EVALUATION OF SINGLE DATE AND MULTI-SEASONAL SPATIAL AND SPECTRAL INFORMATION OF SENTINEL-2 IMAGERY FOR GROWNING STOCK VOLUME OF MEDITERRANEAN FOREST

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Abstract

This study investigates the potential of spectral and spatial features derived from single-date and multi-seasonal Sentinel-2 Multi Spectral Instrument (Sentinel-2 MSI) images, for GSV estimation in a Mediterranean region of Northeastern Greece. Original spectral bands, spectral indices, first-order statistics, Gray-Level Co-Occurrence Matrix (GLCM) texture measures, and local indicators of spatial association (LISA), based on the multi-seasonal and single-date Sentinel-2 MSI imagery, were used for GSV model development using the bagging Lasso algorithm. For both single and multi-date approaches, the spectral indices models were more accurate compared to the respective ones developed with the original Sentinel-2 MSI bands. Also, models based on texture were more efficient than the spectral models. The GLCM measures derived from July image, provided the most accurate single-date estimate of GSV (R^2=0.89, RMSE=35.21), while their multi-seasonal counterparts improved slightly the accuracy (R^2=0.91, RMSE=32.77). Fusion of spatial and textural information resulted in marginal or no-improvement on the texture model accuracy, however the fused models yielded higher predictive results than the spectral models alone.

Introduction

- ✓ The higher temporal frequency, along with the increased spatial resolution of Sentinel-2 MSI, augments the relevance of seasonal and spatial information for improving GSV estimation.
- ✓ Indices with information from the water-sensitive short-wave infrared (SWIR), red-edge or NIR shoulder parts of the spectrum, mitigate saturation effect and improve GSV estimates.
- ✓ Image texture contain important information for forest attributes estimation, due to high temporal frequency of satellite images that increases the ability to observe phenological variation over the growing season
- ✓ The Least Absolute Shrinkage and Selection Operator (Lasso) has been proposed as an effective and efficient technique when working with high-dimensional remote-sensing data

Objective

- ➢ Assess the potential of texture and spectral features extracted from Sentinel-2 MSI images, using penalized regression methods of the bagging Lasso algorithm, for estimating GSV,
- ➢ Evaluation of single-date and multi-seasonal models, considering spectral, spatial and fussed spectral –spatial information, in order to achieve optimal GSV estimation.

The study area Dereio-Dadia-Aisumi Park, is situated in Evros in North Eastern Greece and characterized by black pine (*Pinus nigra*), oaks (*Qercus frainetto, Q. cerris, Q. pubescens*) and beech (*Fagus sylvatica*).

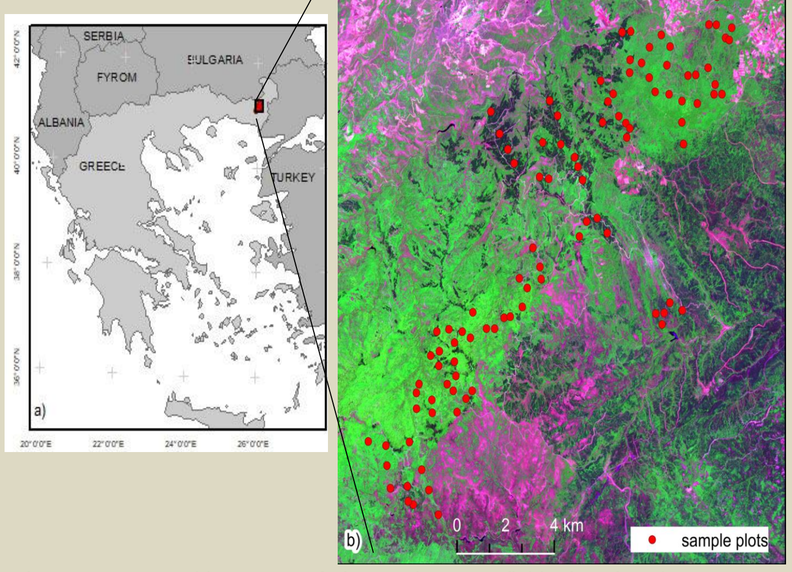
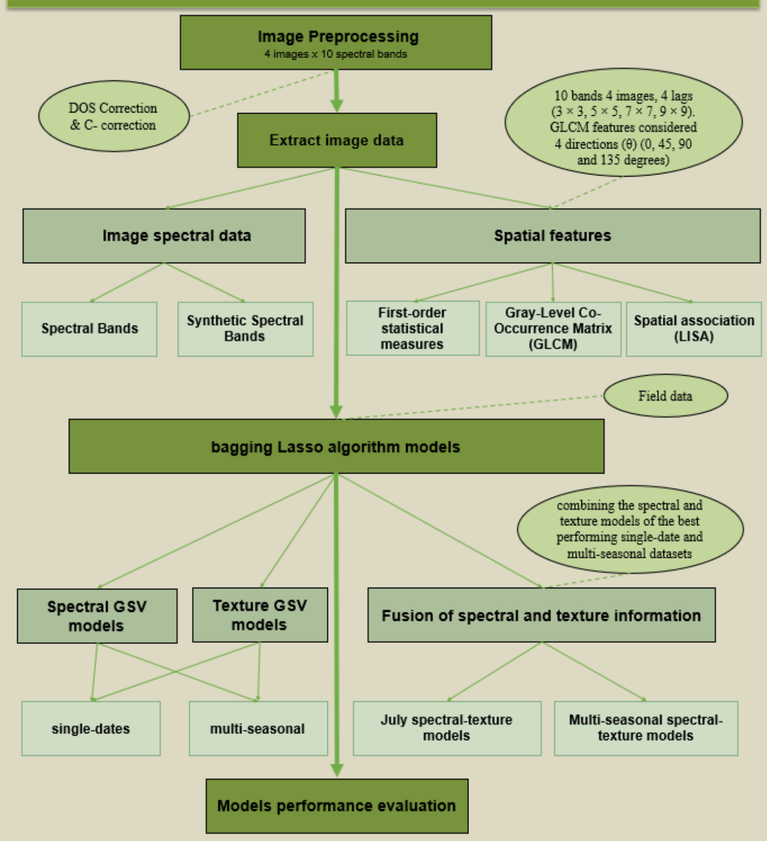


