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Application of Satellite Imagenary in Forestry for Georgia

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ABSTRACT

The one of Earth Observing System (EOS) program component is the investigation of influence of Earth vegetation on large-scale global processes. The most applicable product from satellite observation is Normalized Difference Vegetation Index that is used in observation on vegetation. The Normalized Difference Vegetation Index (NDVI) is an index of plant "greenness" or photosynthetic activity, and is one of the most commonly used vegetation indices. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light.Vegetation indexies are important ecosystem variables widely used in variety of bio-geophysical applications. The Vegetation Health Product (VHP) consists of gridded weekly global vegetation indices (VCI, TCI and VHI) derived from AVHRR GAC orbital data for the global area. The Green Vegetation Fraction (GVF) system was developed to generate GVF as a NOAA-Unique Product (NUP) from data from the Visible Infrared Imager Radiometer Suite (VIIRS) sensor onboard Suomi National Polar-orbiting Partnership (SNPP) satellite, for applications in numerical weather and seasonal climate prediction models. GVF will be produced as a daily rolling weekly composite at 4-km resolution (global scale) and 1-km resolution (regional scale). Satellite data are used to determine values of above listed indices for Georgian territory.

***Key words*: **Satellite data, vegetation index, derived indices, prediction model

Introduction

Satellite observation of the Earth is one of most important components of the general monitoring of different processes, which take place in the environment. In Georgia, in particular, with the use of data of satellite observations, studies according to questions of early warning of the dangerous hydrometeorological phenomena [1,2], estimation of the changeability of snow cover and glaciers [3-6], determination of distribution above the territory of Georgia of aerosols and ozone content [7-10] are carried out . The studies of the plant cover of the territory of Georgia are begun. Thus, in work [11] the MODIS Surface reflectance Daily L2G Global 250m, 500 and 1 km data were used for analysis of vegetation cover of Georgia. NDVI and EVI daily values were calculated on the basis for 2008-2016 period. Mean decadal and monthly maps of NDVI and EVI were compiled with an object of future analysis of vegetation change dynamics. This work is the continuation of the initiated studies.

The Normalized Difference Vegetation Index (NDVI) is an index of plant "greenness" or photosynthetic activity, and is one of the most commonly used vegetation indices. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light. Likewise, non-vegetated surfaces have a much more even reflectance across the light spectrum. When sunlight strikes objects, certain wavelengths of this spectrum are absorbed and other wavelengths are reflected. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has, the more these wavelengths of light are affected respectively. NDVI is calculated on a per-pixel basis as the normalized difference between the red and near infrared bands from an image:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

where NIR is the near infrared band value for a cell and RED is the red band value for the cell. NDVI can be calculated for any image that has a red and a near infrared band. The biophysical interpretation of NDVI is the fraction of absorbed photosynthetically active radiation

NDVI has seen widespread use in rangeland ecosystems. The uses include assessing or monitoring:

- Vegetation dynamics or plant phenological changes over time;
- Biomass production;
- Grazing impacts or attributes related to grazing management (e.g., stocking rates);
- Changes in rangeland condition;
- Vegetation or land cover classification;
- Soil moisture;
- Carbon sequestration or CO_2 flux;

NDVI is a good indicator of the relative healthiness of the plant. By noting the color of the chlorophyll, it usually tells how well the plant is doing and if the plant is under stress. Still, the plants must be of the same type and maturity (as different plants will have different NDVI signatures), and most NDVI images are only good to show you where the stress might be occurring, not what is causing (or caused) it. This is where ground thru thing and common knowledge about the field and environmental conditions comes in. Unless you really know the field, and other stressing factors in the area for that particular area and year, you are going to have to make a trip to field to determine what caused the stress. Even then, you might not be able to figure it out. Effects on healthiness of the plant can be caused by many factors including soil textural differences, rainfall amounts, runoff problems, land leveling (leaving the B or C horizon exposed), thin plant populations, topography (which causes differences in soil texture, water availability, organic matter, etc.), nitrate availability, micronutrients, insect damage, and diseases. About any feature that affects plant growth can be the problem. This is where you have to apply some common sense knowledge about the crop, location, history of the field, and current environmental conditions for that year. Some problems occur naturally in the field (such as soil textural differences), and some are seasonal (such as heavy or light rains).

