Analysis of forest vegetation- climate feedback Regimes through satellite remote sensing imagery

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Abstract. 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 CO_2 concentration. Vegetation impacts climate directly through moisture, energy, and momentum exchanges with the atmosphere and indirectly through biogeochemical processes that alter atmospheric CO2 concentration. Changes in forest vegetation land cover alter the surface albedo and radiation fluxes, leading to a local temperature change and eventually a vegetation response. This albedo (energy) feedback is particularly important when forests mask snow cover. Forest vegetation-climate feedback regimes are designated based on the temporal correlations between the vegetation and and the surface temperature and precipitation. The different feedback regimes are linked to the relative importance of vegetation and soil moisture in determining land surface–atmosphere interactions. The first-climate feedbacks are assessed in terms of the surface albedo and temperature and precipitation correlations. Observed vegetation feedbacks on temperature and precipitation are assessed based on MODIS Terra, and IKONOS satellite data across the forested area in North/Eastern part of Bucharest town, Branesti in Romania for 2001-2013 period. The computed feedback parameters can be used to evaluate vegetation–climate interactions simulated by models with dynamic vegetation. Specific aim of this paper is to assess the forest vegetation climate feedbacks on forest ecosystem and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the remote sensing spectral information basis.

Keywords. Forest vegetation, climate feedback regimes, satellite remote sensing data, Bucharest, Romania.

1. Introduction

Romania is a country with a great biodiversity and a high percentage of intact natural ecosystems, being one of the largest areas of natural forest in Europe.The forested area is a land area covered with forest vegetation characterized by an association of trees or shrubs reproduced in a natural or artificial manner, which form a specific ecosystem. There are also some “other land areas” which includes those zones used for forest culture and production, for forest management needs, lands destined to aforestation as well as unproductive lands existing in silvicultural enclosures.

At the end of 2013, forests make up approximately 6 380 000 ha of the Romanian landscape. Forests are dominated by beech and Norway spruce with an abundance of oak and other conifer species. 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.

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. Forest and trees are long-lived organisms exposed to an evolving environment. Demonstrated global environmental changes have already taken place and will continue with a degree of uncertainty. Predicting how

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forests will be affected, determining how their management can help them to adapt to this involving environment and how they can contribute to mitigate greenhouse effect are the main aims of the research the combination of new sensors, information technology and modeling techniques is paving the way for optimization of the forest –wood chain and for the design of decision support systems. 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) [1].Climate-induced changes at the land surface (e.g., through more intense and higher frequency droughts, flood events) may in turn feedback on the climate itself, for example, through changes in soil moisture, vegetation, radiative characteristics, and surface-atmosphere exchanges of water vapor. Therefore, it is of central importance to understand, model, and monitor climate feedback processes. Specific aim of this paper is to assess the forest vegetation climate feedbacks on a forest test site Branesti and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the remote sensing spectral information basis.

2. Biogeophysical information derived from satellite data

An accurate quantitative estimation of forest vegetation biochemical and canopy biophysical variables is of great importance for a wide range of ecological, agricultural, and meteorological applications. As they define the status of the forest vegetation, they are important inputs to models quantifying the exchange of energy and matter between the land surface and the atmosphere and knowledge of their spatio- temporal distribution is very useful for local, regional or global-scale applications related to vegetation monitoring, weather prediction, and climate change [2], [3].

Analysis of forest vegetation- climate feedback regimes requires increasingly biophysical and biochemical variables, such as Normalized Difference of the Vegetation Index (NDVI), fractional vegetation cover (fCover), leaf area index (LAI), and chlorophyll content, as well as land surface temperature (LST) and land surface albedo as inputs in dynamic global forest vegetation and climate models . These variables can be estimated and monitored using remotely sensed data.

