REMOTE SENSING MONITORING OF AIR POLLUTION AND CLIMATIC CHANGES EFFECTS ON MOUNTAIN FOREST SYSTEMS

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Abstract: The climate system responds in complex ways to changes in forcing that may be natural or human-induced and climate-induced changes at the land surface may in turn feed back on the climate itself through changes in soil moisture, vegetation, radiative characteristics, and surface-atmosphere exchanges of water vapor. Thresholding based on biophysical variables derived from time trajectories of satellite data is a new approach to classifying forest land cover via remote sensing .The input data are composite values of the Normalized Difference Vegetation Index (NDVI). Classification accuracies are function of the class, comparison method and season of the year. The aim of the paper is forest biomass assessment and land-cover changes analysis due to climatic effects. Our analysis indicates a potentially application of threshold techniques to land-cover classification and changes analysis due to climatic effects for Romanian Carpathian montane forest ecosystem . The climate of the Carpathians is moderately cool and humid, with both temperature and precipitation strongly correlated with elevation.Extreme climatic events and anthropogenic effects have a strong impact on forest ecosystem. Specific aim of this paper is to assess, forecast, and mitigate the risks of air pollution and climatic changes and extreme events on mountain forest ecosystem in Prahova Valley, Romanian Carpathians test area and to provide early warning strategies on the basis of spectral information derived from Landsat TM, ETM and MODIS satellite data over 1990- 2006 period as well as numerical simulations the regional climate model RegCM3.

Keywords: *climatic changes, air pollution, spectral vegetation indices, mountain forest, satellite remote sensing*

1. INTRODUCTION

Environmental pollution and its consequences such as climate change, ozone depletion, land, vegetation cover degradation , provides a framework for future research strategies in the frame of international cooperation, involving scientists, research agencies and policy-makers on the necessary measures to be taken at the interface of the Kyoto and the Montreal Protocols. Forest protection represents one of the most important aim involving practical aspects of pest prevention and control, as well as aspects of fundamental and applicative scientific research to find the best solutions for maintaining the appropriate fitosanitary condition of the national public forest area in Romania. Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing, which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate (IPCC, 2007). Climate changes can be initiated by external factors forcing the climate system. These climate forcing include natural factors such as changes in energy flux from the sun, variations in the earth's orbit, and volcanic eruptions, as well as human activities, such as production of greenhouse gases and aerosols and modification of the land surface. Over the next century it is likely that forcing of the climate system by human activities will greatly exceed changes in forcing caused by natural events. Processes in the climate system that can either amplify or damp the system's response to changed forcing are known as feedbacks. According to estimates generated by current climate models, more than half of the warming expected in response to human activities will arise from feedback mechanisms internal to the climate system, and less than half will be a direct response to external factors that directly force changes in the climate system (NRC, 2001).Moreover, a substantial part of the uncertainty in projections of future climates is attributed to inadequate understanding of feedback processes internal to the natural climate system (IPCC, 2001).Therefore, it is of central importance to understand, model, and monitor climate feedback processes.

Multifunctional role of forest is revealed by: short and long-term responses and reactions to a fast changing environment. Long-term monitoring systems of ecosystems and landscapes is developing (as a combination of intensive and in-situ observations and more global techniques , e.g. remote sensing). Satellite remote sensing represents an important investigation tool of forest cover monitoring at regional, national,

and global scales, based on building spectral databases, global large datasets, refining validation, calibration procedures in multi-source, multi-temporal environment. The accelerating impact of the available enabling technologies is very important in Earth's features extraction, interpretation by digital image processing, pattern recognition and features identification.

2.BIOPHYSICAL INFORMATION FROM SATELLITE DATA

In remote sensing data analysis, the estimation of biophysical parameters is of special relevance in order to understand better the environment dynamics at local and global scales. For instance, remotely sensed images can be used to estimate forest parameters: defoliation, biomass, leaf area index, water content, pollution, and chlorophyll concentration. In order to relate the image acquired by the satellite sensor to biophysical parameters, model-based estimation algorithms are commonly used. Two different approaches can be considered. In physical modeling, predefined direct models of the estimated biophysical parameters are adopted. These models are designed to account for all parameters affecting the radiometric characteristics of the remote sensing data, such as atmospheric conditions, sun angle, sensor gain and offset, and viewing geometry.In empirical modeling, regression techniques are commonly developed. These techniques relate the remotely sensed data with the investigated biophysical parameter according to interpolation methods applied over a training set constituted by pairs of in situ measurements and collected radiances.

