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THESIS SUMMARY

Utilizing GIS and Remote Sensing techniques for evaluating forest stand structure and for assessing their ecological status in relation with the climate and climate change, on the external, eastern and south-eastern flank of the Eastern Carpathians

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Introductory aspects

Introduction

This study can be described as complex, interdisciplinarity being one of its main characteristics. The addressed thematic includes problems related to climatology and biogeography. Modern data sources had been utilized, such as high-resolution satellite images and drone images. Their processing has been done using the latest available methods and algorithms related to the Remote Sensing and GIS fields.

Geographical position, limits and extension of the study area

The study area is located in the eastern part of Romania and it is overlapping the eastern flank of the Eastern Carpathians (Figure 1). This area belongs to the western part of the Siret drainage basin.

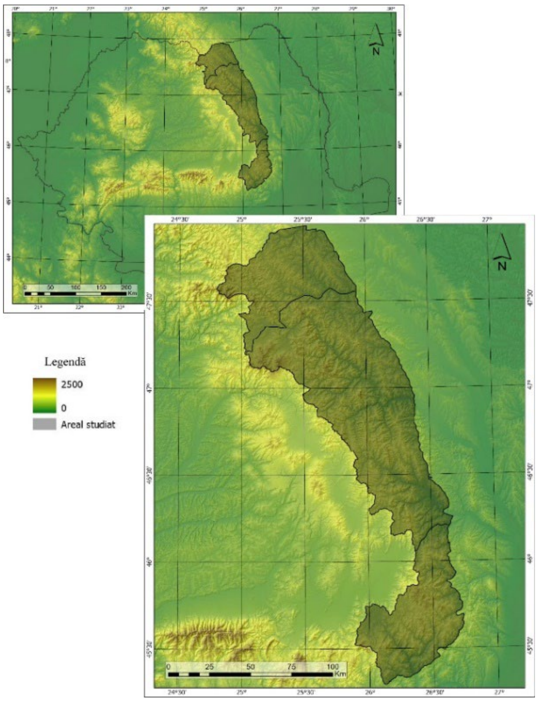

Figure 1. Geographic position of the study area

1. **Methodology**

1.1. Satellite images, aerial images and remote sensing products

1.1.1. Satellite images

Sentinel 2 satellite images are available though the Copernicus Open Access Hub. Sentinel 2 has a multispectral sensor, capable of capturing the electromagnetic radiation from the visible spectrum, near infrared and short-wave infrared.

The images had been radiometrically corrected, the most relevant corrections being the topographic and the atmospheric correction. In order to have a full coverage of the study area, a number o six satellite scenes had been used.

1.1.2. Aerial images

The images were acquired using a fixed wing drone. The result of the processing of the images was an orthophoto with a spatial resolution of 29,7cm and four spectral bands (Figure 2). Also, a digital surface model (DSM) and a digital elevation model (DEM) was generated.

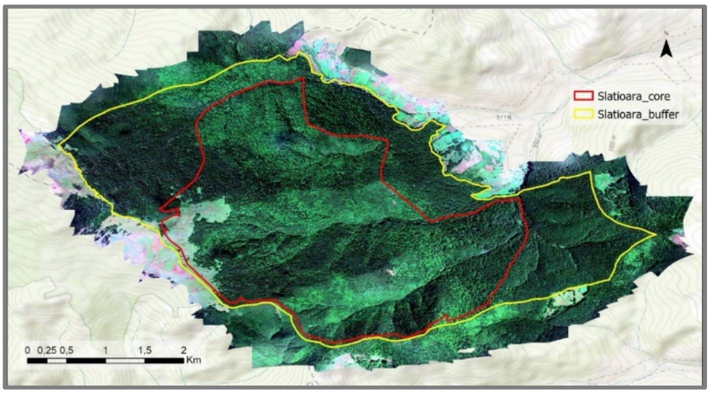

Figure 2. The resulted orthophoto, covering the case study area

1.2. Climate data and processing

For estimating the air temperature in our study area, the ROCADA dataset had been used. The data was processed in ArcGIS Pro, resulting a map of the multiannual average air temperature. A higher spatial resolution was obtain using a linear regression with an ALOS PALSAR DEM (Figure 3).

