NEA-Forest Web Service

User Guide

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1. TOOLS

1.1 Overview of monitoring tools

The NEA-Forest web-based monitoring tool aims to provide updated information on the growth status of boreal and temperate forest in the region of Northeastern Asia. Functioning as world's "lungs", the growth and biomass variation of these forests play an important role in the regulation of carbon balance. To observe overall trends on forest growth, the monitoring tools make use of low spatial resolution remote sensing products generated every 10 days. The monitoring tools include also a statistical module allowing analysis of the vegetation growth trends. These analyses are performed by comparing the biomass synthesis rate with the historical average or with a reference year.

The monitoring tools update two categories of information, describing the forest biomass production and forest growth anomalies principally caused by the forest fires.

The biomass conversion by trees can be assimilated by bio-physical variables derived from earth observation, such as the *fraction of Absorbed Photosynthetically Active Radiation* (*fAPAR*) and the related Net Primary Productivity (NPP). The first variable (fAPAR) describes the portion of certain specific gamma of radiation absorbed by plants. Actually, the photo-synthetically active radiation (PAR) is the radiation with the spectral range from 400-700nm that is used by plants in photosynthesis. fAPAR is commonly used in ecosystem models because it has an important influence on exchanges of energy, water vapour and carbon dioxide between the surface of the earth and the atmosphere. Precipitation and temperature are two of the major factors that determine the proportion of PAR absorbed by plants. It is an important parameter in measuring biomass production because vegetation development is related to the rate at which radiant energy is absorbed by vegetation. fAPAR can be measured on the ground with handheld instruments or inferred from satellite imagery over large spatial scales.

The second variable (NPP) is defined as the net flux of carbon from the atmosphere into green plants per unit time. NPP refers to a rate process, i.e., the amount of vegetable matter produced (or Net Primary Production) per day or year. The NPP can be computed based on fAPAR, the incoming radiation and mean air temperature.

The forest anomalies caused by forest fires are described here by the Burnt Area Estimates (BAE).

Three categories of tools are established to monitor the evolution or trend of forest growth. The Image , Graph and Table Viewers.

The Image Viewers allows the direct visualization of the two above mentioned vegetation indices in form of geo-referenced maps. Both the current values and the difference values against the reference years of two principal vegetation indices (fAPAR and NPP) can be displayed. The web mapping engine incorporated in this web tool allows also a visualization by zooming or zoning (according to the administrative borders).

The Image Viewer enables also displaying of other ancillary variables or intermediary products related directly or indirectly to the computation of the NPP. The variables include

- Mean solar radiation
- Mean Temperature
- Mean precipitation
- Mean snow depth

The Graphic Viewer displays the evolution of a biophysical variable, contributed by a certain land-cover class (for example "closed broadleaved deciduous forest") within certain geographic area.

The Table Viewer provides a summary picture of a variable such as NPP for a certain year in certain region. The Table Viewer shows also the comparison of this variable with the reference years (for example the year 2000 and the historical year). Moreover, the NPP value in this example can be “un-mixed”, providing the details of contribution by each of the related land-cover classes.

