Carbon mapping in Portugal forest and agroforestry systems using direct remote sensing and combine assign approaches

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Introduction

Reducing Emissions from Deforestation and Forest Degradation (REDD and REDD+) recommend specific methodologies for quantifying and spatializing ecosystem services (ES). In the context of climate change, REDD suggests the mapping of carbon stocks and its sequestration by vegetation cover to implement more appropriate environmental management practices and policies against global warming. Several methods and techniques have been developed to map and quantify forest carbon and the net primary production (NPP) (Goetz et al., 2009; Running & Zhao, 2015). This study presents two different approaches to the forest carbon mapping (FCM). On the one hand, using direct remote sensing (DRS) approach, based on MODIS images, on the other, the combine & assign (CA) approach, based on multi-layers information in a geographic information systems (GIS) environment.

Objectives

In this study, we focused on three objectives: 1) FCM for different eco-regions in forest and agroforestry systems of Portugal in 2010 using CA and DRS approaches; 2) mapping the annual carbon balance, by combining the CA approach and atmospheric flow method proposed by IPCC; 3) comparisons of IPCC and MODIS methodologies to monitor carbon dynamics in terrestrial ecosystems.

Methods

Annual NPP accounting (IPCC, 2006):

$$NPP_{IPCC} = \sum_{i,j} \left(A_{i,j} \cdot BCEF_{I(i,j)} \cdot I_{v\,(i,j)} \cdot \left(1 + R_{i,j}\right) \cdot CF_{i,j}\right)$$

$A_{i,j}$ (ha) is the area by species and PROF; $I_{v\,(i,j)}$ ($m^{-3}\,ha^{-1}\,yr^{-1}$) is the annual net increment; $CF_{i,j}$ (t t^{-1}) the biomass carbon fraction, as the ratio between carbon and dry biomass weight; $BCEF_{I(i,j)}$ (t m^{-3}) is the biomass conversion and expansion factor as the ratio between weight of dry biomass and volume; $R_{i,j}$ is the ratio between BGB and AGB (t t^{-1}).

Carbon losses accounting under wildfire disturbances (IPCC, 2006):

$$L_{Fire} = BA \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

BA (ha) is the burnt area, M_B ($tC\,ha^{-1}\,yr^{-1}$) is the weight of dry biomass burned annually per ha, C_f is the combustion factor and G_{ef} ($g\,kg^{-1}$) is the emission factor by burnt dry matter.

Annual NPP (MODIS):

$$NPP_{MOD17} = \sum_{i=1}^{i=365} PsnNet - \left(R_{mo} + R_g\right)$$

$PsnNet$ is the daily net photosynthesis, R_g and R_{mo} are the cost of growth and maintenance respiration (g$C\,m^{-2}$).