2.1.Normalized Difference of the Vegetation Index (NDVI)

Typical visible and NIR vegetation reflectance, spectral features at 500 nm, 550 nm, 675 nm and the red edge (about 690 to 750 nm) are controlled by chlorophyll concentration, while reflectance at 970 nm is related to water concentration. Water concentration is often estimated in remote sensing by examining shortwave infrared reflectance of tree vegetation leaves. The bulk of plant water concentration research has focused around the water bands, spectral water absorption features centered at 970 nm, 1240 nm, 1400 nm, and 1900 nm. As plant water concentration decreases, these bands become less dominant, a feature that is identified with water stress. To improve forest cover condition is necessary a proper management based on scientific knowledge. Considerable efforts have been conducted to study the state and dynamics of forest cover by means of vegetation indices (VIs). Different Vegetation Indices (VIs) have been developed based on combinations of two or more spectral bands, assuming that multiband analysis would provide more information than a single one. Most VIs use 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 and can be collected by any field, airborne, or spaceborne spectrometer or radiometer that covers these spectral regions. Was established that these indices are correlated with various vegetation parameters such as green biomass, chlorophyll concentration, leaf area index, foliar loss and damage, photosynthetic activity, carbon fluxes and more. Also, are useful for

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different image analyses like crop classification, phenology, green coverage, and change detection [4].

The dominant method for interpreting vegetation biophysical properties from optical satellite data is through spectral vegetation indices. Spectral vegetation indices are combinations of reflectances measured in two or more spectral bands and used to retrieve various biophysical variables, most commonly leaf area index. They can be considered a very simplified type of reflectance models with some physically explanations behind them. These indices aim at canopy biophysical properties assessment through enhancing the spectral contribution of vegetation while minimizing the contribution of the underlying soil or understory vegetation.

The most common spectral vegetation index is Normalized Difference of the Vegetation index (NDVI), which is a non-linear transformation of the visible (red) and near-infrared bands of satellite information. NDVI is defined as the difference between the spectral reflectances in near-infrared (NIR) ρ_{NIR} and visible (red) ρ_R bands, over their sum. The NDVI is an alternative measure of vegetation amount and condition. It is associated with vegetation canopy characteristics such as biomass, leaf area index and percentage of vegetation cover.

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

(1)

The NDVI is representative of plant assimilation condition and of its photosynthetic apparatus capacity and biomass concentration. In particular vegetation index dynamics in time are correlated with the Canopy Leaf Index (LAI) and other functional variables. These variables are strongly conditioned by the behavior of precipitation, temperature and daily radiation of the observed area. Vegetation index therefore is representative of plants' photosynthetic efficiency, and it is time varying due to changes in meteorological and environmental parameters. The NDVI values range from -1 to +1 (pixel values 0-255). Seasonal and inter-annual variations can be derived form multi-temporal series of NDVI that can be associated with other ecological variables. Healthy vegetation will have a high NDVI value. Bare soil and rock reflect similar levels of near-infrared and red and so will have NDVI values near zero. Clouds, water, and snow are the opposite of vegetation in that they reflect more visible energy than infrared energy, and so they yield negative NDVI values.

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:

$$f_c = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$

(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 (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) [5]. The fractional cover computed using (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, its 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).

2.2. Leaf area index (LAI)

Leaf area index (LAI) is usually defined as the one-sided green leaf area per unit ground area in canopies [6]. Previous studies have suggested that LAI is one of the most important land-surface parameters for addressing the interaction between terrestrial ecosystem and climate [7]. This index has been widely used in physical and biological process studies associated with land-surface vegetation condition such as canopy conductance, photosynthesis, respiration, gross productivity, transpiration, and the canopy's energy absorption capacity in carbon and hydrology cycle and energy balance [8].

Leaf Area Index (LAI) is the leaf area per unit ground area. LAI is a factor that indicates how many leaf (or photosynthetically active) surfaces are in a column extended from, the ground area under the canopy diameter, up through the canopy. LAI can be estimated from the normalized difference of the vegetation index (NDVI), because NDVI represent the relative seasonal changes in vegetation rather than vegetation amount. There is a significant relationship between NDVI and LAI. Assuming that NDVI/LAI relationship is linear and the maximum NDVI value in a season correspond to the maximum LAI of vegetation cover, LAI can be inferred from NDVI as:

$$LAI_i = LAI_{max} * (NDVI_i – NDVI_{min}) / (NDVI_{max} – NDVI_{min}) \quad (3)$$

where max, min and 'i' are the maximum, minimum and period values observed, respectively. Maximum and Minimum NDVI values can be determined by multi-temporal NDVI observations from satellite data.