1.2 Image Viewer

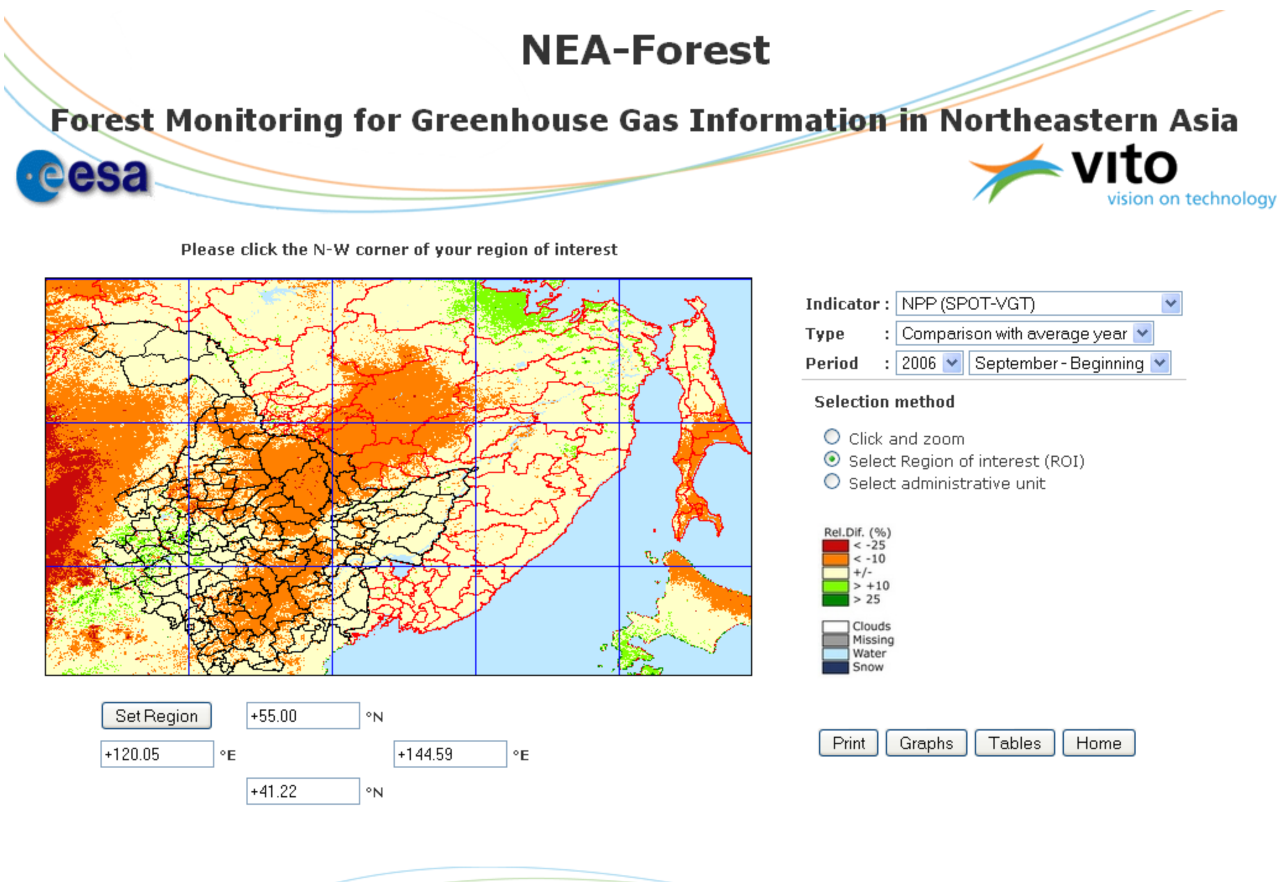
The Image Viewer allows you to visualize images representing the status of the vegetation in different locations of the Northeastern Asia at different periods in time, and at different geographical scales.

An example on the use of the Image Viewer is demonstrated below.

A) Select image of interest

The options for a view session have first to be made. These options include the types of the bio-physical variables or ancillary parameters to be viewed under the selection 'vegetation bio-physical variables'. The second option 'display type' allows to select the difference operators. Two difference operators, against the reference year 2000 and against the historical mean, are available.