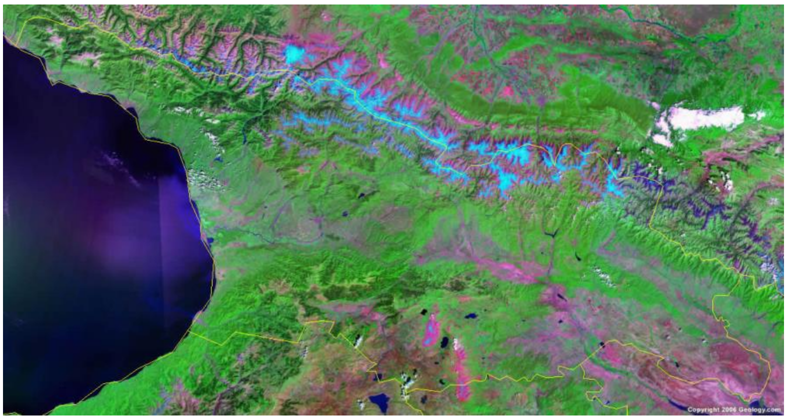
Methods and data

Vegetation Indices (VI) are important ecosystem variables used in a variety of biophysical applications. VIs are optical remote sensing data-derived measures of vegetation greenness (a proxy for vegetation health, vigor and dynamics). Although not a directly measured intrinsic physical quantity (as an LAI, fPAR, etc.), a VI is a ratio derived from the red and near-infrared channels' spectral reflectance, and strongly captures a number of canopy properties and biophysical processes. One of the primary interests of the Earth Observing System (EOS) program is to study the role of terrestrial vegetation in large-scale global processes with the goal of understanding how the Earth functions as a system. This requires an understanding of the global distribution of vegetation types as well as their biophysical and structural properties and spatial/temporal variations [12, 13]. Vegetation Indices (VI) are robust, empirical measures of vegetation activity at the land surface. They are designed to enhance the vegetation signal from measured spectral responses by combining two (or more) different wavebands, often in the red and NIR wavelengths. The MODIS vegetation index (VI) products will provide consistent, spatial and temporal comparisons of global vegetation conditions which will be used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of phenologic, change detection, and biophysical interpretations. Gridded vegetation index maps depicting spatial and temporal variations in vegetation activity are derived at 16-day and monthly intervals for precise seasonal and interannual monitoring of the Earth's vegetation. Two vegetation index (VI) algorithms are to be produced globally for land, at launch. One is the standard normalized difference vegetation index (NDVI), which is referred to as the "continuity index" to the existing NOAA-AVHRR derived NDVI. At the time of launch, there will be nearly a 20-year NDVI global data set (1981 - 1999) from the NOAA- AVHRR series, which could be extended by MODIS data to provide a long term data record for use in operational monitoring studies. The other is an 'enhanced' vegetation index (EVI) with improved sensitivity into high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The two VIs complement each other in global vegetation studies and improve upon the extraction of canopy biophysical parameters. A new compositing scheme that reduces angular, sun-target-sensor variations is also utilized. The gridded vegetation index maps use MODIS surface reflectance, corrected for molecular scattering, ozone absorption, and aerosols, and adjusted to nadir with use of a BRDF model, as input to the VI equations. The gridded vegetation indices will include quality assurance (QA) flags with statistical data that indicate the quality of the VI product and input data.

Reflected red energy decreases with plant development due to chlorophyll absorption within actively photosynthetic leaves. Reflected NIR energy, on the other hand, will increase with plant development through scattering processes (reflection and transmission) in healthy, turgid leaves. Unfortunately, because the amount of red and NIR radiation reflected from a plant canopy and reaching a satellite sensor varies with solar irradiance, atmospheric conditions, canopy background, and canopy structure/ and composition, one cannot use a simple measure of reflected energy to quantify plant biophysical parameters nor monitor vegetation on a global, operational basis. This is made difficult due to the intricate radiant transfer processes at both the leaf level (cell constituents, leaf morphology) and canopy level (leaf elements, orientation, non photosynthetic vegetation (NPV), and background). This problem has been circumvented somewhat by combining two or more bands into an equation or 'vegetation index' (VI). By rationing the difference between the NIR and red bands by their sum;

