasets for the sub-period 2007-2010 (Table 5) .

The mapped deforestation has very little spatial agreement between datasets which leads to greater uncertainty in the 'activity data' component. Further validation of maps is required.

Estimates of total forest carbon stocks are similar between available datasets ranging from 75 Mt C in Saatchi et al. (2011) to 87 Mt C using field-based data, and 91 Mt C in both Baccini et al. (2012) and Carreiras et al. (2012).

AGB densities are higher in Baccini et al. (2012) (68.6 Mg ha^{-1}) and lower in Saatchi et al. (2011) (57.1 Mg ha^{-1}). The other two datasets have values within this range.

Fluxes seem to be particularly affected by the activity data component (deforestation maps), with datasets representing emission factors (AGB) showing better agreement (Table 10-11).

For LDCs, investing in perfect data under unrealistic contexts may prevent them from being ready for REDD+ within an acceptable time frame. Using global datasets based on Earth Observation data can be a cost-effective solution to make REDD+ operational in these countries. However, this analysis suggests that deforestation maps in particular should be used carefully.

:reference emission level variations using available datasets for alternative 'activity data' and 'emission factors'

:freely available global datasets of tree/forest cover Hansen et al. (2013), Shimada et al. (2014)

Forest extent

Table 4. 2010 total forest* area in Guinea-Bissau (ha and % of total area) using the three different datasets – in house data (from section above), Hansen et al. (2013) and Shimada et al. (2014).

In house data (ha)	(%)	Hansen et al., 2013 (ha)	(%)	Shimada et al., 2014 (ha)	(%)
2,946,828	89	2,907,281	86	2,532,042	75

*Forests were defined as areas where the cover of woody vegetation exceeded 10%.

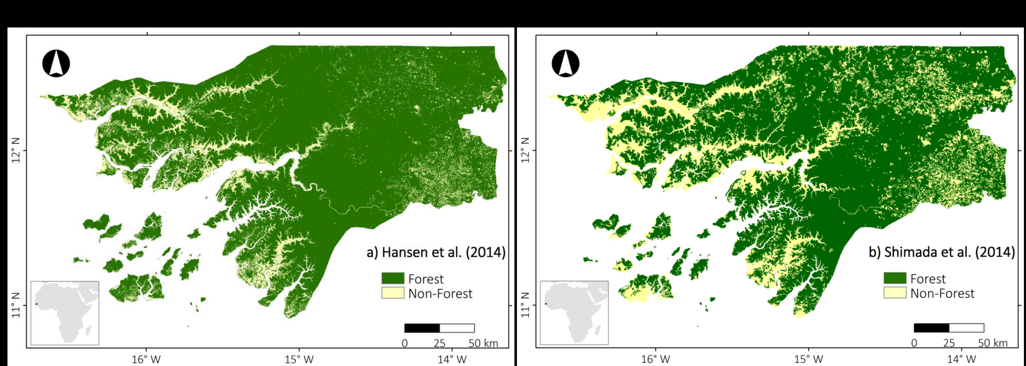


Figure 4. Guinea-Bissau 2010 forest cover maps* obtained from a) Hansen et al. (2013) 30 m resolution dataset of tree cover for the year 2000 and updated with forest loss up to 2010; and b) Shimada et al. (2014) 25 m resolution forest maps based on the JAXA ALOS PALSAR global mosaics between 2007 and 2010.

In the Shimada et al. (2014) map, 'the PALSAR resolution may be too coarse to allow sparse forests and woodlands to be captured in the classification (particularly towards the lower cover threshold of 10%), thereby leading to an underestimate in the total area'

Gross deforestation estimates for the historical reference period 2002-2010 and sub-periods 2002-2007 and 2007-2010

Table 5 shows very different deforestation rates obtained with the three datasets. Table 6 and 7 show that there is also very little spatial agreement in the mapped deforested areas by the three datasets

Table 5. annual gross deforestation (ha yr^{-1}) estimated with three different datasets – in house data (from the section above), Hansen et al. (2013) and Shimada et al. (2014) for the reference period 2002-2010 and sub-periods analysed (2002-2007 and 2007-2010) .