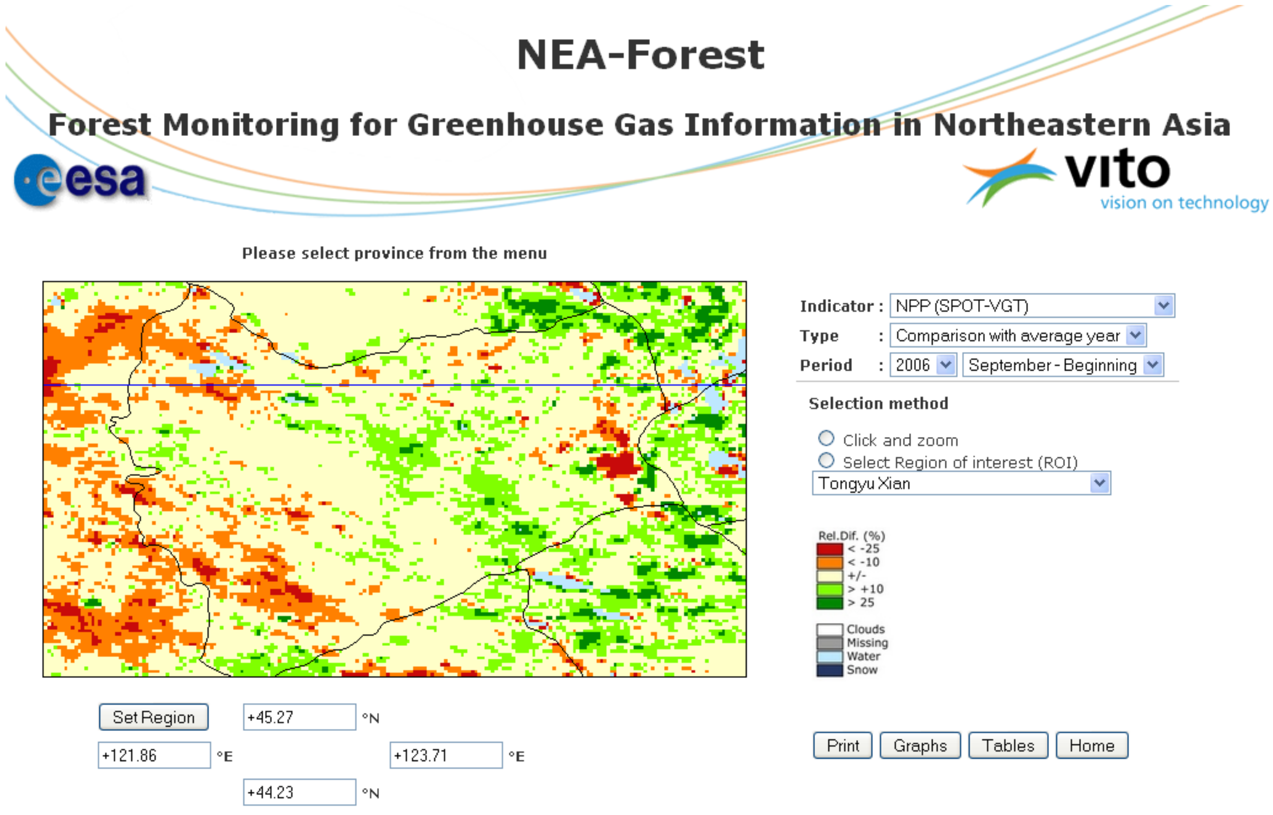
The third option is related to the period of which you would like to view the corresponding image. Once the all options are made, the image corresponding to whole study area will be displayed. A print option is also available. A legend is also provided for a quantified explanation.



Selection of map rendering options and period in time

B) Options of zooming or zoning

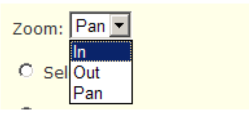
There are various possibilities to explore the images. You can manually zoom to a certain image with the 'click and zoom' function, or zoom by entering the coordinates of a region of interest with 'select ROI'. You can also directly zone by selecting an administrative unit. The coordinates of the current selection appear under the 'ROI coordinates'.



Zooming and zoning of an image

Click and zoom

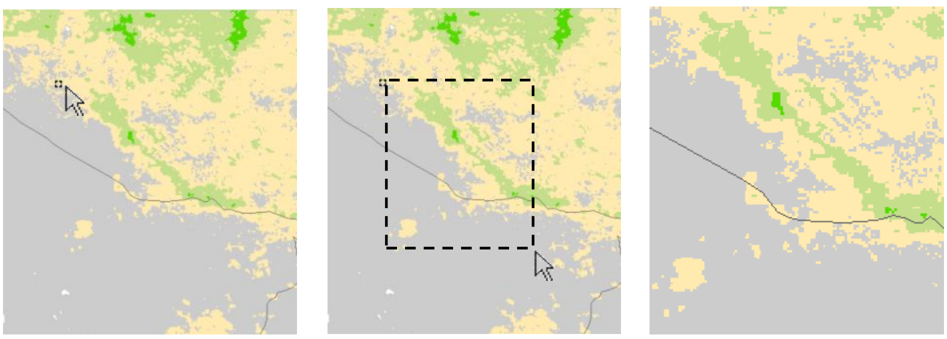
From the zoom menu, a drop down box provides the options ‘in’, ‘out’ and ‘pan’. To zoom in or out, click on the area of interest. To pan, click and drag the image.



Selection of zooming mode

Select ROI

You can select an ROI (Region Of Interest) by drawing a box. To draw a box, click a first time on the image to define the upper left corner and a second time to define the lower right corner of the ROI. The image will be centred to this box.



Selection of region of interest (ROI) by drawing a box: Selection of upper left corner (left image), selection of lower right corner (middle image), ROI will appear (right image)

Select by administrative units

You can directly zoom to a specific administrative unit. For the time being, only the 128 administrative units at the county level within the Chinese border are available. This geographical spatial unit selection may extend into Russian territory in the future.

C) Display type

Current

Each fAPAR and NPP product is generated as a 10 daily composite. In this way a majority of cloud contamination is eliminated.

