USE OF TIME-SERIES SATELLITE REMOTE SENSING DATA FOR ASSESSMENT OF CLIMATE AND ANTHROPOGENIC IMPACTS ON FOREST LAND-COVER

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ABSTRACT

Due to high variation in forest communities, forest structure and the fragmentation of the forested area in Romania, satellite based biophysical parameters information for forest state analysis and assessment of climate and anthropogenic impacts for economic and sustainable forest management needs have to meet particularly high quality requirements. Understanding how land surfaces respond to climate change requires knowledge of land-surface processes, which control the degree to which interannual variability and mean trends in climatic variables affect the surface energy budget and by this forest vegetation. Use of remote sensing to monitor the forest changes due to climatic or anthropogenic stressors is an excellent example of the value of multispectral and multitemporal observations. The aim of this paper was to investigate their pattern dynamics due to the impact of anthropogenic and climate variations on a periurban forest Cernica-Branesti, placed to the North-Eastern part of Bucharest city, Romania. The forest vegetation analysis was based on derived biogeophysical parameters from time-series satellite remote sensing MODIS Terra/Aqua and NOAA AVHRR data and in-situ monitoring ground data over 2002–2013 period. Climate variability and anthropogenic stressors have a great impact on the forest vegetation biophysical parameters dynamics. Satellite remote sensing is a very suited tool to assess the main phenological events based on tracking significant changes on temporal trajectories of Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) and land surface albedo, which are key biophysical variables for studying land surface processes and surface-atmosphere interactions.

INTRODUCTION

Romania is a country with a great biodiversity and a high percentage of intact forest natural ecosystems, being one of the largest areas of natural forest in Europe. At the end of 2003, the total growing stock of forested area in Romania was 6368.5 thousand ha. In addition to that there are about 320 thousand ha with wooden vegetation (afforested pastures, tree lines, etc.) that is 26.7% of the country's area. The national growing stock is not uniformly distributed as regards the geographical zones.

From point of view of species and groups of species as well as of the distribution by geo-climatic zones, the Romanian forest species can be classified in: leaf-bearing species: 70% (31.2% beech, 18.1% quercine species, and 15.1% other hard lead-bearing species, 5.2% soft leaf-bearing) and coniferous species: 30% (22.7% spruce fir, 4.9% fir, 2.4% other coniferous species). Forests made up of mixtures of species are more resistant to adversities. Multifunctional role of forest is revealed by: short and long-term responses and reactions to a fast changing environment; forest must be able to provide ecological and social services; to assure a forest-wood chain that meet the needs for forest based goods and products. Demonstrated global environmental changes have already taken place and will continue with a degree of uncertainty. 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).The climate system responds in complex ways to changes in forcing that may be natural (e.g., variations in the magnitude of solar radiation reaching the top of the atmosphere) or human-induced (e.g., changing atmospheric concentrations of greenhouse gases). Research on geosphere-biosphere-atmosphere interaction depends on scientific information about existing terrestrial vegetation, among which forestry has an important contribution. One of the main sources of systematic change on local, regional, or global scale is due to variations in the composition and distribution of forest vegetation. The assessment of forest ecosystems state as well as the influences of local and regional climate is closely related to land use/cover changes, being very different from region to region.

Satellite based biophysical parameters information for assessment of climate and anthropogenic impacts on forest vegetation for sustainable management needs have to meet particularly high quality requirements. In addition multiple national and international commitments for reporting on forest resources such as the Montréal Process or the Kyoto Protocol, are leading to an increasing demand for expanded information within the framework of forest land cover/use. Forest vegetation and climate interact through a series of complex feedbacks, which are not very well understood. The patterns of forest vegetation are largely determined by temperature, precipitation, solar irradiance, soil conditions and carbon dioxide (CO_2) concentration. Vegetation impacts climate directly through moisture, energy, and momentum exchanges with the atmosphere and indirectly through biogeochemical processes that alter atmospheric CO_2 concentration. Changes in forest vegetation land cover/use alter the surface albedo and radiation fluxes, leading to a local temperature change and eventually a vegetation response. Forest vegetation-climate feedback regimes are designated based on the temporal correlations between the vegetation and the surface temperature and precipitation. The different feedback regimes are linked to the relative importance of vegetation and soil moisture in determining land-atmosphere interactions. Forest vegetation phenology constitutes an efficient bio-indicator of impacts of climate and anthropogenic changes and a key parameter for understanding and modeling vegetation-climate interactions.