Study area

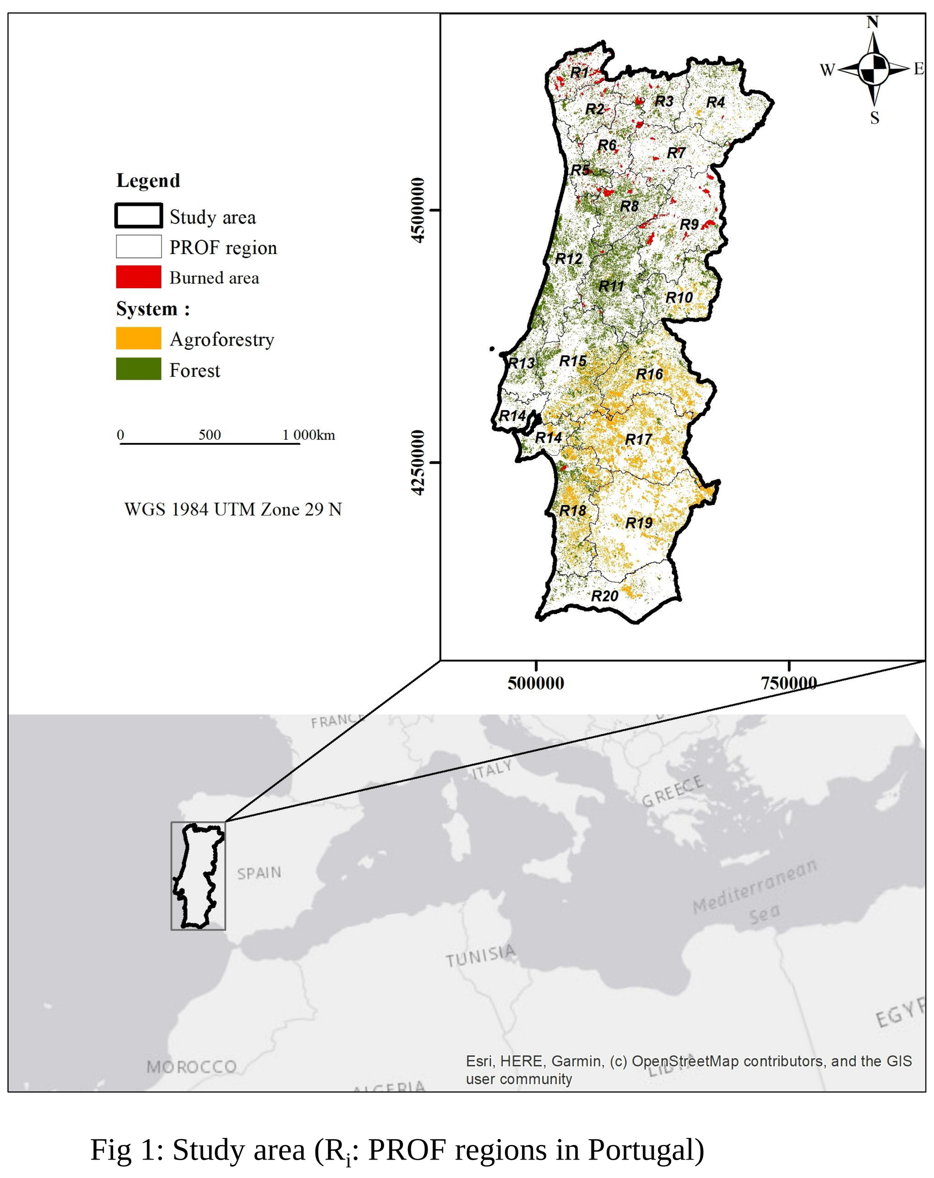

Fig 1: Study area (R_i: PROF regions in Portugal)

Results

- Forest (2.21 $tC\,ha^{-1}$) sequester almost the double of agroforestry systems (1.19 $tC\,ha^{-1}$ (Table 1).
- Under wildfires disturbance, agroforestry systems contributes 3% of carbon emissions and emits 5.89 $tC\,ha^{-1}$, while the forest system contributes 97% and emits 8.50 $tC\,ha^{-1}$ (Table 1).
- UCEA > NPP in both systems (Table 1).

Table 1: Annual NPP average ($tC\,ha^{-1}$), average unit of carbon emission (AUCE; $tC\,ha^{-1}$), and the total carbon gain and losses per species in forest (F) and agroforestry (AF) systems in 2010.

Species	System	UCEA ($tC\,ha^{-1}$)	NPP ($tC\,ha^{-1}$)	Total gain (MtC)	Total losses (MtC)
Maritime pine	F	10.37	1.70	0.85	0.0804
Eucalyptus		13.35	3.42	1.62	0.1047
Acacias		0.00	1.87	0.01	0.0000
Other Broadleaves		5.87	2.68	0.19	0.0138
Other coniferous		12.93	1.40	0.11	0.0130
Mean		8.50	2.21	0.56	0.0424
Chestnut trees	AF	5.45	1.25	0.01	0.0002
Cork oak		8.38	0.72	0.29	0.0028
Holm oak		5.78	0.41	0.17	0.0002
Other oak		4.48	1.34	0.01	0.0006
Stone pine		5.36	2.25	0.13	0.0021
Mean		5.89	1.19	0.60	0.0060