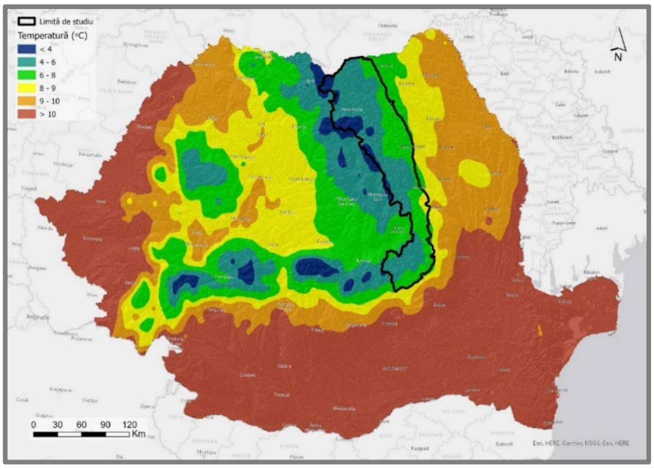

Figure 3. The multianual average air temperature (1961-2013) - derived from ROCADA data

2. Forest cover and species composition of the study area

2.1. Forest cover extraction, using Sentinel 2 satellite images

The forest cover was extracted using an object based, supervised classification method. The visible, NIR and SWIR bands, from the Sentinel 2 dataset, had been used. Only the canopy was extracted, other forest gaps being ignored. The result revealed that a good ortion of the study area, respectively 68,6%, is covered by forest vegetation (Figure 4).

2.2. Tree species classification

The classification was also based on the Sentinel 2 images. The tree species were mapped using a pixel based supervised method, based on the Support Vector Machine (SVM) algorithm. Two classed were obtained, respectively deciduous and coniferous. Thus, the forest cover from our study area is mostly composed of coniferous trees (Figure 4).

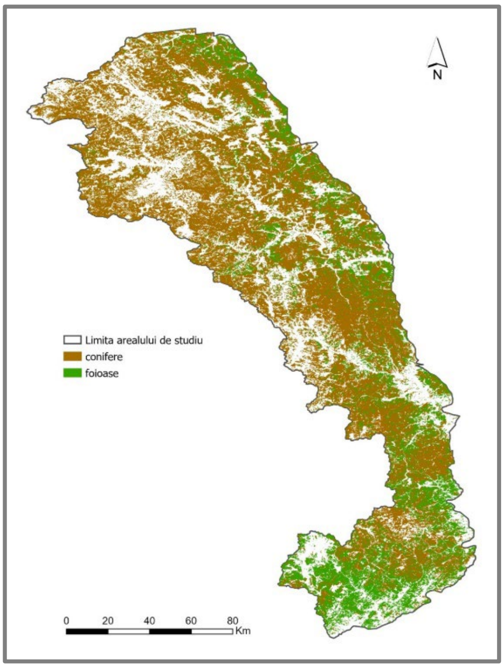

Figure 4. Classification of the coniferous and deciduous species

3. **Spatial distribution of tree species in relation to morphometrical characteristics of the terrain**

3.1. Spatial distribution of tree species in relation to terrain elevation

The terrain elevation was estimated using an ALOS PALSAR model. The coniferous species are mostly found at 1000m, the deciduous species being present at lower altitudes, with a maximum extension at 850m (Figure 5). The maximum altitudine, where forests can be found is approximately 1900-2000m. In the case of the deciduous species, a minor inflexion of the graph line can be observed at the altitudinal value of 1000-1200m. This behavior can be the result of the influence of the temperature inversion phenomena.

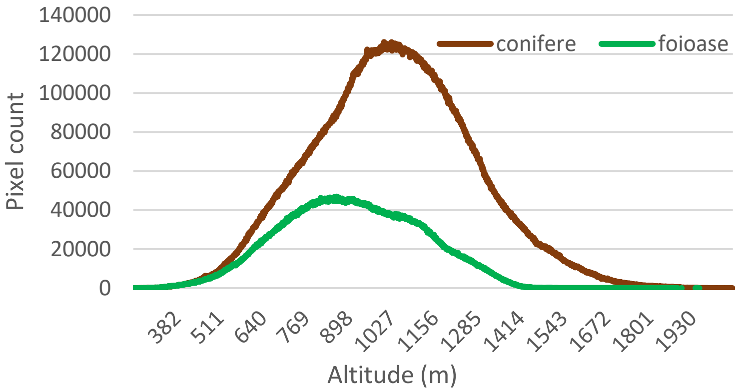

Figure 5. Spatial distribution of tree species, in relation to terrain elevation

3.2. Spatial distribution of tree species in relation to slope orientation

In our study area, the shadowed slopes are prevalent, thus the coniferous species being favored.