CLIMATE AND ANTHROPOGENIC PRESSURES

Climate changes and extreme events like as in temperature, precipitation, cloudiness, increasing dry seasons, droughts, accented frost, intense rain storms, might increase damage forest ecosystems. Another source of spatio-temporal changes in forest ecosystem may be due to anthropogenic influences. Land use/cover changes by human activities, such as deforestation, urbanization, and agriculture practice, influence climate. Land surface conditions affect the dynamics and thermodynamics of the atmosphere by influencing the water cycle and energy budget, may affect local, regional, and possibly global weather and climate. Climate-induced changes at the land surface and extreme climate events (e.g., through more intense and higher frequency droughts, flood or cold) may in turn feed back on the climate itself, for example, through changes in soil moisture, vegetation, radiative characteristics, and surface-atmosphere exchanges of water vapor.

Changes in climatic conditions, land use practices and soil and air and water pollution have large-scale adverse impacts on forest biomass quantity and quality (1). The current knowledge base in forest system management is not adequate to deal with these impacts. The proper functioning of forest system is linked to key biogeochemical processes determining the changes. Air pollution and climate change are two key factors comprising the global change threat to forest health and sustainability. Natural as well as managed forest systems often experience multiple environmental stresses that can come together to cause impacts that are greater than simply additive. Multiple environmental changes can also interact with each other to cause additional, unexpected stresses. The term “multiple stressors” is simply a shorthand way of referring to scenarios where multiple environmental influences are at work with various multi-dimensional interactions among them. Understanding the net impact of a suite of simultaneously occurring environmental modifications (e.g., elevated carbon dioxide; increased oxidants, reactive nitrogen, and acid deposition; decreased stratospheric ozone; increased ultraviolet radiation; higher mean temperature; changes in timing and availability of water; loss of biodiversity, increases in invasive species, rising sea level; coastal development and habitat fragmentation) is essential for developing predictive capabilities and response strategies. Forest ecosystems respond not only to temperature but particularly to decreasing soil moisture that, in turn, induces woody plant mortality, rapid canopy change, and increased soil erosion. Drought-induced tree mortality results in heightened vulnerability to fires. Increased temperature over long periods of time can also facilitate larger infestations of pests that magnify tree mortality and thereby expand the spatial scale of forest fires. Ecotones, or zones of transition between

Forest ecosystems, appear to be most susceptible to rapid vegetation change under stress (2). As reductions in herbaceous groundcover increase, the distribution of near-ground energy is altered and can affect a wide range of ecosystem processes dependent on that energy. The threat of nonlinear increases in soil erosion rises significantly as a consequence of that shift in near-ground energy (3).

Air pollutants affecting forest health at national and multinational scales include increasing tropospheric, or surface level, ozone (O3) concentrations, increasing atmospheric carbon dioxide (CO2) concentrations, and acidic precipitation. At a regional to local scale, emissions of sulphur dioxide (SO2), oxides of nitrogen (NOx) and a number of other pollutants such as ammonia (NH3) emissions from animal feeding operations affect forests downwind of point or urban sources, particularly in rapidly industrializing regions of the world. Increasing levels of ultraviolet-B radiation from stratospheric O3 depletion at a global scale are possibly a threat to forest health. There is evidence as well for an increasing emission of persistent organic pollutants (POPs) (4). Coincidentally, the world's climate is changing and anthropogenic influences are strongly implicated (5).

SATELLITE REMOTE SENSING IMAGERY IN FOREST RESEARCH

Satellite remote sensing data in the visible and near-infrared (VNIR) optical wavelengths domains represent a useful source of information for biogeophysical parameters (leaf area index, canopy cover, clumping index, fraction of absorbed photosynthetically active radiation, chlorophyll content, net primary production, canopy water stress, etc.) estimation of forested areas.

Recent advances of information technology has allowed the development of tools and techniques to handle geospatial data and/or derived. With differences in scales, datum, projections, formats, or resolution, the data are often difficult to handle and even more difficult to integrate. With the advent of space-based observations, geoscientists can extend that use in three important ways: the advantage of large area or synoptic coverage allows them to examine in single scenes (or in mosaics) the biogeophysical portrayal of forest ecosystems on a regional basis; the ability to analyze multispectral bands quantitatively in terms of numbers (DNs) permits them to apply special computer processing routines to discern and enhance certain compositional properties of Earth materials; the capability of merging different types of remote sensing products (e.g., reflectance images with radar or with thermal imagery) or combining these with topographic elevation data and with other kinds of information bases (e.g., thematic maps; biogeophysical measurements and biochemical sampling surveys) enables new solutions to determining interrelations among various natural properties of forest land cover.