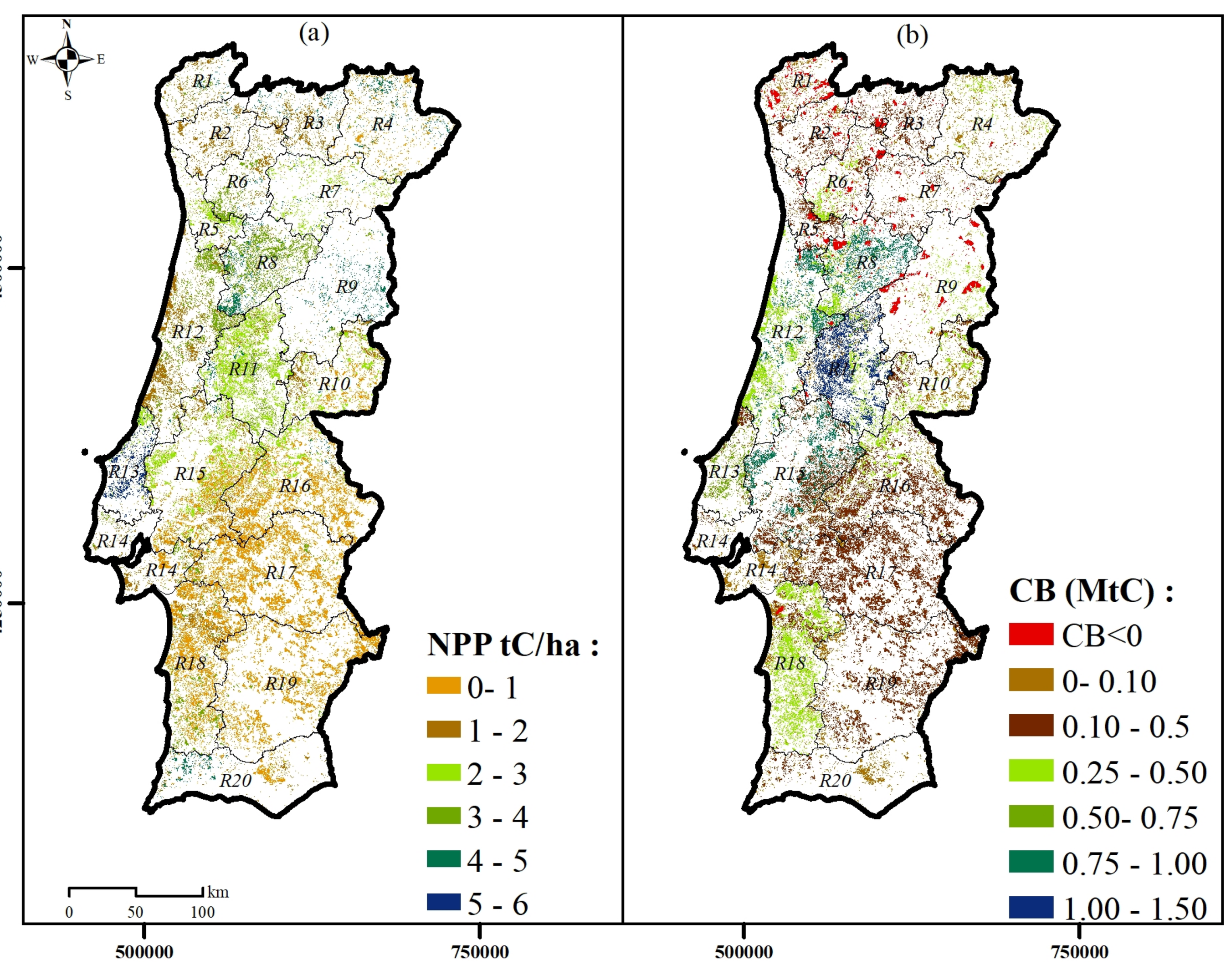

Fig 2: a) Annual NPP map (a) and Carbon balance (CB) map (b) using CA approach based on IPCC.

- The central and coastal regions were the most productive (NPP_{IPCC} varying from 2 to 6 $tC\,ha^{-1}$). In the southwest and northern regions, we observed the lowest NPP_{IPCC} (inferior to 2 $tC\,ha^{-1}$) (Fig 2).
- The Portugal Forest increasingly affected by fire, and which are thus the most vulnerable, were in the northern regions (CB<0) (Fig 2).
- Across different land uses in Portugal, the highest annual productivity was recorded in coastal and central zones ($NPP_{MOD17} > 10tC\,ha^{-1}$). The Northeast and Southeast regions were the less productive ($NPP_{MOD17} > 10tC\,ha^{-1}$) (Fig 3).
- The DRS approach is the most effective to FCM in large scale studies.
- CA approach is more appropriate to FCM in local scale studies.