2.3. Land Surface Temperature (LST)

Environmental microclimate variables that are important for human thermal comfort include solar radiation, land surface temperature (LST), air temperature, and humidity and wind speed. Forest vegetation can ameliorate these environmental variables by preventing solar radiation from heating the surrounding buildings and surfaces, cooling the air by evapotranspiration, and reducing wind speed. An important inverse relationship between LST and NDVI has been well presented in the remote sensing literature for both urban and rural environments [7]. The basis of this relationship is that higher levels of latent heat exchange are more typical of areas characterized by significant vegetation cover as compared to areas with little or no vegetation cover and low surface moisture availability, such as densely developed urban areas, where sensible heat exchange is favored. Radiance values from the ETM+ thermal band were transformed to radiant surface temperature values using thermal calibration constants supplied by the following relation:

$$LST = \frac{K2}{\ln\left(\frac{K1}{L\lambda}+1\right)}$$

(4)

where LST is radiant surface temperature (K), K_1 = 666.09 is calibration constant 1, K_2 =1282.71 is calibration constant 2 and $L\lambda$ is spectral radiance of thermal band pixels, expressed by the following equation:

$$L\lambda = gainxDN + offset \quad (5)$$

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where Digital Numbers (DNs) in each band of the Level 1G ETM+ imagery used were converted to physical measurements of at sensor radiance (LE) using a formula that accounts for the transformation function used to convert the analog signal received at the sensor to DNs stored in the resulting image pixels, gain = slope of the radiance/DN conversion function, DN= digital number of a given pixel, and offset = intercept of the radiance/DN conversion function [8]. Gain and offset values are supplied in metadata accompanying each ETM+ image, and the DN to radiance formula.

2.4.Land surface albedo

Land surface albedo is an important parameter in describing the radiative properties of the earth's surface. 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.

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 μ m) 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. This allows more accurate estimation of climate models.

In the IPCC third assessment report [3], 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.

In the physical climate system, albedo determines the radiation balance of the surface and affects the surface temperature and boundary-layer structure of the atmosphere. In forest systems, albedo controls the microclimate conditions of tree and forest vegetation and their radiation absorption, which, in turn, affects ecosystem physical, physiological, and biogeochemical processes such as energy balance, evapotranspiration, photosynthesis, and respiration. It has long been recognized that accurate surface albedo information is important for weather forecasting, climate projection and ecosystem modeling [9].

Surface albedo dynamics are closely related to forest ecosystem dynamics. Therefore, impacts of climate change and variations on forest ecosystem processes could possibly affect surface albedo characteristics [10]. Since the physical climate system is very sensitive to surface albedo, forest ecosystems could significantly feedback to the projected climate scenarios through albedo changes. Such impacts of climate change on surface albedo and ecosystem feedbacks have been recommended for further investigation[11]. This is of particular significance for those ecosystems whose structure is highly responsive to climate change and variations.

3.Study test site and data used

Forest test area, Branesti is placed in the North -Eastern part of metropolitan area 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 data and climate data observations during a period of 13 years (2001–2013), each of which having different climatic regime. Have been used also Landsat TM: 18/08/1984, 20/08/1989, and Landsat ETM: 12/09/2004, 08/08/2012 and IKONOS 27/07/2005 and IKONOS 12/07/2009 images. Data have been digitally processed and classified with ENVI 4.7, ILWIS 3.1 and IDL 6.3 software. Furthermore, we used the long-term time series of temperature, precipitation, and soil moisture to investigate the correlations with NDVI and LAI from 2001 to 2013.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.Study test site Branesti forest area, North-East of Bucharest

4. 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 1.4^{o}C to 5.8^{o}C by the end of 21st century [3]. 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. 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

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that are most vulnerable to environmental stress and changes and the identification of time periods in which they occur.

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 [12]. 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. 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 [13], [14].