4. **The influence of some climate elements on the studied forest types**

4.1. Air temperature and its influence over the forest growth

For our study area, the average value of the air temperature is 5,5°C. The temperature values have a significant extension (Figure 6). The maximum values, of 8-9°C, can be found in

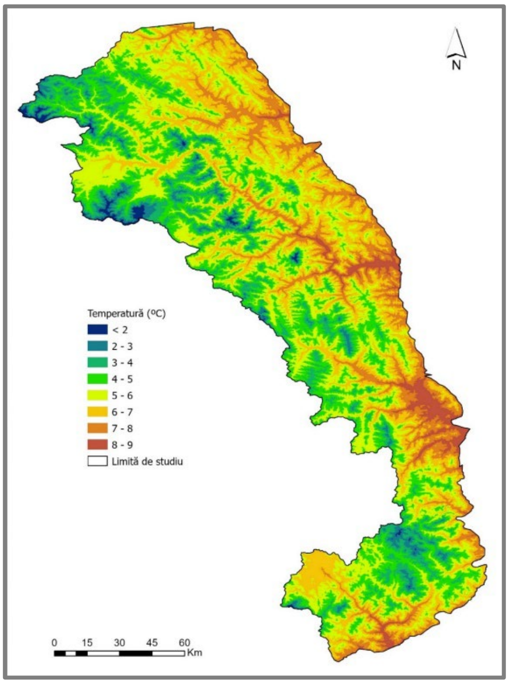

Figure 6. The multinual average air temperature (1961-2013), for our study area – from ROCADA data

valleys and depressions lower than 400m. The minim values, under 0ºC, can be found on the highest mountain peaks, in the Rodnei and Călimani mountains.

4.2. Tree species distribution in relation to air temperature

Most of the coniferous trees can be found in areas characterized by an average temperature of 5 ºC. The minimum temperature that can sustain the growth of the coniferous species is around 0,5-1ºC. Deciduous species can be found at higher temperature, above 3ºC.

4.3. Aspects related to air temperature and atmospheric precipitation in the study area, in the context of climate change and their influence over the ecological status

Climate change is affecting the spatial distribution of the vegetation zones. Because the temperature is rising in a short amount of time, in the near future many forests that are adapted to a certain type of climate will not have optimal growth conditions.

For our study area, the biggest temperature rise was registered in the northern part. The precipitations are predicted to be very variable, with a rise in quantity in the northern part of the study area and decreasing in the southern part.

5. The analysis of vegetation inversions in correlation with temperature inversions, utilizing GIS techniques

5.1. Spatial distribution of vegetation inversions and their correlation with temperature inversion areas

The temperature inversion regions had been identified utilizing an indirect approach, by observing the influence of the climate on the forest cover species structure. Thus, the proposed algorithms will identify the vegetation inversion areas, presuming that the temperature inversions will have a high probability of manifestation in those regions.

5.1.1. Vegetation inversion identification using CLC Data

Firstly, a vector layer containing the slopes of the study area was generated. The polygons were obtained using the Multiresolution segmentation algorithm found in the eCognition software. To highlight the areas where vegetation inversions are present, the polygons (slopes) where the mean altitude of the deciduous species is higher comparing to the mean of the coniferous species altitude, were selected (Figure 7).