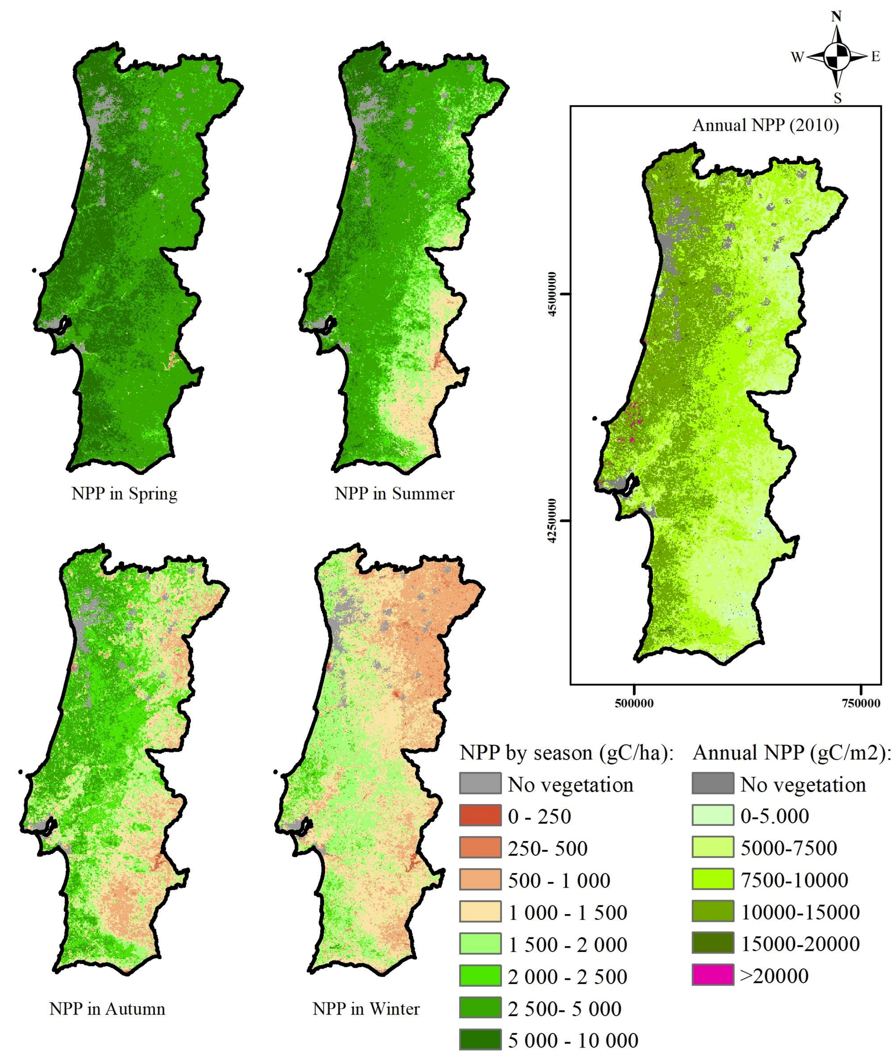

Fig 3: Seasonal NPP and the Annual NPP obtain by DRS approach from MODIS products (MOD17)

Comparison of IPCC and MODIS:

- NPP_{IPCC} mean = 3.10 ± 0.12 $tC\,ha^{-1}$ (Variance = 0.38).
- NPP_{MOD17} mean = 3.06±0.10 $tC\,ha^{-1}$ (Variance = 0.26).
- There is a significant difference between these two methods (P-value < α) (Wilcoxon Test).
- Both methods showed similar averages.

Conclusions

- The species selection and the geographic orientation of afforestation seems a necessary step to offset carbon emission from wildfires.
- In coastal and central zones, particularly in industrial forests, an effective stand density of eucalyptus and pines (forest systems) should be applied to reduce their emissions.
- Agroforestry system species are particularly resistant to wildfires, because of their carbon stock stability. The afforestation with cork oak and stone pine in southern areas and other oaks in the northeast could be a good strategy for climate change mitigation.
- The use of IPCC methodology with high precision (Tier 2 and 3) could be applied to MOD17 accuracy assessment.

References

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