For the purpose of estimating land surface fluxes over a forest area, use of remote sensing techniques is and will be essential. Particularly, "in situ" collection of ground truth data has been a very important task for the development of satellite oriented "algorithms".

Geospatial information is an important technology in forest research analysis of ecosystems spatio-temporal dynamics being an important investigation tool of forest cover monitoring at regional, national, and global scales. Is based on building spectral databases, global large datasets, refining validation, calibration procedures in multi-source, multi-temporal environment. Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard the National Aeronautics and

Space Administration's Terra and Aqua satellite platforms have provided researchers with unprecedented spatial, spectral, and temporal information on the land surface's radiative characteristics. These dataset characteristics afford the necessary spatial, spectral, and temporal resolutions to accurately provide radiative properties of the surface.

However, these new sensors demand new information-extraction methods. Techniques required inferring land use and land-use change from the raw spectral signals that are recorded. This can be achieved most effectively when the image data are analyzed, in conjunction with ancillary spatial data, within a geographical information system (GIS) environment. Digital map data products can provide information on various aspects of the forested areas. Vegetation cover can be mapped directly at these scales from the apparent brightness measured in several spectral bands. Forest monitoring is a major application field for remote sensing techniques, which are capable of providing synoptic information over wide spatial scales and with high acquisition frequency. Satellite remote sensing in particular offers the possibility to estimate and monitor some basic parameters that are descriptive of forest vegetation status (species, density, volume, etc.). These parameters are usable by themselves but assume greater importance as input for models that simulate forest ecosystem processes, such as transpiration and photosynthesis. While in fact remote sensing data are not suited to directly measure such processes, they report information, which, integrated with conventional data, can initialize and drive models simulating the main ecosystem functions.

BIOGEOPHYSICAL INFORMATION

Knowledge on biophysical properties of forest vegetation retrieved from satellite images enables to improve monitoring of these unique areas, very often impenetrable.

Vegetation Index

The vegetation indices are calculated from Earth Observation satellite data taking into account jointly the features of vegetation responsible for reflection in various bands and combining this information from several spectral bands. They are usually easy to calculate without additional meteorological data.

Forest cover dynamics was 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 (6) . This study used Normalized Difference Vegetation Index NDVI expressed as:

$$NDVI = (\rho_{NIR} - \rho_R)/(\rho_{NIR} + \rho_R) \qquad (1)$$

For *Green Vegetative Cover* of forested areas, the most commonly used index is the NDVI and it has been used in mixture modeling to compute green fractional vegetation cover (*fc*) the following relationship:

$$f_c = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \qquad (2)$$

where NDVIsoil is the NDVI value of bare soils and $NDVI_{veg}$ is the NDVI value of a pure vegetation pixel. In order to use Eq.2 to compute fractional green cover, we used two parameters, $NDVI_{soil}$ and $NDVI_{veg}$, which can be empirically determined (0.1 and 0.8) as suggested in literature.

The fractional cover computed using Eq.2 is only an estimate of the green component. Vegetation can be distinguished using remote sensing data from most other (mainly inorganic) materials by virtue of its notable absorption in the red and blue segments of the visible spectrum, its higher green reflectance and, especially, it's very strong reflectance in the near-IR. Different types of vegetation show often distinctive variability from one another owing to such parameters as leaf shape and size, overall plant shape, water content, and associated background (e.g., soil types and spacing of the plants (density of vegetative cover within the scene).

Land surface albedo

In general, part of the incident energy striking a surface may be absorbed, reflected, and transmitted. The corresponding surface properties associated with these three processes are absorptivity, reflectivity, and transmissivity. The fractions of the total incident energy associated with these properties are termed as absorptance, reflectance, and transmittance. When the sun is the source of the incident energy, the term albedo (α) is commonly used instead of reflectance.

Solar radiation incident on vertical and inclined surfaces consists of beam, sky-diffuse and ground-reflected components. The ground-reflected component may be significant, particularly in the northern latitudes due to low elevations of the sun and, at times, due to the presence of highly-reflecting snow cover. Accurate estimation of ground-reflected radiation would require knowledge of the foreground type and geometry, its reflectivity, degree of isotropy, the details of the surrounding skyline and the condition of the sky.

Land surface albedo is an important parameter in describing the radiative properties of the Earth's surface in particular in forest research. Land surface albedo is important for the remote sensing of atmospheric aerosol , cloud properties from space, climatic analysis, biophysically based land surface modeling of the exchange of energy, water, momentum, and carbon for various land use categories as forestry and agriculture, as well as for surface energy balance studies. Forestry and agriculture applications need proper representation of the surface albedo's spatial and spectral variation, due in part to the distribution of vegetated surface types and growing conditions, and temporal variations, due largely to changes in the amount of vegetation over phenological growth cycles.