Figure 2 presents a NDVI change map on test forest area based on IKONOS 27/07/2005 and 12/07/2009 images. NDVI changes (dark green areas) have been attributed to anthropogenic changes (deforestation) as well as to natural stressors like drought events in 2007 and 2009 events.

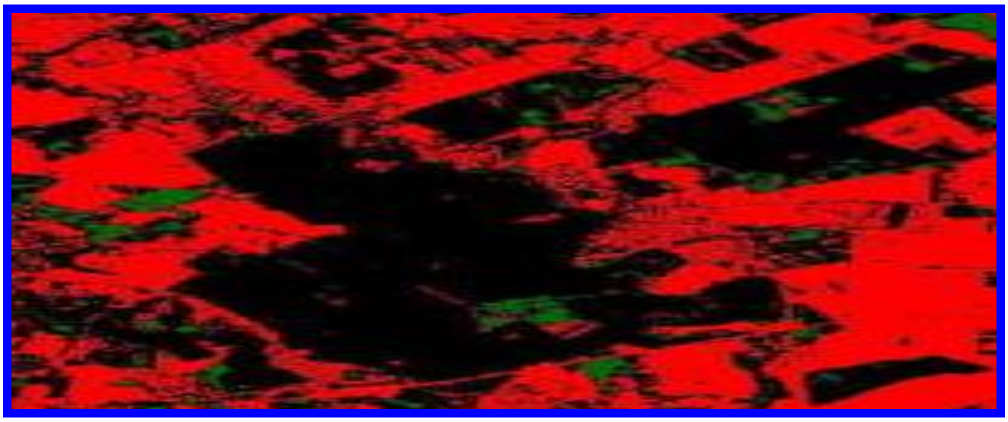

Figure 2. NDVI change map on Branesti forest between 2005-2009 from IKONOS 27/07/2005 and 12/07/2009 images.

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.

Based on 11 years time- series of MODIS data (2001–2013) another interesting analysis was done. Years 2003 and 2007 have been affected by serious heat wave during summer periods in South-Eastern part of Romania, where is placed our forest test area Branesti. Table 1 shows the air temperature as average high and average low per month for 2001–2013 in the investigated forest area Branesti. 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 Branesti and its changes due to the impact of anthropogenic and climate variations as well as due to forest- climate feedbacks.

Time series MODIS 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.

Table 1. Mean air Temperature and Precipitation and VIS and NIR albedo for 2001-2013 periods in Branesti forest area.

Month	Average high T (^{o}C)	Average low T (^{o}C)	Average Precipitation (cm)	Mean solar Irradiance on horizontal Surface W/m^2)	VIS Average Broad-band Albedo from MODIS data	NIR Average Broad-band Albedo from MODIS data
January	2.0	-6.1	4.0	211	0.23	0.26
February	4.8	-3.6	4.0	346	0.69	0.53
March	11.9	0.5	4.0	466	0.51	0.40
April	18.4	6.8	5.0	578	0.08	0.24
May	23.7	11.3	7.0	727	0.08	0.23
June	27.9	14.5	8.0	759	0.08	0.24
July	29.7	16.6	6.0	827	0.07	0.25
August	30.0	15.7	6.0	799	0,10	0.27
September	25.6	11.9	4.0	678	0.08	0.23
October	18.7	6.7	3.0	440	0.25	0.31
November	10.8	2.4	5.0	307	0.12	0.22
December	4.6	-3.9	4.0	180	0.12	0.23

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.

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.

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 hy-

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drological 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.

Forest vegetation is governed above all by climate through precipitation, temperature, light, and CO_2. It can also feed back on climate, both directly on the energy budget through surface albedo and exchanges of heat, water, and momentum and indirectly on the biogeochemical process through its effect on the atmospheric CO_2.

At monthly-to-interannual time scales, leaf phenology plays an important role in vegetation–climate interaction. The seasonal development of forest tree leaves and grasses are affected by temperature and precipitation variability, and can in turn alter surface energy and hydrological budgets to impact the climate.