Comparison to the reference year 2000 and the average year

For each decade in a year, the corresponding ‘average year’ (also termed “historical year” or ‘long term average’) is calculated.

The ‘average year’ reflects the condition that occurs “in average” and is considered as one of the two references. The other is referred to the year 2000 which is often considered as a reference year for climate change studies. Calculating the difference between the ‘current’ vegetation condition and the condition of the reference years can reveal changes or anomalies.

D) Print

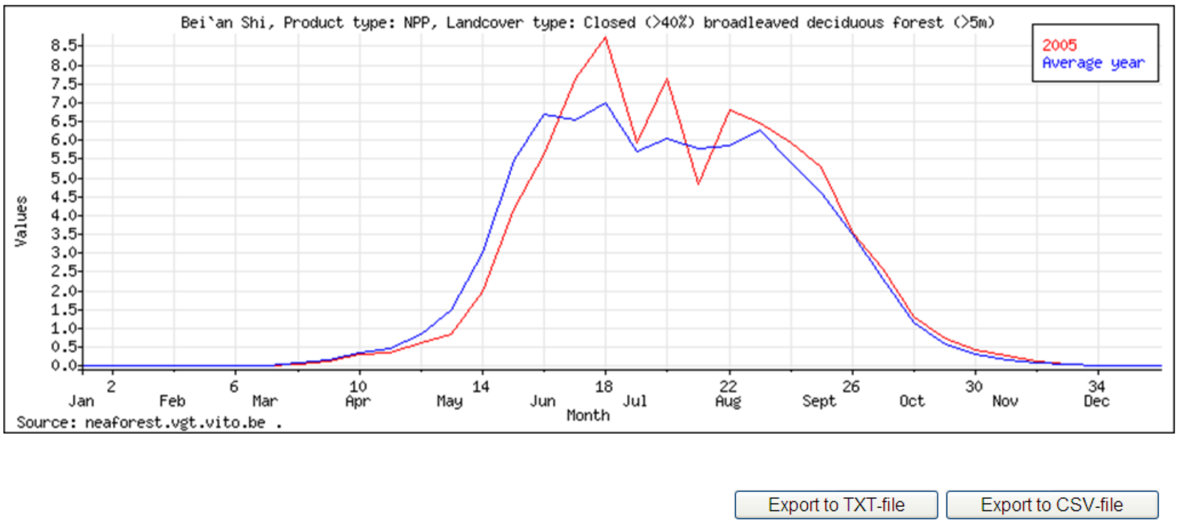
You can print what is displayed in the image viewer by clicking on the ‘print’ button beneath the image window.

1.3 Statistic analysis tools

We know now that the Image Viewer allows to examine precisely the spatial distribution of the vegetation status in the study area. More detailed analysis within a geographical zone can be carried out using two statistical or monitoring tools offered by the NEA-Forest web site: the Graph and Table Viewers.

Graph Viewer

This tool plots the temporal evolution of a vegetation index (or vegetation bio-physical variable, for example NPP in the year 2005), contributed by a certain vegetation class (for example “closed broadleaved deciduous forest”) within certain geographic area (for example the administrative region: Bei An Shi).