	2002-2007 (ha yr^{-1})	2007-2010 (ha yr^{-1})	2002-2010 (ha yr^{-1})
In house data	36,809	41,858	38,702
Hansen et al., 2013	5,492	7,598	6,282
Shimada et al., 2014		128,993	

Table 6. areas (ha) of spatial agreement between the 2002-2010 gross deforestation maps produced with the in-house and Hansen et al. (2014) datasets. Proportion (%) of the deforested area of each dataset that overlaps the deforested area mapped by the other dataset.

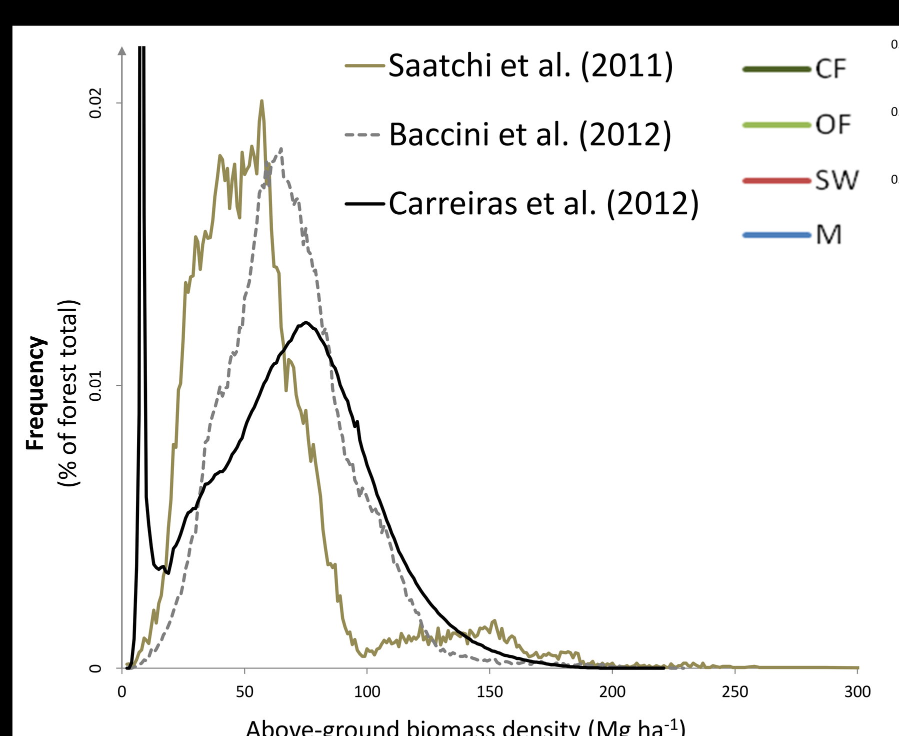
	Area (ha)	Proportion (%) In-house	Hansen
Agreement	11,623	4%	23%

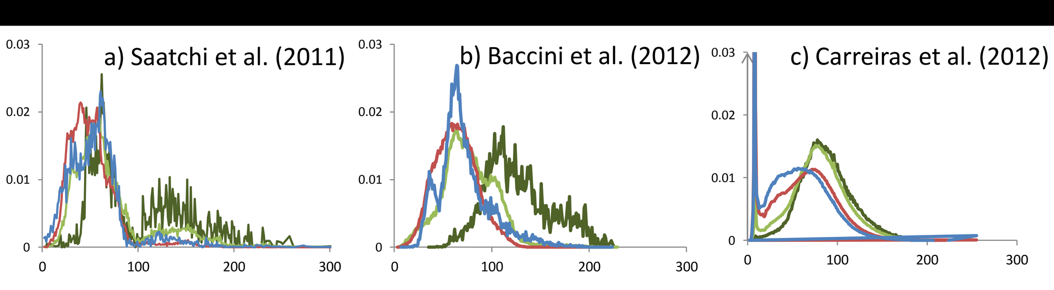
Table 7. areas (ha) of spatial agreement between the 2007-2010 gross deforestation maps produced with the in-house , Shimada et al. (2014) and Hansen et al. (2013) datasets. Proportion (%) of the deforested area of each dataset that overlaps an area mapped by at least another dataset.

