Training a satellite imagery texture based approach to monitor AGB in mangrove using aerial lidar

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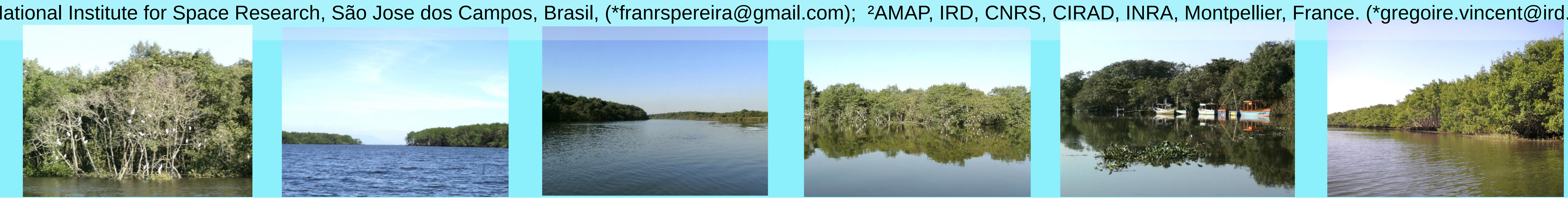
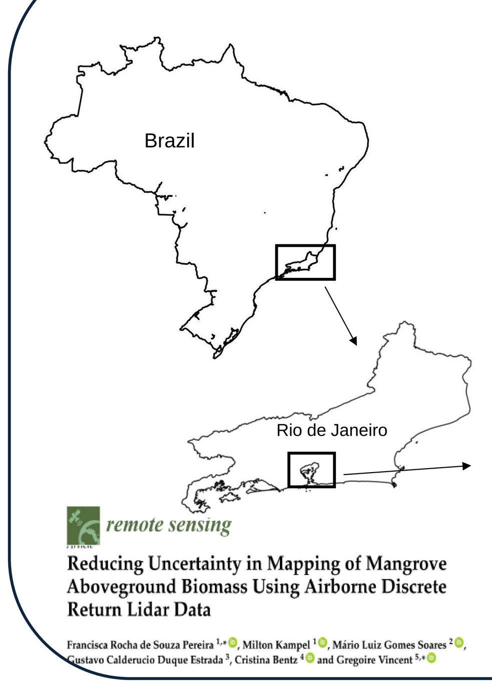
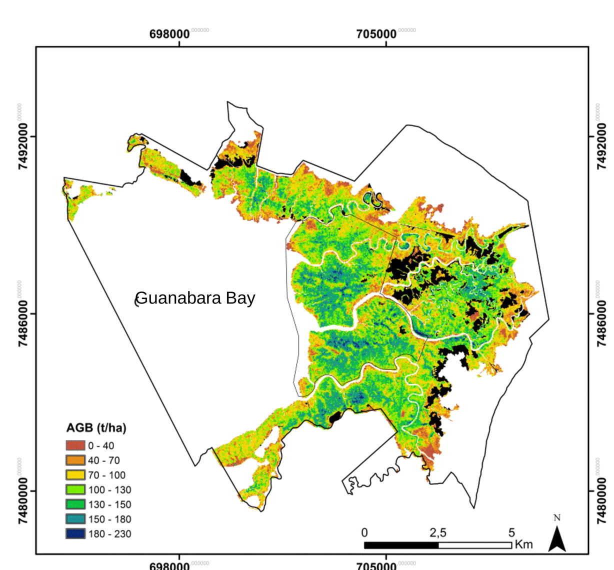