Currently, a partial atmospheric correction for Rayleigh scattering and ozone absorption is used operationally for the generation of the Advanced Very High Resolution Radiometer; (AVHRR) Pathfinder and the IGBP Global 1km NDVI data sets. As a vegetation monitoring tool, the NDVI is utilized to construct seasonal, temporal profiles of vegetation activity enabling interannual comparisons of these profiles. The temporal profile of the NDVI has been shown to depict seasonal and phonologic activity, length of the growing season, peak greenness, onset of greenness, and leaf turn over or 'dry-down' period. The construction of seasonal, temporal profiles requires a separate 'compositing' algorithm in which several VI images, over a given time interval (7, 10 days) are merged to create a single cloud-free image VI map with minimal atmospheric and sun-surface-sensor angular effects (Holben, 1986). Moderate and coarse resolution satellite systems, such as MODIS, the AVHRR, SPOT4-VEGETATION SeaWiFS (Sea-Viewing Wide Field-of-View Sensor and GLI (Global Imager) acquire global bi-directional radiance data of the Earth's surface under a wide variety of solar illumination angles, sensor view angles, atmospheres, and cloud conditions. The global operational use of a vegetation index requires that it not only be calculated in a uniform manner, but that the results be comparable over time and location. The limitations of VI optimization techniques can result from various external influences including: Calibration and instrument characteristics; Clouds and cloud shadows; Atmospheric effects due to variable aerosols, water vapor, and residual clouds; Sun-target-sensor geometric configurations and the resulting interactions of surface and atmospheric anisotropies on the angular dependent signal. In addition to these external influences, there are influences inherent to vegetated canopies which restrict the use and/or interpretation of vegetation indices. These include: Canopy background contamination in which the background reflected signal intimately mixes with the vegetation signal and influences the resulting VI value [14].

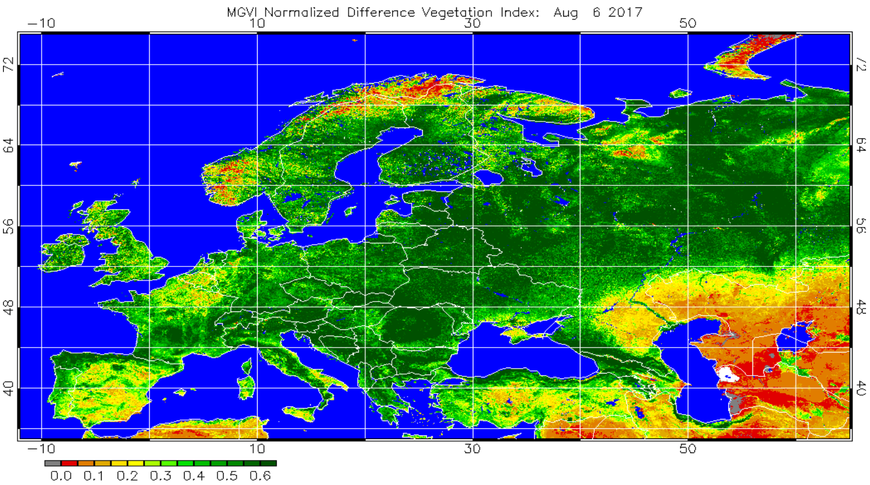
Canopy background signals vary with soils, litter covers, snow, and surface wetness. Saturation problems whereby VI values remain invariant to changes in the amount, type, and condition of vegetation, normally associated with a saturated chlorophyll signal in densely vegetated canopies.