Land surface albedo (α) can be calculated from the following equations:

$$H_m = H^{'}\{1-\alpha[0.25(S/S_o)+0.6(1-0.25(S/S_o))]\} \quad (3)$$

with H' monthly average of daily global irradiation that strikes the surface, defined by

$$H^{'} = H_o[A+(BS/S_o)] \quad (4)$$

H_m, S and S_o are monthly averages of measured daily global irradiation, S_o monthly averages of daily sunshine duration and monthly of the daily maximum possible duration of sunshine hours.

$$H_m = H_o[A+(BS/S_o)] \quad (5)$$

$$S_o^{'} = 2/15\cos^{-1}[(\cos 85^o - \sin L \sin \partial)/(\cos L \cos \partial)] \quad (6)$$

with L latitude of the sites in degrees, ∂ the declination angle of the sun in degrees and H_o the estimation of the monthly average of daily extraterrestrial irradiation. Then, can be defined A and B regression constants in the previous equations Eq.5-6 for each month of the year (7), (8).

In a shortened case surface albedo is defined as the ratio of reflected to incident solar radiation flux intensity (measured in W m^{-2}) on the earth's surface. The total energy reflected by the earth's surface in the short-wave domain is characterized by the short-wave (0.3±4.0 μm) broadband albedo. The shortwave broadband albedo is one of the most important physical parameters for climate models, because it governs the exchange of solar radiation between the land surface and the atmosphere. Solar radiation energy is the fundamental source of power that drives the circulation of water and energy in the atmosphere, continents, and sea. Moreover, solar radiation at the ground level affects global climate and meteorology. Therefore, accuracy in the measurement of short-wave broadband albedo directly affects the results of a climate model.

However, using satellite remote sensing techniques, albedo can be determined at the pixel level over an entire area (9). This allows more accurate estimation of climate models.

In the IPCC third assessment report, surface albedo is listed among those radiatively important components that are known at a very low confidence level. The uncertainty of radiative forcing due to insufficient knowledge of surface reflective properties is believed to be comparable or higher than radiative forcing produced by ozone, sulphate aerosols and aerosols from biomass and fossil fuel burning (10).

STUDY AREA AND DATA USED

Forest test area, Cernica- Branesti is placed in the North -Eastern part of urban zone Bucharest (Figure 1), Romania, being centered at latitude 44.4437 °N and longitude 26.298 °E. It is characterized by a land sandy area, with a diversity of forest types which contains hardwoods like maple tree and oak tree as well as different crops and vegetation, characteristic for sylvosteppe region. Soils are of chernozem types. Time series satellite remote sensing MODIS Terra/Aqua and NOAA AVHRR data and climate data observations during a period of 12 years (2002–2013), each of which having different climatic regime. Have been used also Landsat ETM: 12/09/2004, 08/08/2012 and IKONOS 27/07/2005 and IKONOS 12/07/2009 images.

The investigations have been focused on estimating forest vegetation land cover dynamics using time series MODIS Terra/Aqua data. We used 16-day MODIS NDVI composites with a 250 m spatial resolution (MOD13Q1 collection 5) mainly for their capacity to detect climate impact on forest vegetation land cover changes. The MOD13Q1 images were acquired between 2000 and 2014 period and were used to derive NDVI temporal profiles. Missing values were replaced by linear interpolation considering neighboring values within the NDVI time series [19]. Also have been used MOD15A2 8-Day Composite products. In situ-monitoring spectroradiometrical additional data were used. Data have been digitally processed and classified with ENVI 4.7, ILWIS 3.1 and IDL 6.3 software. The images have been 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.

Figure 1.IKONOS 12/07/2009 image over test site Cernica forest area

RESULTS

Large scale vegetation distribution is largely controlled by climate. Many studies indicate global climate change occurs as a result of anthropogenic greenhouse gases (GHG). The global average temperature increased by $0.5^{o}C$ over the past century, and it is expected to continue increasing by an additional 1.4ºC to 5.8ºC by the end of 21st century (11) Romania also experienced a trend of climate variability with warming and flooding events. Climate change will result in changes in vegetation distributions, and then affect the environment of humans (12). It is important to assess possible responses of vegetation distribution to climate change. The common approaches in assessing vegetation distribution changes caused by climate change are bioclimatic classification schemes. The dynamic vegetation models integrated into vegetation succession processes and physiological responses to transient climate change are providing an opportunity to evaluate vegetation response to transient and long-term climate change. But these models require more data or physiological parameters, and are limited by knowledge on vegetation dynamics, responses of plants to elevated CO_2 and other physiological processes. Traditionally, forest vegetation changes monitoring by remotely sensed data has been carried out using vegetation indices, which are mainly derived from mathematical transformations of reflectance data in red (R) and near-infrared (NIR) channels. One of the most widely used indices is the well-known normalized difference vegetation index (NDVI) .Vegetation monitoring demands high temporal frequency information to follow the rapid vegetation phenological change. As indicated by GMES (Global Monitoring for Environment and Security , the guidelines needed in order to obtain the best information from remote sensing data for environmental purposes consider as the first step the identification of the forested areas that are most vulnerable to environmental stress and changes and the identification of time periods in which they occur.