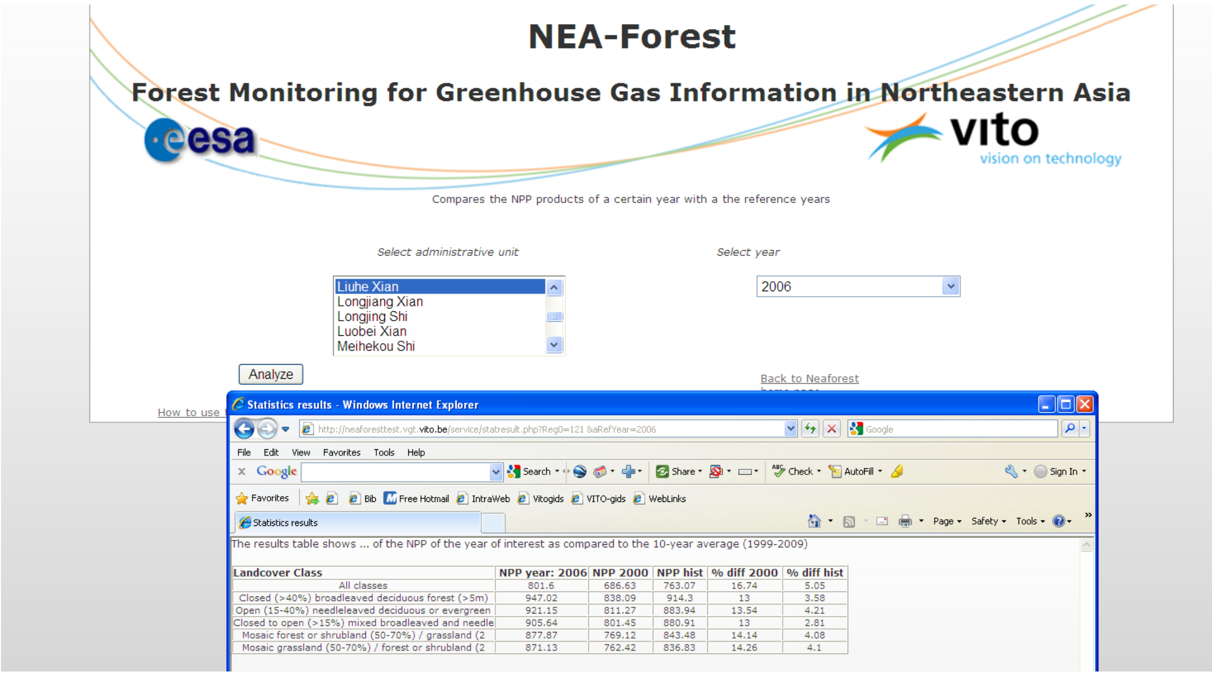


To carry out this analysis, you need to select successively the biophysical variable that you focus, the geographic area in which you are interested, the vegetation class that you are analyzing and the period (year) you will view.

Two curves will be plotted. The **red curve** shows the temporal evolution of the variable during your year of interest, and the **blue curve** the vegetation variable for the ‘average year’. The ‘average year’ corresponds to the ten year average (1999-2008) of the vegetation variable.

Table Viewer

Using the Table Viewer, you can create a table with the percentage increase or decrease of the vegetation variable for a certain period (year) in certain region compared to the values of the reference year or the historical year. For the time being, this function is only available for the bio-physical variable NPP. In the example shown below, a summary of the variable NPP is provide by the Table viewer for the year 2006 in Liuhe county. The NPP value in this example is shown “un-mixed”, providing the details of contribution by each of the related vegetation classes (in this example, the NPP value in Liuhe county was contributed by 5 vegetation classes).



Landcover Class	NPP year: 2006	NPP 2000	NPP hist	% diff 2000	% diff hist
All classes	801.6	686.63	763.07	16.74	5.05
Closed (>40%) broadleaved deciduous forest (>5m)	947.02	838.09	914.3	13	3.58
Open (15-40%) needleleaved deciduous or evergreen	921.15	811.27	883.94	13.54	4.21
Closed to open (>15%) mixed broadleaved and needle	905.64	801.45	880.91	13	2.81
Mosaic forest or shrubland (50-70%) / grassland (2	877.87	769.12	843.48	14.14	4.08
Mosaic grassland (50-70%) / forest or shrubland (2	871.13	762.42	836.83	14.26	4.1

2. DATA PRODUCTS

The vegetation bio-physical variables or vegetation indices that we monitor in this web service are:

fAPAR– Vegetation health & density
DMP – Vegetation growth rate

These variables or indices can be displayed in two status

Current
Comparison with the 'reference years'

2.1 Vegetation bio-physical variables or vegetation indices: fAPAR

Definition

The **fraction of Absorbed Photosynthetically Active Radiation (fAPAR)** is a non-dimensional value that measures the fraction of the incoming solar radiation at the top of the vegetation canopy that contributes to the photosynthetic activity of plants, and thus indicates the presence and productivity of live green vegetation. Spatially-detailed descriptions of fAPAR provide information about the strength and location of the assimilation of carbon dioxide in vegetation.

Interpretation

Ground-based estimates of fAPAR require the simultaneous measurement of PAR above and below the canopy. fAPAR can also be retrieved from space remote sensing platforms using physically-based inverse methods. Interpretation can be performed by validating the retrieved values with the ground measurements.

fAPAR is most often inferred from models describing the transfer of solar radiation in plant canopies, using remote-sensing observations as constraints. Daily recovery of fAPAR is possible in principle, but cloud and thick aerosols often obscure the surface and result in incomplete maps. This issue is normally addressed by generating time-composited FAPAR maps that aim to convey information on central tendencies (statistical first moments of the distribution) while providing as complete a spatial coverage as possible.