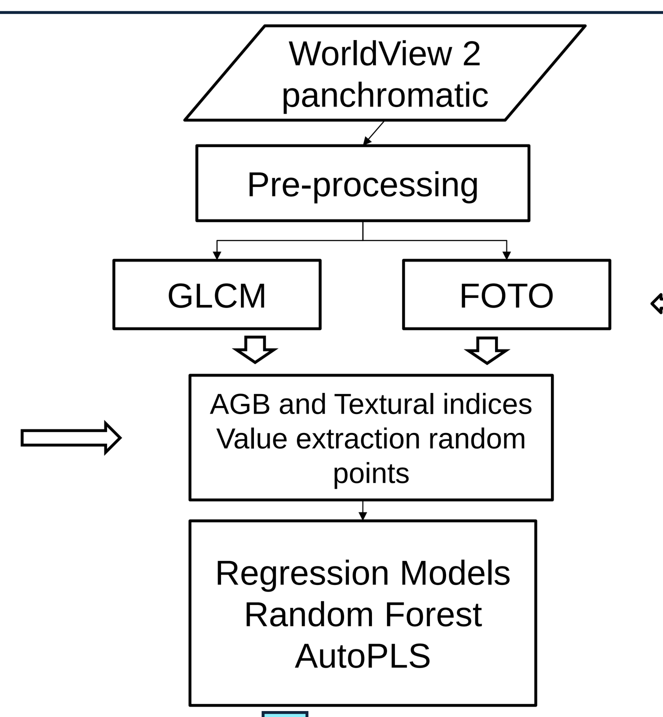

Abstract: Mangroves are important intertidal ecosystems typically in tropical and subtropical regions. Their restoration and conservation are important for the regulation of carbon fluxes and climate change control, also to maintain their valuable services for the coastal zone. The main goal of this study is to investigate the potential use of textural indices derived from a very high spatial resolution WorldView-2 image to estimate the aboveground biomass (AGB) of a mangrove forest in the Environmental Protection Area of Guapimirim (RJ, Brazil) subject to different levels of disturbance. Fourier-based Textural Ordination (FOTO) (Couteron, 2002, Proisy et al. 2007) and Grey-Level Co-occurrence Matrix (GLCM) (Haralick et al. 1973) textural indices were extracted from the panchromatic optical image. An accurate map of AGB was derived from lidar data and this map was used to train and test Random Forest, and AutoPLS methods to estimate AGB. The textural variability pattern associated with the canopy characteristics of the mangrove measured by FOTO and GLCM indices showed reasonable relationships with AGB. When many training points (from lidar) and both types of texture indices were used together the results improved markedly (RMSE (LOO) =25.64 t/ha, R^2(LOO) =0.41). One source of uncertainty comes from the fact that degraded forests with low AGB values present coarse textures and can be confused with the textural pattern of high and more preserved forest characterized by large crowns. Our methodology can be applied to forests with different degrees of development but requires cautions for degraded forests for which texture gradients are not univocal. Nevertheless, the Random Forest classification based on the textural indices showed good results for the discrimination of different types of land cover such as non-mangrove, altered and preserved mangroves. Efforts such as those developed in this work are necessary to quantify AGB and carbon stocks, for monitoring purposes, as to assist public policies for the conservation and protection of these ecosystems.

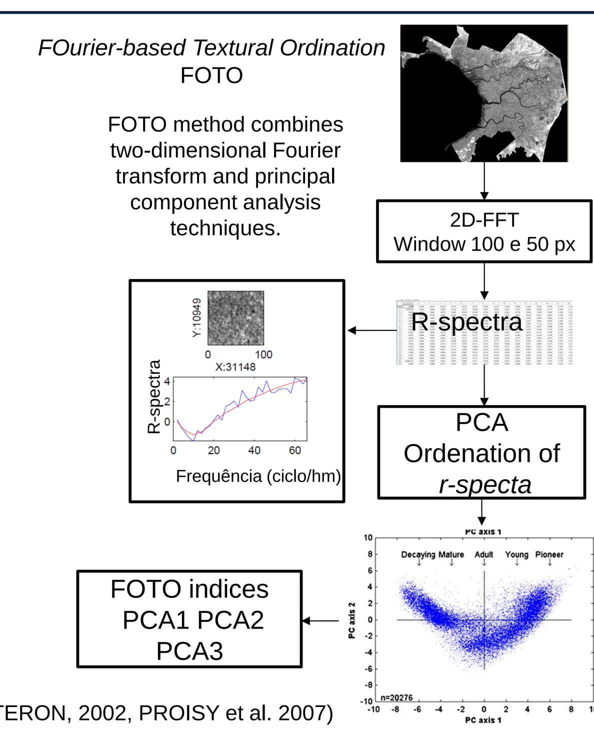
Objective: *The main goal of this study is to investigate the potential use of textural indices derived from a very high resolution WorldView-2 image to estimate the aboveground biomass (AGB) of a mangrove forest in the Environmental Protection Area of Guapimirim (RJ, Brazil) subject to different levels of disturbance. Also to detect mangroves with different levels of disturbance using Random Forest classification.*