Forest vegetation land cover can be mapped directly at different scales from the apparent brightness measured by satellite imagery in several spectral bands.The reflectance (ρ) from satellite images is:

$$\rho = \left[\pi(L_{sat} - L_{d})/\tau_v\right]/\left[(E_0)\cos\theta\tau_z + E_d\right] \tag{1}$$

where: Lsat = spectral radiance at satellite, Ld = upwelling atmospheric radiance, τ_v = atmospheric transmittance along the target–sensor path, τ_z = atmospheric transmittance along the sun–target path, Eo = exoatmospheric solar spectral irradiance, cos θ = cosine of the solar zenith angle, and Ed = scattered downwelling spectral irradiance. Some of these variables can be derived from satellite images themselves or from published data (Moran et al, 1992). A more realistic interpretation of path transmittances would be to assume a Rayleigh scattering atmosphere, with τ_z and τ_v defined as:

$$\tau_z = e^{-\tau r}/\cos\theta_z \qquad \text{and } \tau_v = e^{-\tau r}/\cos\theta_v \tag{2}$$

Optical thickness for such an atmosphere is defined as:

$$\tau_r = 0.008569\lambda^{-4}(1 + 0.0113\lambda^{-2} + 0.00013\lambda^{-4}) \tag{3}$$

Where λ is wavelength, Ed is calculated for a Rayleigh atmosphere from the radiative transfer code (RTC) 6S (Song et al, 2001). While optical bands of satellite sensors are very useful for assessment of forest vegetation cover health and seasonal changes, thermal infrared bands are providing information regarding forest system dynamics. The assessment of biophysical parameters via the analysis of remote sensing data for forested areas plays a fundamental role for estimation of: biomass concentration and soil moisture content, which represents a key parameter in environmental studies characterized by the soil–vegetation–atmosphere system. Forest cover dynamics is studied by means of vegetation indices (VIs) developed based on combinations of two or more spectral bands, using radiance, surface reflectance (r), or apparent reflectance (measured at the top of the atmosphere) values in the red (R), and the near infrared (NIR) spectral bands . This study used NDVI extressed as:

$$NDVI = (\rho_{NIR} - \rho_R)/(\rho_{NIR} + \rho_R) \tag{4}$$

3. STUDY AREA AND DATA USED

Prahova Valley, test area is located in Southern Carpathian Mountains (45.40N and 45.38N, 25.65E and 26.31E).The investigations were focused on the analysis of forest biophysical parameters and spatio-temporal changes in relation with climatic and anthropogenic changes extracted from satellite data: Landsat

TM 12/04/1990, and 23/05/2000 and Landsat ETM 10/07/2006 as well as MODIS TERRA and AQUA data for ten years period till September 2006. Data were digitally processed and classifieds with ENVI 4.1, ILWIS 3 and IDL softwares.The images were geometrically corrected to fit a topographic map with a scale of 1:50 000, on which vectors were digitized for the subsequent geocoding of the satellite images.

4.METHODOLOGY

Satellite data were digitally processed and classifieds with ENVI 4.3 ,ILWIS 3 softwares.The vegetation indices are calculated from Earth Observation satellite taking into account jointly the features of vegetation responsible for reflection in various bands and combining this information from several spectral bands. Difference Vegetation Index (NDVI) is well known and widely used for vegetation monitoring on a global and local scale (Nackaerts, 2005).Weakness of NDVI is its sensitivity to atmospheric effects. Thresholding based on biophysical variables derived from time trajectories of satellite data is a new approach to classifying forest land cover via remote sensing .The input data are composite values of the Normalized Difference Vegetation Index (NDVI). Associated with these values are radiances in three thermal bands that are used to estimate surface temperature. The classification algorithm, accepts mean growing-season NDVI, mean growing-season near-infrared radiance, NDVI amplitude and surface temperature as input parameters for the composite NDVI and surface temperature data. The units recognized are broad life-form vegetation classes, such as evergreen needle leaf forest, evergreen broadleaf forest, shrubs, etc. Classification accuracies are function of the class, comparison method and season of the year. Our analysis indicates a potentially application of threshold techniques to land-cover classification and changes analysis due to climatic effects for Romanian Carpathian montane forest ecosystem.

The primary tools to study climate changes are the coupled global (GCMs), regional nested models and the transient climate-change simulations obtained when those models are run with projected anthropogenic forcing. Regional Climate Models (RCMs) offer a better understanding of feedbacks between climate and mountain forest systems for the assessment of climate change and anthropogenic effects impacts. RegCM3 used in this study offers higher spatial resolution allowing simulations for greater topographic complexity and finer-scale atmospheric dynamics, very useful for regional impact studies. However, Gems and RCMs are subject to various errors. The climate quality simulated by regional models depends on the internal dynamics and physics of the regional model and also on the quality of the driving data at the lateral boundaries. In spite of the errors in climate models, climate-change signal is usually evaluated as differences between future and current simulated climates and is based on the assumption that systematic errors in the underlying model may partially cancel between the current and future simulations.

4.RESULTS

To evaluate the impacts of the management practice on biophysical properties of the mountain forest system, a set of biophysical variables were estimated from Landsat TM and ETM+ and MODIS data. The data included vegetation indices, surface broadband albedos. To study climatic and anthropogenic impacts ,several classifications of forest vegetation over tested area have been done (see Figure 1). Image pairs of the same vegetation index, for subsequent years, were subtracted producing continuous maps indicating areas of change. Statistical analysis was carried out to see if there is a correlation between the two sets of output.