Application

Since fAPAR is a vegetation biophysical variable that characterizes energy, mass, and momentum exchanges, the variable is used extensively in models that represent the transfer of energy, carbon, water, and the biogeochemistry of terrestrial ecosystems. More specifically, it is the main input for estimation of the Net Primary Productivity (NPP) in the Carbon balance assessment.

2.2 Vegetation bio-physical variables: NPP – Net primary productivity

Definition

Primary production is the production of organic compounds from atmospheric or aquatic carbon dioxide, principally through the process of photosynthesis, with chemosynthesis being much less important. Almost all life on earth is directly or indirectly reliant on primary production. The organisms responsible for primary production are known as *primary producers* or autotrophs, and form the base of the food chain. In terrestrial eco-regions, these are mainly plants, while in aquatic eco-regions algae are primarily responsible. Primary production is distinguished as either *net* or *gross*, the former accounting for losses to processes such as cellular respiration, the latter not.

Net primary productivity (NPP) is defined as the net flux of carbon from the atmosphere into green plants per unit time. NPP refers to a rate process, i.e., the amount of vegetable matter produced (net primary production) per day, week, or year.

Computation

Two main approaches can be identified for obtaining larger scale estimates of carbon balance: i) employment of physiological process-based models, and ii) direct estimates from diagnostic models driven by remotely sensed data. The former approach simulates ecosystem processes using detailed data sets of biophysical and meteorological conditions as input (e.g. Running and Hunt Jr, 1993; Liu et al., 1997). This is required for prognostic purposes, but an advanced process-based model is not necessarily more accurate than simpler models, mainly because of the high input demands. The second approach is based on the light-use efficiency concept devised by Monteith which decomposes net primary productivity (NPP) into external influences (incoming solar radiation) and conversion efficiencies, that account for the conversion of radiation during photosynthesis and for the losses of autotrophic respiration. The equation was adapted and simplified by Veroustraete for application using satellite imagery. Stress factors such as water surplus or deficit, poor availability of nutrients or occurrence of pests are not directly considered in the calculation, and as such 'vegetation production' should be interpreted as indicative for "potential" production.

This indicator gives the amount of net carbon influx in g C $m^{-2}yr^{-1}$ (or g C $m^{-2}d^{-1}$). The physical NPP values can vary from 50 to 4000 gC $m^{-2}yr^{-1}$, where higher values indicate a higher growth rate, so more production of dry matter biomass.

Applications

Net Primary Productivity (NPP) products represent repeatable estimates of the carbon uptake of terrestrial vegetation by photosynthesis subtracted with the autotrophic respiration. These carbon fluxes are quantified using different assimilation models. Monitoring this biophysical variable represents therefore a crucial way to assess the carbon dynamics (carbon sink or source) of terrestrial ecosystems.

NPP anomalies

NPP anomalies express the deviation of the time series of the variable NPP from a reference NPP time series representing one full year. It thus provides information on how actual NPP varies in comparison with the values of the reference year.

The following two reference years will be used in this demonstration project, such that the anomaly time series will provide complementary information.

- The year 2000 (DIF_{2000})
- The historical year (DIF_{HY}) which is composed by the mean values over the period 1998-2007

The DIF_{2000} dataset is relevant, since the year 2000 is often considered as a reference year for the inventory and reporting of sequestered carbon by forests. The DIF_{2000} provides information on how the other years have performed in comparison with the reference year 2000 in terms of the forest biomass variation.

DIF_{HY} values express the difference of the forest biomass growth of the current year against that of the average (historical) year. The value of the average year (HY) for a certain decade is obtained by averaging all NPP values for this decade over the period of 1999-2007.

NPP anomalies can be viewed by selecting the display type.

2.3 Burnt Area Estimates

Burnt Area Estimates (BAE) is the product generated in the frame of GlobCarbon project. It describes incremental monthly information of burnt areas, in which only the first detection of a burnt area was retained. The product was derived from combined results of two studies, GBA2000 and GlobScar.

GBA2000 made use of various algorithms, each applied on different regions in the world. Only two algorithms were retained in the final version of GlobCarbon, i.e. the IFI algorithm from the Russian International Forest Institute and the UTL-Africa algorithm from the Technical University of Lisbon. GlobScar action made use of two algorithms, K1 and E1. The K1 algorithm is a contextual algorithm based on the geometrical characteristics of the burnt pixels in the NIR/TIR space, while the E1 algorithm consists of a series of fixed threshold tests applied to the data using information from four spectral channels.

The BAE product of GlobCarbon takes into account the detection results using the algorithms UTL, IFI and E1/K1, as well as the retrieved values from three active fire databases WFA, TRMM and FireM3.