Romanian 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. In order to forecast the trends or degrading forest vegetation risks, local forest unities must benefit of medium and long term assessment of changes. Classical methods coupled with new modern data processing and visualization techniques as well as integrating systems like as Geographic Information Systems offers new perspectives .Vegetation reflectance and image characteristics have been used for many years to determine ground cover, water status, yield, and other vegetation growth parameters.

Understanding interactions between vegetated surfaces and the atmosphere is critical for modeling and predicting the earth's climate on local, regional, and global scales. Some important hydrological variables, such as soil moisture, vegetation water content, and vegetation coverage, affect the depth of the planetary boundary layer, mesoscale circulation, and energy, carbon, and hydrological cycles. Consequently, they represent the response of the land surface to atmospheric water flux, solar radiation, temperature, and other atmospheric forcing. On the other hand, ecosystems affect both cloud formation, through the process of evapotranspiration, and cloud properties, by influencing aerosol and water vapor concentrations. Certainly, aerosols play an important role in perturbing the radiative balance through both direct and indirect interactions with solar radiation. Characterizing a regional climatology of aerosols and clouds and their relationships to forest cover is important to understanding the interaction of ecosystems and the atmosphere.

Figure 2 presents a land cover classification of the selected test area Cernica Branesti forest, based on MODIS/Terra time series data for 2000-2013 years MODIS Land Cover Classification (Collection 5 IGBP Type_1 2005), land cover region for user selected area 9 km Wide x 9 km High, Shannon Diversity Components: richness=7 , evenness=0.7884; 17 of 81 pixels [20.99%] belong to the same class as the center pixel "(4) Deciduous Broadleaf Forest".

Forest vegetation land cover change is a direct measure of quantitative increases or decreases of the dimension of extreme climate events and changes that determine environment quality. Spatio-temporal monitoring of forest vegetation land cover changes is a very important task for establishing the links between policy decisions, regulatory actions and subsequent land use activities. This study explored the use of time-series MODIS Terra/Aqua Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI), data to provide change detection information for Cernica- Branesti forest area, near Bucharest in Romania. The mean detection accuracy for period 2000- 2013 was assessed to be of 89%, with a reasonable balance between change commission errors (21.7%), change omission errors (28.5%), and Kappa coefficient of 0.69. Annual change detection rates across the investigated forest area over the study period (2000–2013) were estimated at 0.78% per annum in the range of 0.45% (2000) to 0.65% (2013).

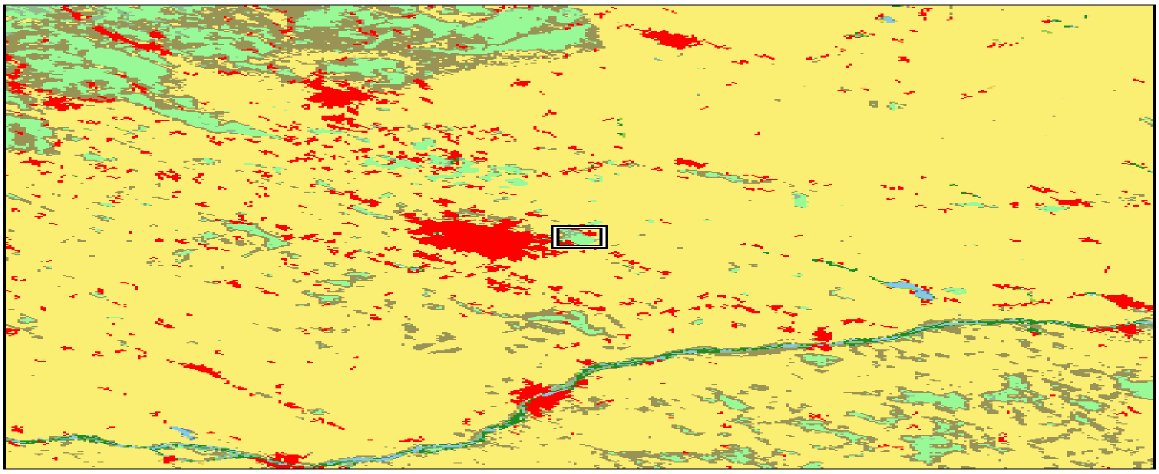

Figure 2. Land cover classification for Cernica Branesti forest, based on MODIS/Terra time series data for 2002-2013 period.