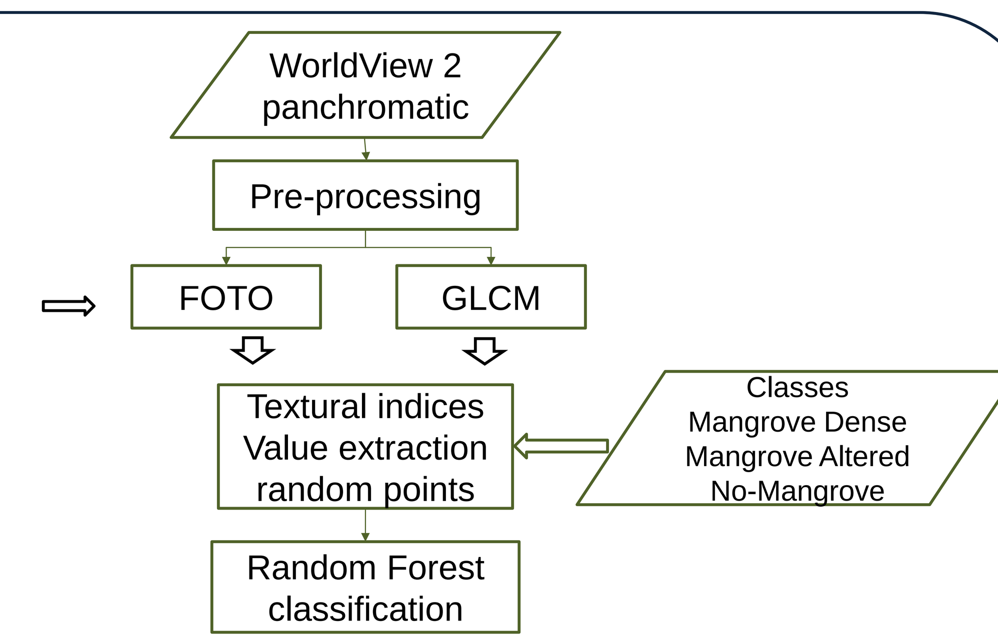
Methodology









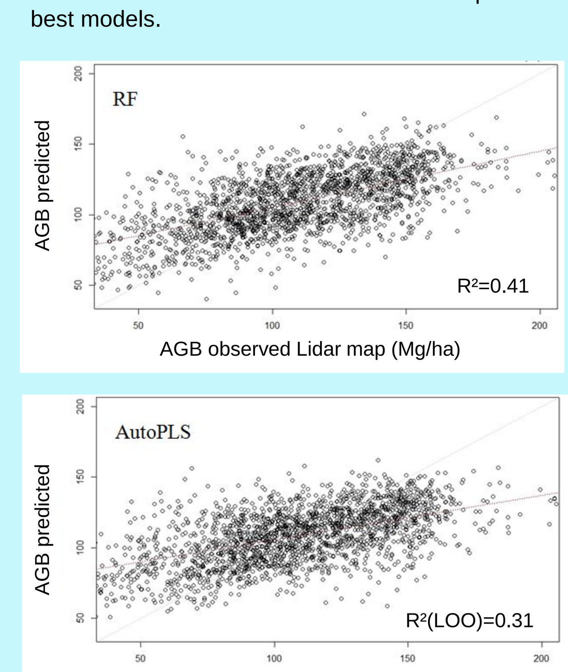


Results

Table 1- Results of the models for AGB estimates (R^2, RMSE (Mg/ha)).

Models	Variable	AutoPLS (a)	Random Forest (b)
M.FOTO 2000p	FOTO 50 PCA1, FOTO 50 PCA2, FOTO 50 PCA3, FOTO 100 PCA1, FOTO 100 PCA2, FOTO 100 PCA3	RMSE(CAL)= 33.0 RMSE(LOO)= 33.0 R2(CAL)= 0.02 R2(LOO)= 0.02	RMSE=32.9 R^2=0. 25
M.GLCM 2000p	*Mean,variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation*	RMSE(CAL)= 27.2 RMSE(LOO)= 27.4 R2(CAL)= 0.33 R2(LOO)= 0.32	RMSE=26.1 R^2= 0.38
M.GLCM+ FOTO 50p	FOTO 50 PCA1, FOTO 50 PCA2, FOTO 50 PCA3, FOTO 100 PCA1, FOTO 100 PCA2, FOTO 100 PCA3, *Mean,variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation*	RMSE(CAL)= 27.4 RMSE(LOO)= 29.0 R2(CAL)= 0.23 R2(LOO)= 0.13	RMSE=31.3 R^2= -0.50
M.GLCM+ FOTO 100p	FOTO 50 PCA1, FOTO 50 PCA2, FOTO 50 PCA3, FOTO 100 PCA1, FOTO 100 PCA2, FOTO 100 PCA3, *Mean,variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation*	RMSE(CAL)= 27.0 RMSE(LOO)= 28.1 R2(CAL)= 0.26 R2(LOO)= 0.19	RMSE=28.3 R^2= 0.18
M.GLCM+ FOTO 2000p	FOTO 50 PCA1, FOTO 50 PCA2, FOTO 50 PCA3, FOTO 100 PCA1, FOTO 100 PCA2, FOTO 100 PCA3, *Mean,variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation*	RMSE(CAL)= 29.4 RMSE(LOO)= 29.5 R2(CAL)= 0.32 R2(LOO)= 0.31	RMSE= 25.6 R^2= 0.41

Figure 1- Scatter plots of predicted versus observed AGB for Random Forest and Autopls best models.