Figure 1 Geographic extent of the study area, field plots location over a Sentinel-2 MSI image (path 182, row 31) acquired on July 2017. (R: SWIR-2 G: NIR B: Green)

Method



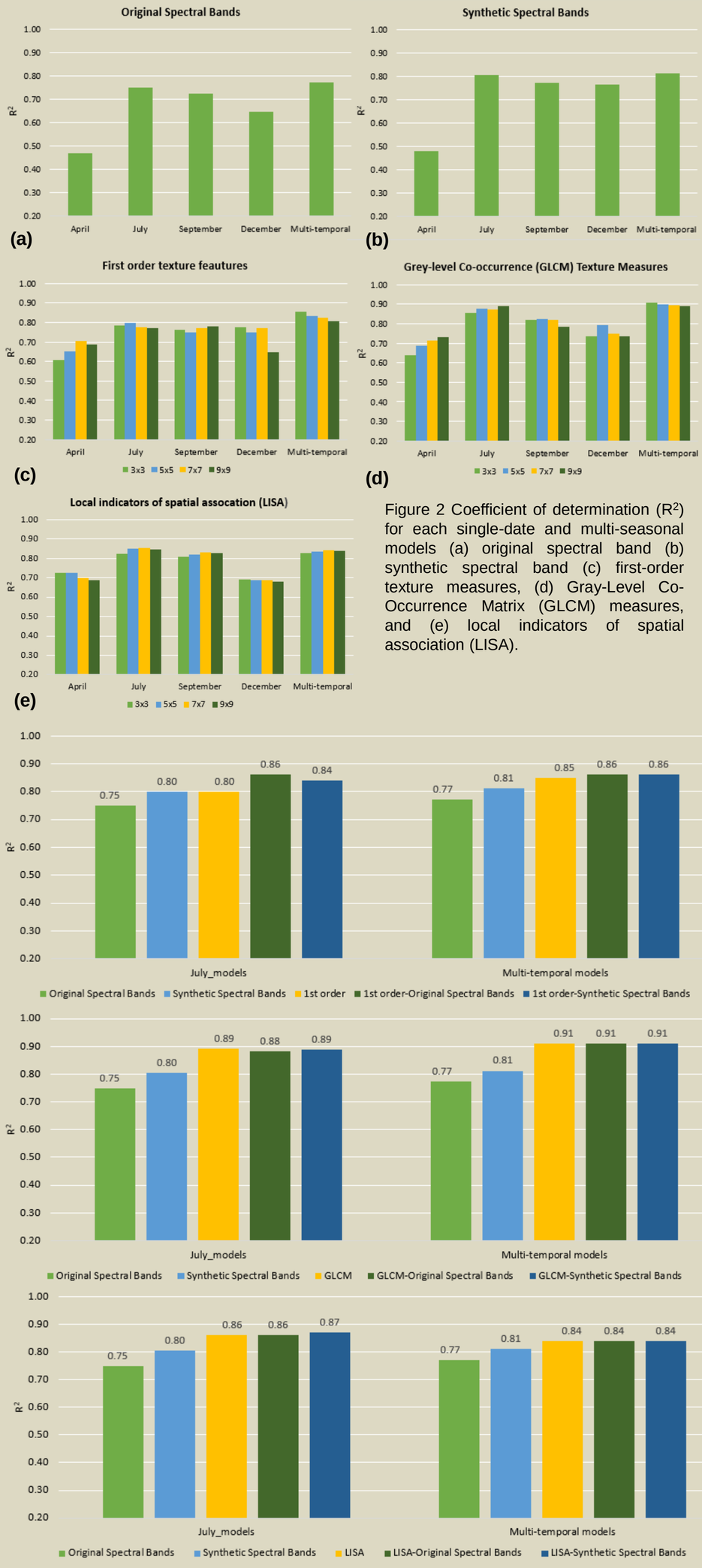


Figure 2 Coefficient of determination (R^2) for each single-date and multi-seasonal models (a) original spectral band (b) synthetic spectral band (c) first-order texture measures, (d) Gray-Level Co-Occurrence Matrix (GLCM) measures, and (e) local indicators of spatial association (LISA).