For NEA-Forest project, the detection by all four algorithms with inclusion criteria is retained as the burnt criteria.

The annual BAE is an accumulation of the monthly BAE values

The Frequency of BAE is an average of all annual BAE values during the period 1999-2007.

As the fire occurrence involves the area at the pixel level, the best way to inspect the fire occurrence or the fire frequency for a specific region is to visualize first the fire frequency for the whole period 1999-2007. The year of the occurrence can then be found out. Subsequently the month of the fire occurring can be determined.

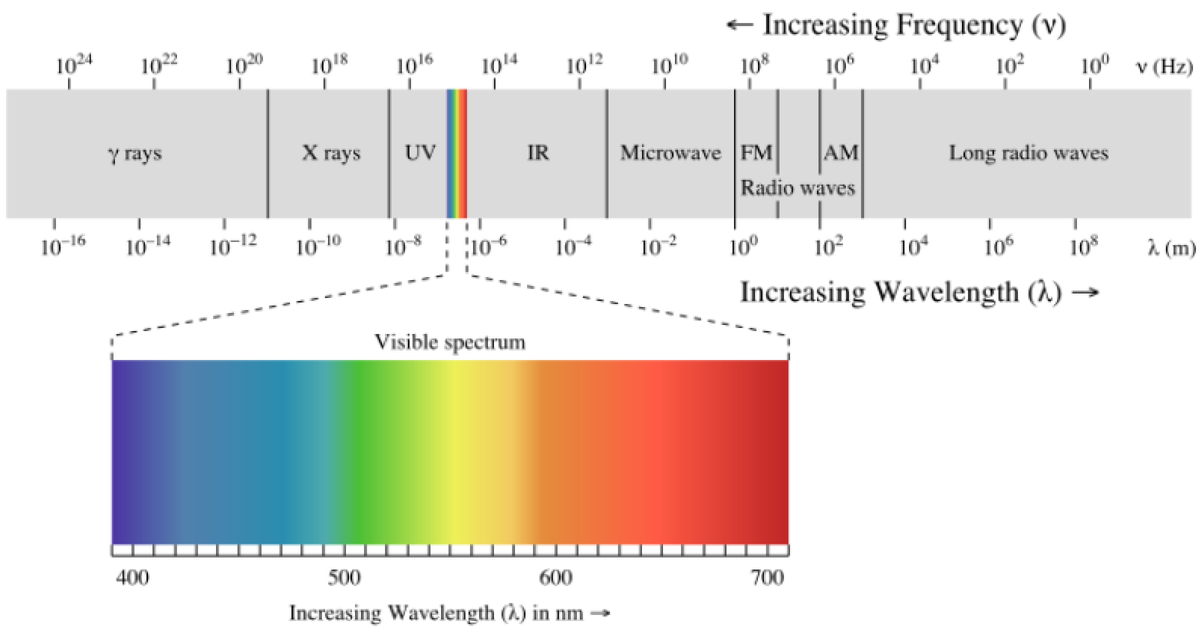
3. BACKGROUND

3.1 Remote sensing terminology

Remote sensing
Remote sensing is the science of observing the Earth's surface and assimilating the observed information without actually being in contact with it. This is achieved by sensing and recording reflected or emitted electromagnetic information and processing, analyzing that information.

Electromagnetic radiation
Remote sensing requires an energy source to illuminate the target or to be emitted from the target. This energy is in the form of **electromagnetic radiation**. Electromagnetic radiation consists of electromagnetic waves characterized by their wavelength and frequency. The sensors used in this NEA-Forest project detect objects on the earth surface illuminated by the sun.

Electromagnetic spectrum
The **electromagnetic spectrum** ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). Only a small part of the spectrum, the visible light, can be sensed by the human eye. To record the energy in other parts of the spectrum, specific sensors are required.



Electromagnetic spectrum

The observation or information acquired in NEA-Forest monitoring tools are found in the visible and infrared part of the spectrum.

Spectral response
When electromagnetic radiation interacts with the Earth's surface part of it is absorbed or transmitted, while another part is reflected back into the atmosphere. The proportion of the incoming radiation that is absorbed, transmitted, or reflected depends on the wavelength of the incoming radiation and on the characteristics of the target. Remote sensing can be used to measure the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths. This way the **spectral response** of a target can be measured. By comparing the response patterns of different features we may be able to distinguish between them, where we might not be able to, if we only compared them at one wavelength. For example, water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Water absorbs most of the incoming infrared

wavelengths, while green vegetation reflects most of the infrared wavelengths. As a consequence in an infrared image water appears dark (low reflectance values) and vegetation appears bright (high reflectance values).