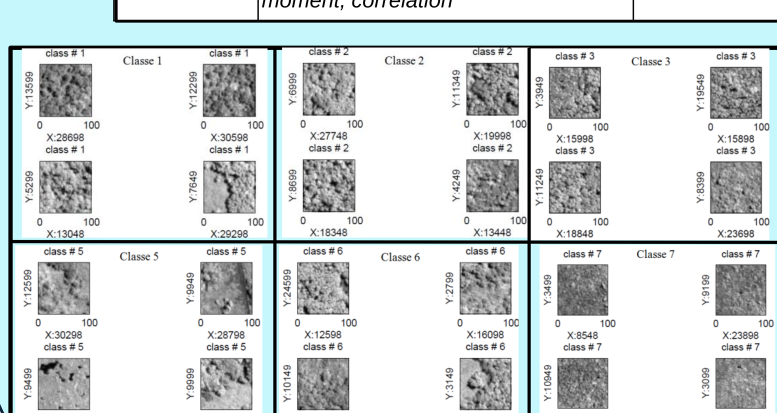


Figure 2- Panchromatic cut image representative of each window (100 pixels) of the class of analysis.

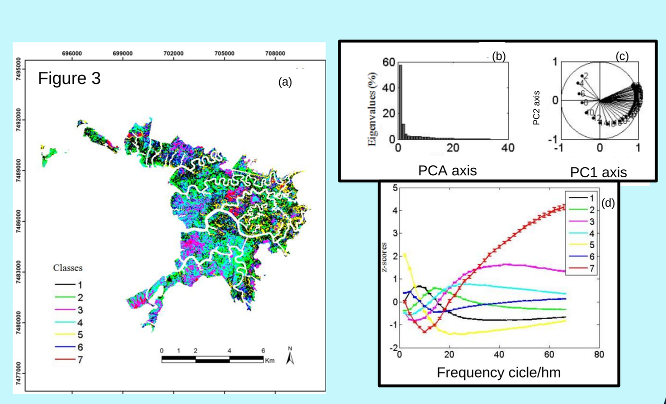


Figure 3- (a) 7 classes of k-means grouped (b) porcentage of total variance for axis of the PCA; (c) correlation of PCA axis and spatial frequency (cicle/hm); (d) behavior of mean r-spectra of 7 classes grouped in k-means .

Table 2- Results of Random Forest classification using FOTO and GLCM variables.

Variable FOTO + GLCM **Error rate OOB: 4.06%**	FOTO 50 PCA1, FOTO 50 PCA2, FOTO 50 PCA3, FOTO 100 PCA1, FOTO 100 PCA2, FOTO 100 PCA3 *Mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment, correlation*			
Confusion matrix	**Mangrove-Altered**	**Mangrove-Dense**	**No-Mangrove**	**Classific. Error**
Mangrove-Altered	659	39	10	0.069
Mangrove- Dense	21	1003	2	0.022
No-Mangrove	15	4	488	0.037
Variable/ importance	**Mangrove-Altered**	**Mangrove-Dense**	**No-Mangrove**	**Gini indice**
FOTO 50 PCA1	3.16	6.01	7.78	16.4
FOTO 50 PCA2	11.45	6.21	7.48	23.98
FOTO 50 PCA3	-2.65	0.33	1.6	10.31
FOTO 100 PCA1	64.68	52.68	19.44	254.69
FOTO 100 PCA2	27.18	10.97	20.6	63.83
FOTO 100 PCA3	4.54	12.07	12.57	25.12
Mean	44.61	46.5	16.17	71.05
Variance	17.47	16.74	13.85	147.46
Homogeneity	18.82	23.41	14.13	172.52
Contrast	16.59	23.2	15.36	161.86
Dissimilarity	17.9	21.25	13.44	162.57
Entropy	19.08	14.13	17.13	119.27