We used FPAR parameter as a proxy for forest vegetation greenness (value ranging from 0 to 1). FPAR represents the fraction of photosynthetically active radiation absorbed by the green leaves and brown leaves and is linked closely to the maximum photosynthetic capacity of forest vegetation. FPAR is proportional to the normalized difference vegetation index (NDVI) and leaf area index (LAI), all reflecting the intensity of vegetation activity. In general, greening vegetation during the growing season tends to increase FPAR, and vice versa. Was observed that forest vegetation feedback on air temperature is dominantly positive, but the feedback on precipitation has no dominant sign. We mainly examined monthly-to-interannual variability by examining the cross correlation/cross covariance between FPAR and climate variables during 2001–2013 (Figure 3).

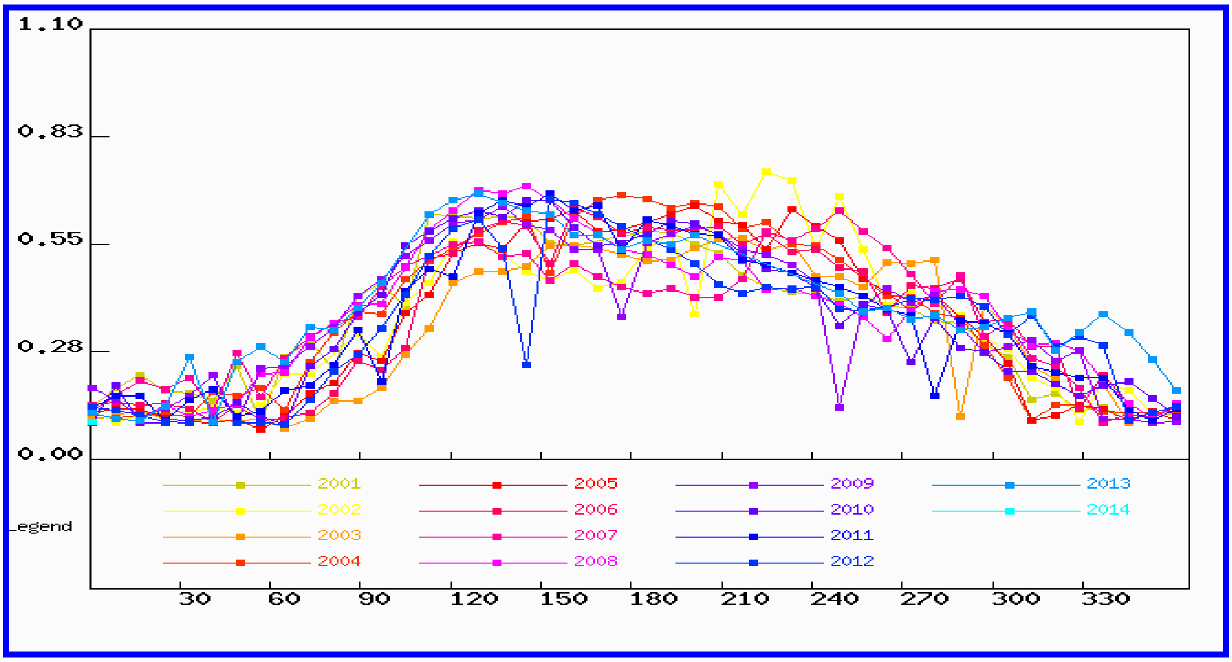

Figure 3. FPAR yearly variation during 2001-2013 based on MODIS Terra for Branesti forested area

5. Conclusions

Specific aim of this paper was to assess based on MODIS Terra time series satellite data the forest vegetation –climate feedbacks on forest ecosystem Branesti and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the remote sensing spectral

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information basis. A preliminary analysis seems to suggest an enhanced intensity of the vegetation feedback, especially on surface temperature and lower on precipitation, at longer time scales and over a larger forest grid box area. 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. 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. Austere aims at a better understanding of the system as a whole by identifying relevant processes, quantifying the associated parameters and developing numerical models to identify adverse trends in forest functioning, of soil and air quality. As climatic change is becoming a worldwide concern that will affect in the future drastically changes of forest ecosystems, freshwater, and other, leading to more floods or droughts in different regions is necessary to address well in advance such events in order to reduce the associated risks.

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