The analysis of different classifications over selected test area have shown mountain forest changes due to high levels of atmospheric pollution mainly close of main road traffic and some local industries, air masses dynamics at local and regional level as well as due to deforestation for land-use conversion, insect and disease epidemics. This type of digital change detection has the advantage of (1) being repeatable; (2) facilitating the incorporation of biophysically relevant features from the visible, infrared and microwave parts of the electromagnetic spectrum ; and (3) requiring relatively low operational costs.

Forest cover has also a great impact on local mountain climate. In this paper we studied the sensitivity of projected climate-change signal, associated with the annual and monthly climatology of various surface forest fields and pollution (dray and wet deposition, CO_2, SO_2, CO-organic carbon, BC-black carbon, dust). Based on meteorological data and regional climatic model RegCM3 simulations have been analized changes in temperature and precipitation regime in association with aerosols circulation and dynamics. Was demonstrated: 80% of total direct radiation is absorbed by forest cover, comparative with non-forested areas daily temperature is lower in forested areas and greater during night time, while humidity is higher in

forested areas. Also, have been studied the changes induced on the regional climate corresponding to forest–types (deciduous, coniferous and mixed forests.)land cover by the air pollution .Was simulated a 10-year summer season regional climate using ECMWF analysis as lateral boundary conditions, for six forcing cases: background and dust ; background and anthropogenic ; background, anthropogenic, biomass and dust , without forests (grass cover was put in place) ; with doubled background , and only background (control case) aerosols. As an illustration, Figure 2 shows difference of radiative forcing (Forest- NonForest) for mixed forests in Prahova Valley. The inter-comparison of these simulations demonstrated: the direct effect of the aerosols on the forest regional micro-climate, the individual radiative and climatic effect of each aerosol type, and the effect of increasing the amount of forcing. Although the rapid climate change scenarios are purely theoretical, they are useful for demonstrating the direction of change. Comparison of different climate scenarios shows that the effects are in the same direction regardless of the level of change or the initial composition of forests.

Romanian mountain forest system is under continuous influence of characteristic meteorological-climatic fluctuations of continental climate. Periodically, are registered dry or excessive dry seasons during summer with serious impact on existent forests vitality and more over new plantations and forest regeneration process in progress. For long dry seasons there are several high risks like: forest fire and insects mass multiplication. For management and decision making is important to be done medium and long term changes forecasting.
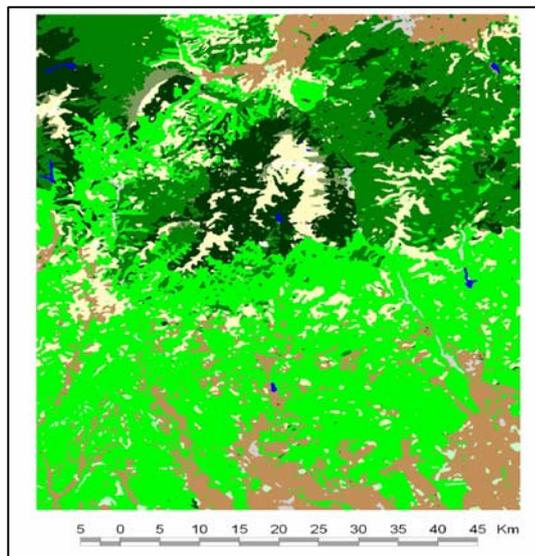

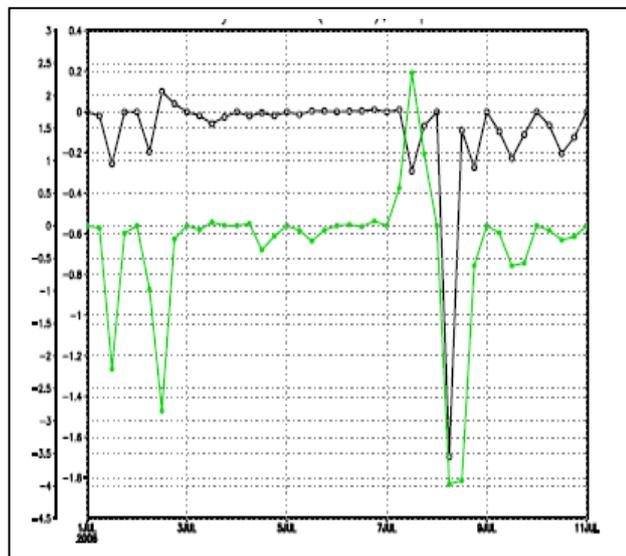**Figure 1 :** Forest vegetation classification on Landsat ETM 10/07/2006 .

Figure 2 : Difference radiative forcing (Forest – NoForest for mixed forests on Prahova Valley, 1-11/07/2006.

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