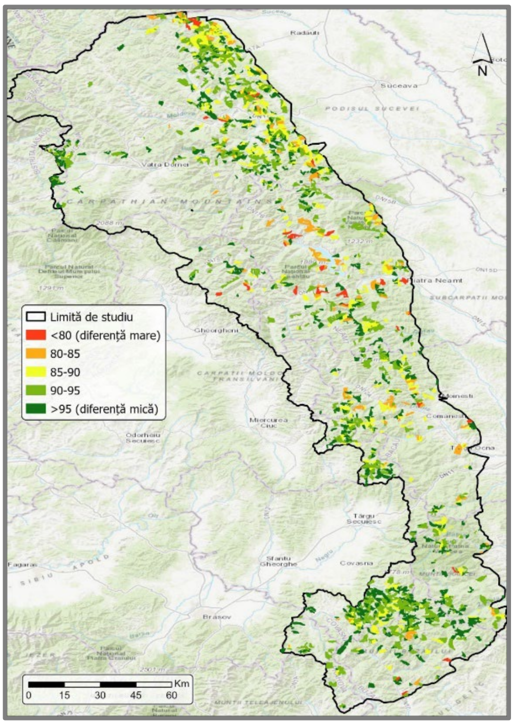

Figure 7. The result of the CLC analysis

5.1.2. Vegetation inversion identification using satellite derived data

The same principle, mentioned above, was applied using satellite derived forest data, instead of CLC data. This time, the analysis was done not only at the level of the segmented polygons (slopes), but also at the drainage basin level and finally, the drainage basins were split in to and the analysis was run at the level of the drainage basin sides. The later case was considered to be the most relevant. Instead of the mean altitude, the median altitude was calculated for each polygon (Figure 8).

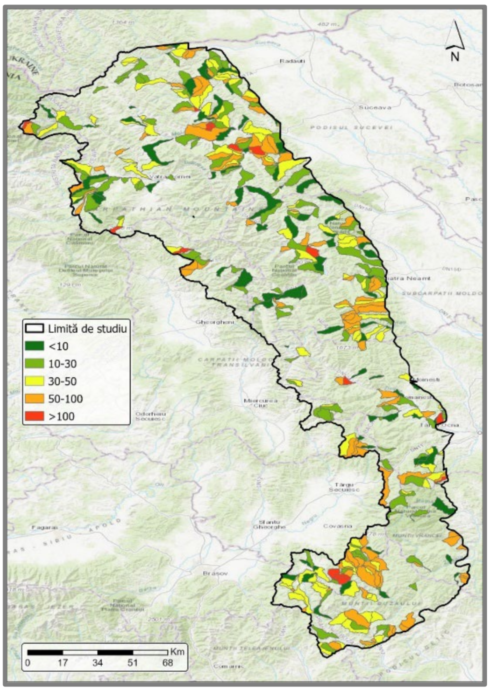

Figure 8. Drainage basi sides from our study area, where the median altitude of the deciduous forests is higher than the one of the coniferous forests

5.2. Slope orientation of the vegetation inversion areas

The prevalent orientation of the vegetation inversion areas is north and south. The northern-orientated slopes are the most common.

5.3. Spatial distribution of tree species of the vegetation inversion areas, in relation to the terrain elevation and slope orientation

The vegetation inversion areas were classified by terrain orientation and each forest class was analyzed in correlation with the terrain altitude, for each one of the eight orientation classes.

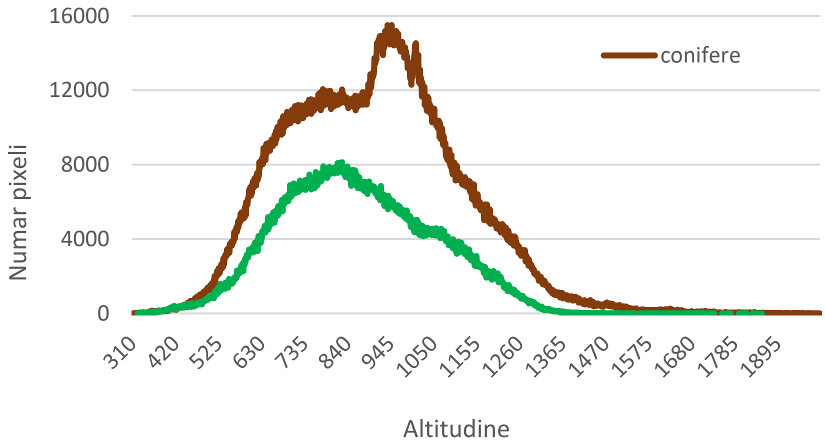

Figure 9. Coniferous and deciduous tree species distribution of the vegetation inversion areas, related to the terrain altitude, on the northern slopes

Some patterns were identified, where the altitudinal distribution of the tree species is very different compared to the whole study area. These situations can be the result of the local climate conditions or anthropic intervention. These observations were corelated with the temperature inversion phenomena, some of the anomalies identified in the altitudinal distribution of the tree species indicating a greater frequency and intensity of the mentioned phenomena.