Pic.1. Satellite image of NDVI for Georgia TERRA-MODIS NASA 2014, May

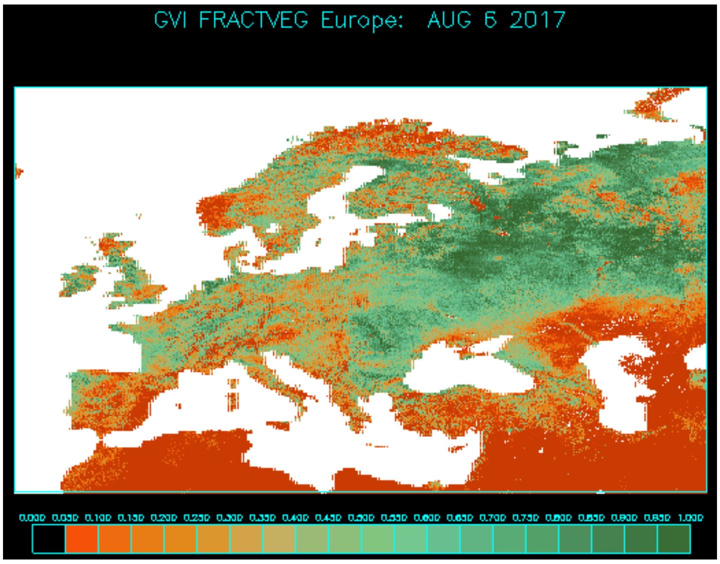
The atmosphere degrades the NDVI value by reducing the contrast between the red and NIR reflected signals. The red signal normally increases as a result of scattered, upwelling path radiance contributions from the atmosphere, while the NIR signal tends to decrease as a result of atmospheric attenuation associated with scattering and water vapor absorption. The net result is a drop in the NDVI signal and an underestimation of the amount of vegetation at the surface. The degradation in NDVI signal is dependent on the aerosol content of the atmosphere, with the turbid atmospheres resulting in the lowest NDVI signals (Pic.1). The impact of atmospheric effects on NDVI values is most serious with aerosol scattering (0.04 - 0.20 unit decreases), followed by water vapor (0.04 - 0.08), and Rayleigh scattering (0.02 - 0.04). The atmosphere problem may be corrected through direct and indirect means. Atmospheric effects on the MODIS VI's will become minimal as a result of the atmospheric correction algorithms being implemented (MODIS-09) prior to VI computation [15]. However, some residual aerosol contamination will be expected in the NDVI product, due to the coarse resolution of the aerosol product (~20 km resolution) compared to the 250m NDVI product. Thus, spatial variations in smoke, gaseous and particulate pollutants, and light cirrus clouds, may be present at the finer spatial resolutions. The accuracy of atmospheric correction will also vary with the availability of 'dark-objects', which are needed for the best corrections (Pic. 2).

The Green Vegetation Fraction (GVF) is the primary product of the Global Vegetation Process System (GVPS), which is important for land surface heat fluxes calculation in coupled land-atmospheric models. In this system, GVF is derived weekly using ACDF adjusted smoothed NDVI, which is based on the 6 selected year's smoothed NDVI. For Georgian territory it varies from 0.1 to 0.3



Pic. 2. NDVI . 6 August, 2017 [16]

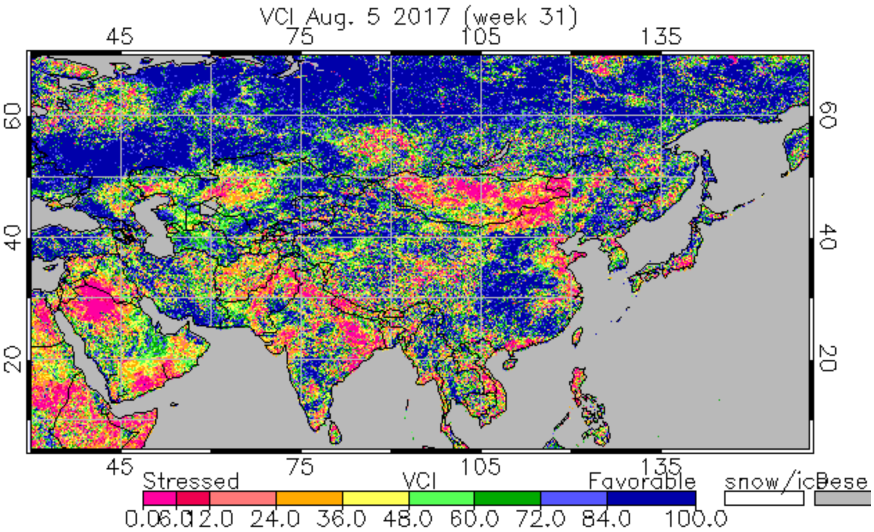
Fractional vegetation is essentially NDVI displayed as a fraction (or a percentage if the fractional vegetation values are multiplied by 100%). NDVI values less than or equal to .07 are set to 0.0 and NDVI values greater or equal to .57 are set to 1.0 (NDVI values between .07 and .57 increase linearly from 0.0 to 1.0 as fractional vegetation) (Pic.3).