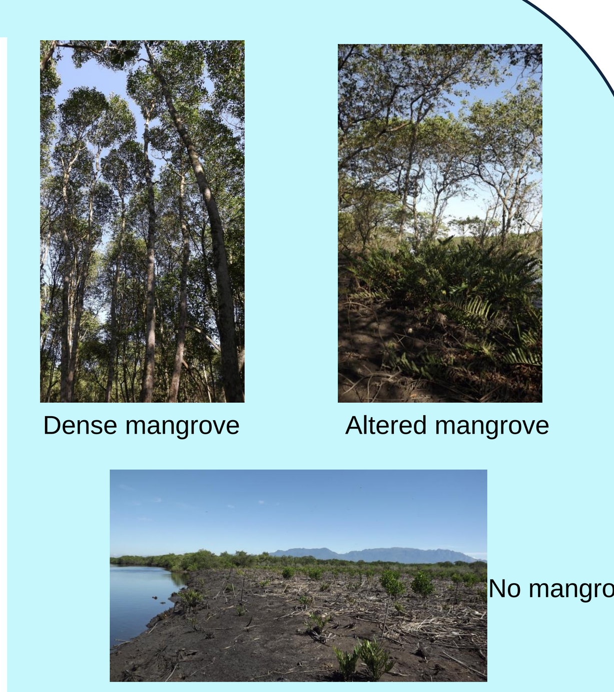
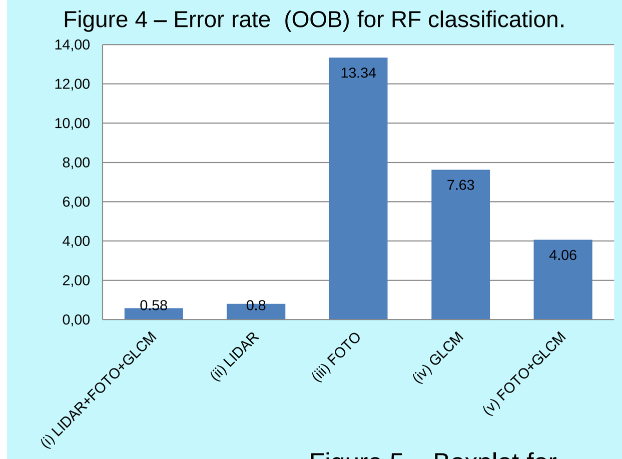


Figure 4 – Error rate (OOB) for RF classification.



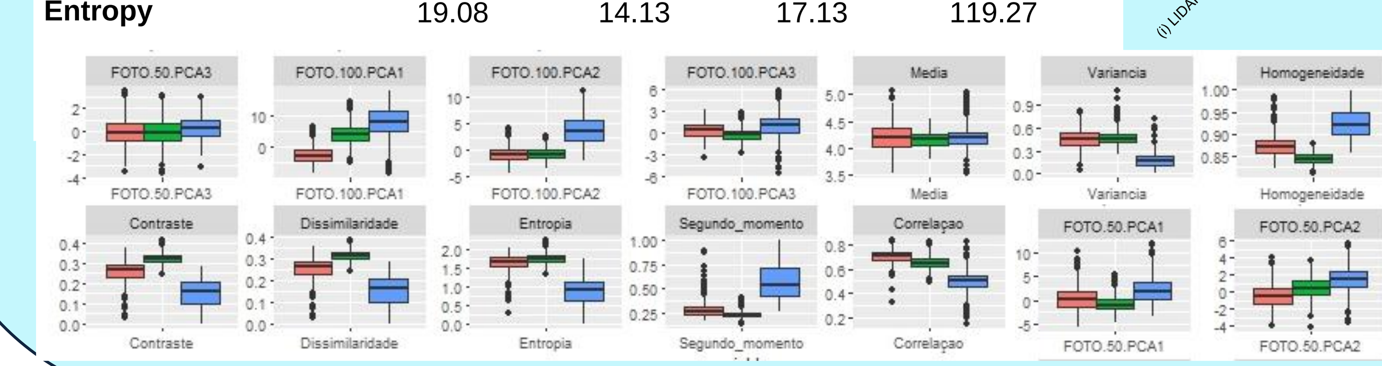


Figure 5 – Boxplot for FOTO and GLCM to discriminate mangrove classes.

Acknowledgment:

Conclusions: In this work we investigated the potential of textural indices (GLCM and FOTO) for AGB prediction of a mangrove forest with different degrees of alteration. The best results for AGB modelling were obtained with the complementarity between GLCM and FOTO. This investigation highlight the importance of having a large number of training samples to reduce the uncertainty of the AGB estimates. The use of the textural indices allowed the discrimination of different types of land cover such as non-mangrove, altered and preserved mangroves Our understanding is that the use of these textural indices to estimate the AGB of degraded mangroves still requires additional research efforts. However, studies like the one developed here are required to quantify carbon stocks on mangrove landscape scale using remote sensing techniques.