Spectral bands
Remote sensing sensors consist of different spectral bands that measure a certain range of wavelengths within the electromagnetic spectrum. For example the SPOT-VEGETATION sensor consists of four bands: a blue band, a red band, a Near Infrared (NIR) band, and a Shortwave Infrared (SWIR) band.

Spectral resolution
Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular spectral band.
Some features, for example water and vegetation, are easily distinguishable as their spectral response is very different. In other cases, for example, when we want to separate different types of vegetation, the spectral response might be much more similar. Therefore, bands with fine wavelength ranges will be required to separate these different vegetation types.

Spatial resolution
The detail discernible in an image is dependent on the **spatial resolution** of the sensor and refers to the size of the smallest possible feature that can be detected. For example, a sensor with a spatial resolution of 30 meters will be able to detect objects measuring 30 meters or larger. Images where only large features are visible are said to have **coarse or low resolution.** For example, images acquired by SPOT-VEGETATION have a spatial resolution of 1000 meters. Sensors with low spatial resolution often have a higher temporal resolution (shorter revisiting time) and are therefore better suited for continued vegetation monitoring over large areas.

Pixels
Remote sensing images are composed of a matrix of picture elements, or **pixels**, which are the smallest units of an image. In most cases, the size of the pixels is set to the spatial resolution of the sensor.

Temporal resolution
The temporal resolution of a sensor refers to the ability to collect images of the same area of the Earth's surface at different periods. The higher the temporal resolution, the more frequent images of the same area can be captured.

Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing **multi-temporal** imagery. For example, during the growing season, most species of vegetation are in a continual state of change and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. By imaging on a continuing basis at different times we are able to monitor the changes that take place on the Earth's surface, whether they are naturally occurring (such as changes in natural vegetation cover or flooding) or induced by humans (such as urban development or deforestation).

Source:
- Tutorial: Fundamentals of Remote Sensing. Canada Centre for Remote Sensing. http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php
- BELSPO remote sensing tutorial. http://eoedu.belspo.be/

3.2 Sensors

SPOT-VEGETATION

The first SPOT-VEGETATION instrument was launched aboard the SPOT 4 satellite on the 24th of March 1998; the SPOT-VEGETATION2 instrument is operational from the SPOT5 satellite since 1st February 2003. The sensor covers the whole earth daily at 1 km resolution in 4 spectral bands: blue, red, near infrared and shortwave infrared. It is mainly designed for decision support in the fields of agriculture and early warning, forest monitoring and management of natural resources. SPOT-VEGETATION data are pre-processed, archived and distributed by VITO. Achieves older than three months are available free of charges.

METOP-AVHRR

The Advanced Very High Resolution Radiometer (AVHRR/3) is one of the complement of American instruments provided by the National Oceanic and Atmospheric Administration (NOAA) to fly on MetOp-A, B and C. Previously pay-loaded on the satellites NOAA 15 to 19, AVHRR/3 has a resolution of 1 km and is used for a wide range of applications. Twice a day, the instrument provides images of the cloud cover over the entire world, and it also offers frequent images of the land and sea surfaces. The instrument is especially well-suited for studying vegetation on a world scale, e.g. for the study of seasonal changes. Moreover, with AVHRR one can monitor the surface temperatures of the sea and the ice or vegetation covering.

Band	Band width
1 (visible)	0,58 - 0,68 µm
2 (Near infrared)	0,725 - 1,00 µm
3A (Near infrared)	1,580 - 1,64 µm
3B (IR)	3,550 - 3,93 µm
4 (IR)	10,30 - 11,30 µm
5 (IR)	11,50 - 12,50 µm

Operating since 2008, VITO has been producing ‘Metop-AVHRR 10-daily composites. It’s web-site provides all information (http://www.metops10.vito.be/) on the MA10 products and gives access to the catalogue where the available data can be searched and downloaded freely for non-commercial use.

4. SUMMARY OF THE NEA-FOREST PROJECT

The project NEA-Forest aims to monitor the growth state and anomalies (including fires) of boreal forests in North-eastern Asia. The service consists of a web-based application capable of updating the state of the forest and the extent of forest fires through vegetation indices such as Net Primary Productivity (NPP), NPP anomalies or burnt areas and burnt areas history. To this end, the proposed service will take advantage of the GlobSeries project data, namely GlobCarbon and GlobCover.

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