Figure 3 illustrates temporal variation of MODIS/Terra NDVI parameter from MOD13Q1/250m_16_days_NDVI for the same test area, Cernica Branesti forest.

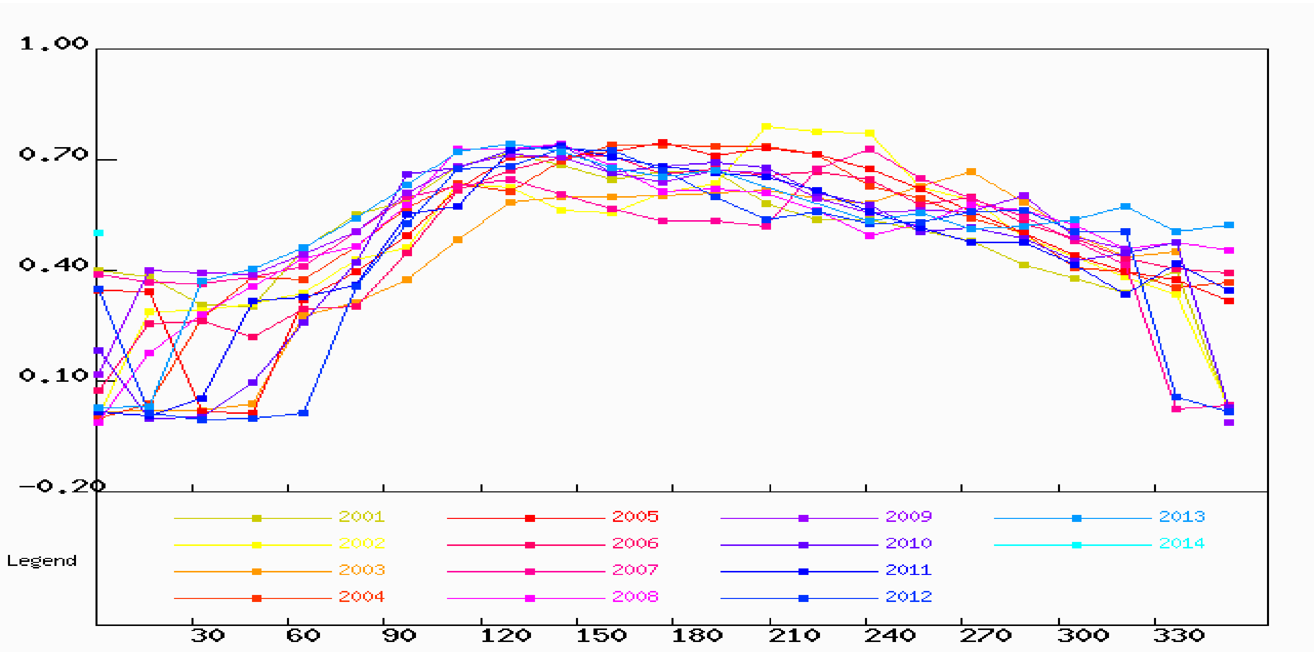

Figure 3. NDVI variation for Cernica Branesti forest area, based on MODIS/Terra time series data for 2002-2013 period

NDVI changes have been attributed to anthropogenic changes (deforestation) as well as to natural stressors like drought events. Based on 12 years analysis of MODIS Terra/Aqua data (2002–

2013) NDVI vegetation was severe stressed during years 2003, 2007, 2010 and 2012 when have been recorded serious heat waves and droughts during hot summer periods in South-Eastern part of Romania, where is placed our forest test area Cernica (as can be seen in Figure 4). The driest test regions prove to be the most sensitive to climate impact. The spatial and temporal patterns of the mean NDVI are the same, while they are partially different for the seasonal difference. Under stress conditions, it is evident that environmental factors such as soil type, parent material, and topography are not correlated with NDVI dynamics.