Figure 3 Model comparison using the coefficient of determination (R^2)

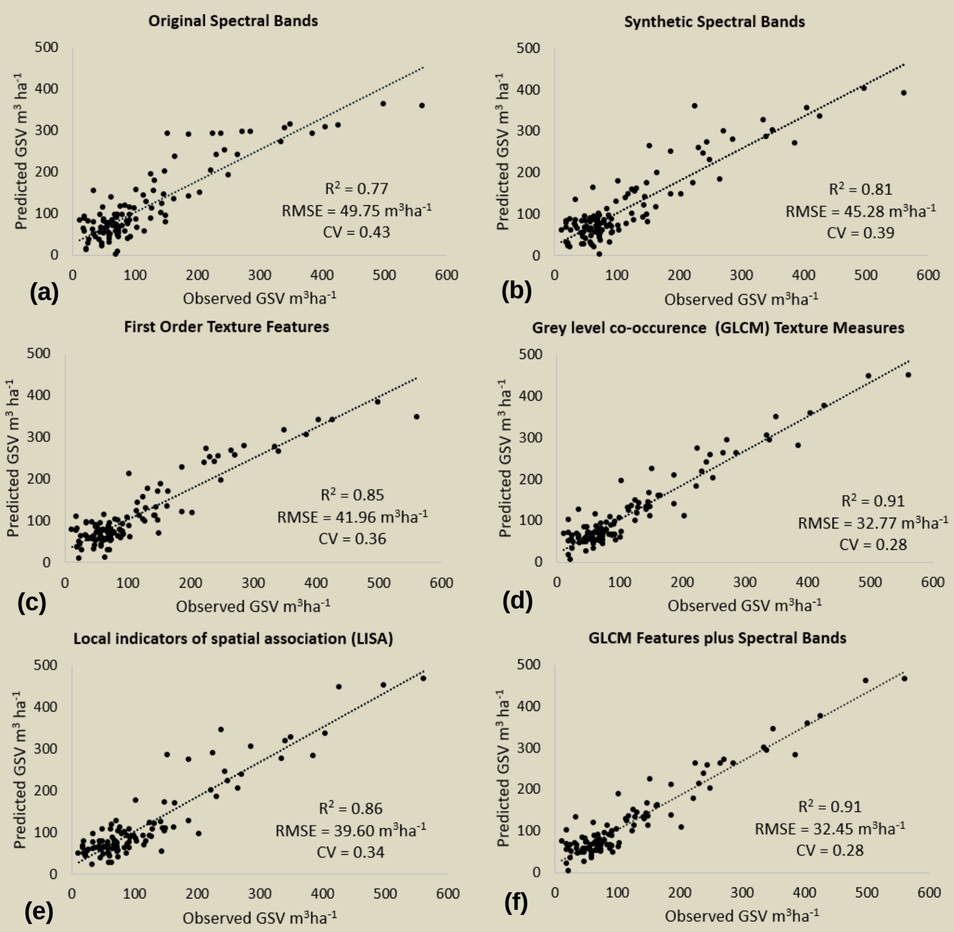


Figure 4 Scatter plots of predicted versus observed growing stock volume (GSV) using the best bagging Lasso models for (a) original spectral bands, (b) synthetic spectral bands, (c) first-order texture features, (d) Grey level co-occurrence matrix (GLCM) texture measures (e) local indicators of spatial association (LISA), f) GLCM texture plus spectral bands. The dashed line shows an optimal model fit