Pic.3. Fraction vegetation August 6, 2017 [16]

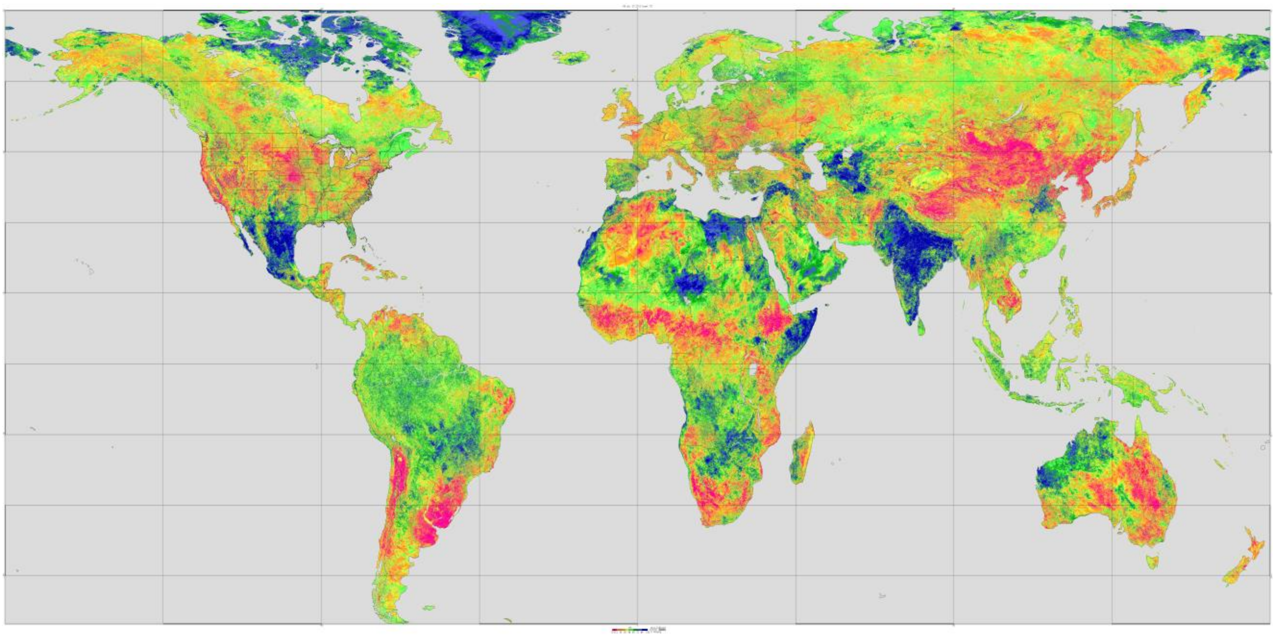
The Green Vegetation Fraction (GVF) is the primary product of the Global Vegetation Process System (GVPS), which is important for land surface heat fluxes calculation in coupled land-atmospheric models.

In this system, GVF is derived weekly using ACDF adjusted smoothed NDVI, which is based on the 6 selected year's smoothed NDVI. The Vegetation Health Product (VHP) consists of gridded weekly global vegetation indices (VCI, TCI and VHI) derived from AVHRR GAC orbital data for the global area between latitude 55°S to 75°N. The projection of VHP is Plate Carree (also called geographic projection or equal latitude-longitude interval grid). The interval of grid is 0.036° (about 4km at equator). Noise is minimized by applying the time series smoothing technique and other correction algorithms (Pic. 4). It is effective enough to be used as proxy data for monitoring vegetation health, drought, moisture, thermal condition, etc.



Pic. 4. Vegetation health index. August 5, 2017 [16]

The VIIRS Vegetation Health Product (VVHP) VIIRS-VH product is gridded weekly global vegetation indices (Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI).) derived from VIIRS Scientific Data Records (SDR) for the global area between latitude 55°S to 75°N (Pic. 5).



Pic. 5. VIIRS Vegetation Health Product (VVHP). August 2017 [16]

The projection of VHP product is Plate Carree projection (geographic projection, a grid with equal latitude-longitude interval). The interval of grid is 0.036 degree (about 4km at equator). Noise is minimized by applying the time series smoothing technique and other correction algorithms.