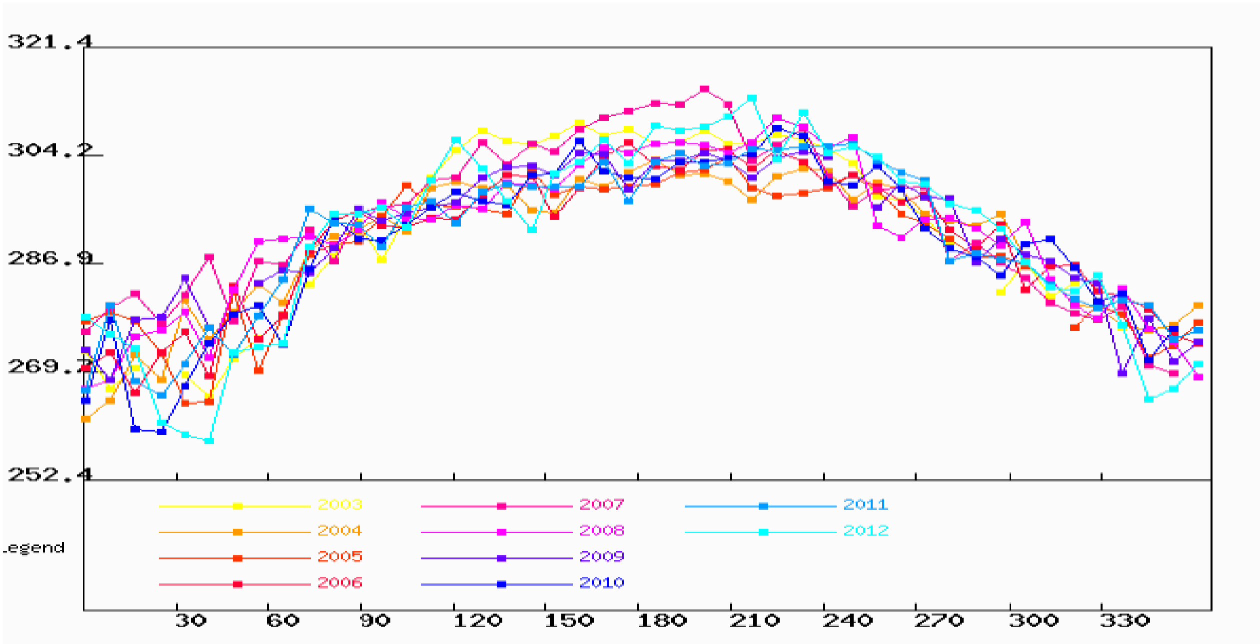

Figure 4. LST variation for Cernica Branesti forest area, based on MODIS/Terra time series data for 2002-2013 period

Figure 5 shows the temporal variation of NOAA/AVHRR mean NDVI parameter (with noise reduced) during 2002-2013 periods for Cernica Branesti forest. There is a good correlation between NDVI values recorded by MODIS Terra/Aqua and AVHRR/NOAA satellite data for Cernica Branesti forest. Figure 5 presents the temporal variation of MODIS/Terra LAI parameter during 2000-2013 periods for Cernica Branesti forest. As a result, phenology has recently emerged as an important topic with relevance to a wide array of climate and ecological research including regional and global carbon modeling, ecological assessment, and agroforest monitoring. Accurate information is essential for estimation of changes in surface energy balance and atmospheric greenhouse gas emissions as well as forest land cover dynamics in frame of global warming.
Seasonal solar radiation was changed dramatically throughout the year, having maximum values during summer months and minimum values during winter season. Albedo controls surface energy balance and affects the microclimate conditions of forest ecosystem.
Changes in albedo could induce significant changes in climate. Anthropogenic and natural factors, such as land cover and land use change, could result in the albedo change of land surfaces. In this study we used time series Moderate Imaging Spectroradiometer (MODIS) data and climate station observations to investigate the albedo patterns of test forest area Cernica and its changes due to the impact of anthropogenic and climate variations.