7. Case study, regarding primary forests

7.1. Study area

The study area is located in Suceava county and it is a protected area consisting in a primary forest. The protected area has a surface of about 1038ha, including the buffer and the core zone.

7.2. Technical equipment

The images were acquired using a fixed wing drone, equipped with a multispectral camera. The sensor outputs images captured in green, red, red-edge and near-infrared.

7.3. Flight planning

The flight path and flight characteristics were calculated using the Mission planner software. The purpose was to obtain a high spatial resolution of the resulting images, considering the very fragmented terrain, which limited the flight altitude to about 240m.

7.4. Image processing

The captured images were processed in Agisoft Metashape. The purpose was to obtain an orthophoto, a digital surface model (DSM) and a digital elevation model (DEM).

7.5. Tree species classification, using the resulted orthophoto

The resulted orthophoto was used for classifying the coniferous and the deciduous tree species. The classification algorithm is the same as for the whole study area. From a total of 1080ha of forest cover, 76% were classified as coniferous and 24% as deciduous (Figure 10).

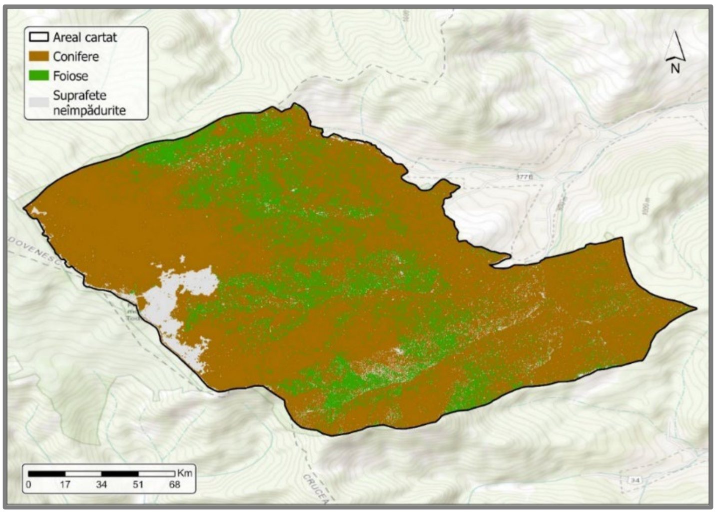

Figure 10. Species classification result, in the test area

7.6. Tree species spatial distribution, in relation to the morphometrical characteristics of the terrain

The tree species distribution from the test area, in relation with altitude, was compared to the distribution of the entire study area. In the case of the deciduous species, a difference of about 200m was observed, when compared to the whole study area. This difference could be the result of the influence of the thermal inversion phenomena.

Conclusions

This is an interdisciplinary study, covering subjects related to biogeography, forest science and climatology.

The data sources used in this study are diverse. Freely available data was used, such as Corine Land Cover data and Sentinel 2 images, or ROCADA climate data. Some of the data, respectively the drone derived data, was obtained using private resources.

The classification of the Sentinel 2 satellite images revealed a total of 987.235ha of forest cover, representing about 68,6% of the study area.

The spatial distribution of the classified tree species was corelated with the altitudinal values extracted from a digital elevation model. This correlation was useful in finding the preferred altitudinal values for the coniferous and deciduous tree species.

The ROCADA data was used for estimating the multiannual average air temperature of the entire study area. The spatial resolution of the data was improved using a linear regression with the terrain altitude derived from an ALOS PALSAR DEM.

In chapter 5, the present study proposes a unique methodology for mapping the spatial distribution of temperature inversions. Further observation revealed some quantitative data, regarding the mentioned phenomena, such as the position of the warm band.

Finally, a case study was conducted on a smaller, more representative area. The main reason for the case study was to observe the spatial distribution of the tree species of a primary forest, thus excluding the anthropic influence.

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