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თანამგზავრული გამოსახულებების გამოყენება მეტყევეობაში საქართველოში

მ. ტატიშვილი, ი. მკურნალიძე, ი. სამხარაძე, ლ. ჩინჩალაძე

რეზიუმე

დედამიწის სადამკვირვებლო სისტემა (EOS) პროგრამის კომპონენტია დედამიწის მცენარეული საფარის გავლენის გამოკვლევა ფართომასშტაბიან გლობალურ პროცესებზე. თანამგზავრული დაკვირვების ყველაზე გავრცელებული პროდუქტი ვეგეტაციური ინდექსის ნორმალიზებულ სხვაობაა, რომელიც გამოიყენება მცენარეების მწვანე საფარის დაკვირვებაში. ვეგეტაციური ინდექსის ნორმალიზებული სხვაობა (NDVI) არის მცენარეთა "მწვანეობის" ანუ ფოტოსინთეზური აქტივობის მაჩვენებელი და ერთ-ერთი ყველაზე გავრცელებული მცენარეული მაჩვენებელია. მცენარეული ინდექსები ეფუძნება იმ ფაქტს, რომ სხვადასხვა ზედაპირები სხვადასხვა სახის სინათლეს განსხვავებულად აირეკლავს. ფოტოინთეზურად აქტიური მცენარეულობა, შთანთქავს მასზე დაცემულ უმეტეს წითელ სინათლეს, ხოლო ახლო ინფრაწითელი სინათლის აირეკლავს. მცენარეულობა, რომელიც მკვდარია ან დაზიანებული

უფრო აირეკლავს წითელ სინათლეს ვიდრე ახლო ინფრაწითელ სინათლეს. ვეგეტაციური ინდექსები მნიშვნელოვანი ეკოსისტემური ცვლადებია, რომლებიც ფართოდ გამოიყენება მრავალ ბიო-გეოფიზიკურ ამოცანებში. მცენარეული ჯანმრთელობის პროდუქტი (VHP) შედგება გლობალური არეალისთვის განკუთვნილ ყოველკვირეული ბადური მცენარეული ინდექსებისგან (VCI, TCI და VHI) წარმოებულს AVHRR GAC ორბიტალური მონაცემებით. მწვანე მცენარეული ფრაქციის (GVF) სისტემა შემუშავდა GVF- ის გენერირებისთვის, როგორც NOAA- ის უნიკალური პროდუქტის (NUP) იმ მონაცემებისგან, რომელსაც Visible Infrared Imager Radiometer Suite (VIIRS) სენსორი იძლევა, სუომის ნაციონალური პოლარული ორბიტალური პარტნიორობის (SNPP) სატელიტიდან, გამიზნულს ამინდის და სეზონური კლიმატის რიცხვით პროგნოზირების მოდელებში გამოსაყენებლად. GVF ყოველდღიურად იწარმოება ყოველდღიური 4-კილომეტრიანი რეზოლუციის (გლობალური მასშტაბით) და 1 კმ-ს რეზოლუციის (რეგიონული მასშტაბით) მონაცემებისგან. თანამგზავრული მონაცემები გამოყენებულია ზემოთ ჩამოთვლილი ინდექსების მნიშვნელობების დასადგენად საქართველოს ტერიტორიაზე.

Применение спутникового изображения в лесном хозяйстве для Грузии

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Резюме

Одним из компонентов программы системы наблюдения Земли (EOS) является исследование влияния растительности Земли на крупномасштабные глобальные процессы. Наиболее применимым продуктом из спутниковых наблюдений является нормализованный разностный индекс вегетации, который используется при наблюдении за растительностью. Нормализованный разностный индекс вегетации (NDVI) является показателем растительной «зелени» или фотосинтетической активности и является одним из наиболее часто используемых индексов растительности. Индексы вегетации основаны на наблюдении, что разные поверхности отражают разные типы света по-разному. Фотосинтетически активная растительность, в частности, поглощает большую часть красного света, который поражает его, отражая большую часть ближнего инфракрасного света. Растительность, которая является мертвой или поврежденной, отражает больше красного света и меньше инфракрасного света. Индексы вегетации являются важными экосистемными переменными, широко используемыми в различных био-геофизических приложениях. Продукт растительного здоровья (VHP) состоит из недельных глобальных индексов растительности с привязкой к сетке (VCI, TCI и VHI), полученных из орбитальных данных AVHRR GAC для глобальной области. Система Green Vegetation Fraction (GVF) была разработана для генерации GVF как NOAA-уникального продукта (NUP) по данным датчика видимого инфракрасного датчика рентгеновского излучения (VIIRS) на спутнике Suomi (SNPP) для приложений в численных моделей погоды и сезонных климатических прогнозов. GVF производиться как ежедневная сводная композиция с разрешением 4 км (глобальный масштаб) и 1-километровое разрешение (региональная шкала). Спутниковые данные используются для определения значений вышеперечисленных индексов для территории Грузии.