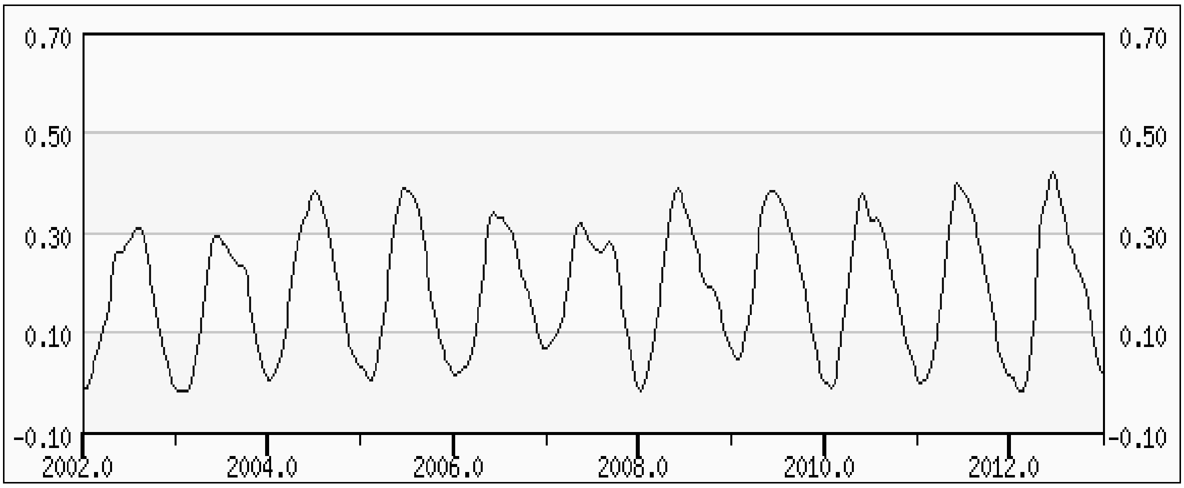

Figure 5. Temporal variation of NOAA/AVHRR means NDVI parameter during 2002-2013 periods for Cernica Branesti forest.

Time series MODIS Terra/Aqua data analysis suggest : (a) during the winter-to-summer and summer-to-winter transitional periods, air temperature plays an important role in determining the surface albedo by controlling snow absence and presence; (b) in the winter season, the amount of precipitation (snow) greatly affects the surface albedo of this ecosystem; (c) in the spring-summer-autumn seasons, ecosystem water conditions can significantly alter the surface albedo of the forest ecosystem through their impact on tree growth and ecosystem conditions. These results show that surface albedo changes of this temperate forest system highly respond to climate variations. The results of this study have a number of implications in weather forecasting, climate change, and forest ecosystem studies. Our results stress the importance of (a) accurately simulating snow coverage fractions in regions where snow cover tends to exist throughout a long winter season, and thus, has a large influence on surface albedo; (b) accurately simulating temperatures during seasonal transitional periods (winter–summer or summer–winter) since they determine the dates that snow covers the land surface and, in turn, strongly impact on simulations of surface albedo; (c) explicitly linking the impacts of climate change with variations on surface albedo, and the feedbacks of the albedo response to the physical climate system, in the climate model projections.

Surface albedo dynamics are closely related to ecosystem dynamics. Therefore, impacts of climate change and variations on forest ecosystem processes could possibly affect surface albedo characteristics. Since the physical climate system is very sensitive to surface albedo, forest ecosystems could significantly feedback to the projected climate scenarios through albedo changes. As such, impacts of climate change on surface albedo and ecosystem feedbacks have been recommended for further investigation. This is of particular significance for those ecosystems whose structure is highly responsive to climate change and variations. The phenological patterns, biomass production, and species composition of forest ecosystem, are strongly affected by the climatic conditions of the region, especially precipitation which is highly variable both inter-annually and intra-annually.

Specific aim of this paper was to assess, forecast, and mitigate the risks of climatic changes on forest systems and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the basis of spectral information derived from satellite data regarding atmospheric effects of forest biome degradation .

CONCLUSIONS

For investigated test area, considerable NDVI decline have been observed during heat wave and drought events of 2003, 2007 and 2012 years. Under water stress conditions, it is evident that environmental factors such as soil type, parent material, and topography are not correlated with NDVI dynamics. The joint analysis of in-situ and satellite remote sensing monitoring of forest vegetation biogeophysical parameters and the spatial patterns of NDVI derived from AVHRR/NOAA and MODIS Terra/Aqua satellites represents a successful tool for assessment of the functional response of vegetation to climate stress and for quantifying vegetation covers dynamics in periurban areas. In conclusion, our results show that, in normal and dry years, most periurban forest vegetation land covers are affected by drought conditions and heat waves periods. This finding has important implications for predicting long-term environmental impacts in the face of accelerating urbanization and future climate changes. As most climate models predict for next years a warmer and drier climate for this area, the difference between the urban and rural regions may become larger. To better prioritise adaptation strategies to a changing climate that are currently being developed, there is an urgent need for quantitative local and regional level assessment of forest systems that are systematic and comparable across multiple extreme climate hazards. Predicting future changes of Romanian forest vegetation in response to warming over the next century is important for understanding future ecosystem and economic services and for planning approaches to mitigate negative impacts of climate and anthropogenic changes. A first step in such prediction is identifying meteorological drivers of tree disturbances in current forests.

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