Results

1. Spectral GSV models

- ✓ The highest R^2 (Figure 2) was generated by the multi-seasonal model. Among single-date models, July model presented the best predictive accuracy.

2. Texture GSV models

- ✓ The best first-order texture model resulted from the multi-seasonal texture model including a final set of 180 features extracted from a 3×3 window.
- ✓ The best GLCM model resulted from the multi-seasonal model, extracted from a 3×3 window size and a 0º direction, including a final set of 288 variables.
- ✓ The most accurate LISA model resulted from the July LISA features and a 7×7 window including a final set of 27 predictors.

3. Fusion of spectral and texture information

- ✓ Both original and synthetic spectral bands improved the first-order texture model of July.
- ✓ The results of the spectral-texture models, compared to the GLCM and LISA models, indicated marginal or no-improvement.
- ✓ The prediction accuracy increased when the fused models were compared to the models that used spectral data only.

Discussion

multicollinearity effects and large number of predictors	tackled by…	bagging Lasso algorithm
the multi-seasonal and July's models were the most accurate spectral models	explained due…	diversity in leaf-onset observed over stands of deciduous and mixed forests during wet-season over the area.
increased accuracy of texture models using the multi-seasonal images	due to…	quality of phenological information contained in the combination of the four single-date images
texture appears more important than spectral information for forest parameters estimation	since…	spectral responses are affected by biomass levels with multiple layering and species diversity texture measures are sensitive to canopy shadow information
in terms of optimal window identification, there was no consistency among different image dates	confirming that	no single window size could adequately characterize the range of textural conditions over complex scenes
fused models presented marginal or no improvement compared to texture-only models	confirming that	texture information is more important than spectral, for GSV estimation in sites with complicated forest stand structure

Conclusions

i) the synthetic spectral bands result to a subtle prediction accuracy compared to the original bands,
ii) the use of the GLCM texture measures provide more accurate GSV models compared to other texture measures and spectral models as well,
iii) the improved spatial, spectral and radiometric characteristics of Sentinel-2 enhance the ability of imagery acquired during dry season leaf-on conditions to estimate forest parameters in Mediterranean mixed ecosystems,
iv) the fusion of the multi-seasonal spectral and spatial information provide marginal or no improvement over texture-only models.

Overall, this study demonstrates the large potential of spatial features derived from the Sentinel-2 MSI multispectral data and bagging Lasso algorithm, for retrieval of GSV in Mediterranean regions. Spatial information inherent within the improved technical characteristics of the MSI sensor, could be streamlined and operationalized in GSV estimation models and algorithms, improving prediction accuracy.

References

Chrysafis, I., Mallinis, G., Gitas, I., Tsakiri-Strati, M., 2017a. Estimating Mediterranean forest parameters using multi seasonal Landsat 8 OLI imagery and an ensemble learning method. Remote Sens. Environ. 199, 154–166. doi:10.1016/j.rse.2017.07.018

Chrysafis, I., Mallinis, G., Siachalou, S., Patias, P., 2017b. Assessing the relationships between growing stock volume and Sentinel-2 imagery in a Mediterranean forest ecosystem. Remote Sens. Lett. 8, 508–517. doi:10.1080/2150704X.2017.1295479

Dube, T., Mutanga, O., 2015. Investigating the robustness of the new Landsat-8 Operational Land Imager derived texture metrics in estimating plantation forest aboveground biomass in resource constrained areas. ISPRS J. Photogramm. Remote Sens. 108, 12–32. doi:10.1016/j.isprsjprs.2015.06.002

Mura, M., Bottalico, F., Giannetti, F., Bertani, R., Giannini, R., Mancini, M., Orlandini, S., Travaglini, D., Chirici, G., 2018. Exploiting the capabilities of the Sentinel-2 multi spectral instrument for predicting growing stock volume in forest ecosystems. Int. J. Appl. Earth Obs. Geoinf. 66, 126–134. doi:10.1016/j.jag.2017.11.013