	Area (ha)	Proportion (%) in house	Shimada	Hansen
Total agreement	976	1%	0%	4%
Agreement in-house + Hansen	2,070	2%	-	9%
Agreement in-house + Shimada	19,436	15%	5%	-
Agreement Shimada + Hansen	4,178	-	1%	18%

:freely available global AGB datasets at 1km from Saatchi et al. (2011), and 500m from Baccini et al. (2012)

:50-m scale remote sensing-based AGB map at national scale (circa 2008) (Carreiras et al., 2012)





Classes dominated by average AGB values up to 100 Mg ha^{-1} (open forest, savanna woodland and mangrove) have a similar AGB distribution in the three datasets.

Carreiras et al. (2012) clearly shows (Fig. 5 c) the limitations of using L-band radar data to retrieve above ground biomass (AGB) greater than 100 Mg ha^{-1}. The closed forest class, with higher mean AGB values (Table 1: 180.5 Mg ha^{-1}), is clearly better represented in the datasets based on LiDAR data, i.e., Saatchi et al. (2011) (Fig. 5 a) and Baccini et al. (2012) (Fig. 5 b).

Figure 5. AGB distribution (Mg ha^{-1}) in Guinea-Bissau using the three different datasets –Saatchi et al. (2011), Baccini et al. (2012), and Carreiras et al. (2012). The distribution per forest sub-class is also shown in the sub-figures a) Saatchi et al. (2011), b) Baccini et al. (2012), and Carreiras et al. (2012).

Table 8. AGB density (Mg ha^{-1}) per forest sub-class and total, for the different datasets – in house data (from Table 1), Saatchi et al. (2011), Baccini et al. (2012), and Carreiras et al. (2012).

Forest class	In house data	Saatchi et al. (2011)	Baccini et al. (2012)	Carreiras et al. (2012)
CF	180.5	98.6	127.3	87.5
OF	86.3	70.9	76.5	79.5
SW	53.2	51.2	63.6	60.8
M	45.6	51.8	72.0	57.8
Total Forest	62.8	57.1	68.6	65.7

Table 9. AGB stocks (Mt C) in Guinea-Bissau using the different datasets – in house data (from the section above), Saatchi et al. (2011), Baccini et al. (2012), and Carreiras et al. (2012)

In house data	Saatchi et al. (2011)	Baccini et al. (2012)	Carreiras et al. (2012)
86.9	75.4	90.9	91.0

:reference emission level variations

Table 10. reference emission level (in Mt C yr^{-1}) for the historical reference period 2002-2010. Variations using all possible combinations of historical deforestation / 'activity data' (in-house and Hansen et al., 2013) and 'potential emission factors' from Saatchi et al. (2011), Baccini et al. (2012), Carreiras et al. (2012) and the in-house dataset (from Table 3)

2002-2010	Fluxes (Mt C yr^{-1}) Saatchi et al. (2011)	Baccini et al. (2012)	Carreiras et al. (2012)	in-house
in-house	0.74	0.85	0.71	1.04
Hansen et al. (2013)	0.17	0.19	0.15	0.19

Table 11. reference emission level (in Mt C yr^{-1}) for a sub-period 2007-2010 to assess the implications of using Shimada et al. (2014) dataset. Variations using all possible combinations.

2007-2010	Fluxes (Mt C yr^{-1}) Saatchi et al. (2011)	Baccini et al. (2012)	Carreiras et al. (2012)	in-house
in-house	0.84	0.96	0.76	1.12
Hansen et al. (2013)	0.23	0.25	0.23	0.22
Shimada et al. (2014)	2.96	3.45	3.44	3.81

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