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# APPLICATION OF MODIS MCD45 DATA FOR BURNED AREA CALCULATION IN BOREAL ZONE OF THE EUROPEAN PART OF RUSSIA

Information on burned areas is very useful data for retrospective estimation of the role of forest fires. One of the sources for this information is data obtained from the sensor MODIS. In this research, the data MODIS MCD45 was checked for quality and availability. After the positive results the spatial and temporal analysis of forest fires and burned areas was conducted. The tendency of distribution of forest fires across the boreal zone of the European part of Russia was analyzed. The calculation of burned areas across the regions and landscapes was performed.
**Keywords:** forest fires, boreal forest, MODIS MCD45, taiga.

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**ИСПОЛЬЗОВАНИЕ ДАННЫХ MODIS MCD45 ДЛЯ ОЦЕНКИ ПЛОЩАДЕЙ ВЫГОРЕВШИХ ТЕРРИТОРИЙ БОРЕАЛЬНОГО ПОДПОЯСА ЕВРОПЕЙСКОЙ ЧАСТИ РОССИИ**
Данные о площадях выгоревших территорий представляют собой качественный материал для ретроспективной оценки роли пирогенного фактора. Одним из источников такой информации являются данные сенсора MODIS. В работе была проведена оценка качества данных MODIS MCD45. По удовлетворительным результатам был проведен пространственно-временной анализ очагов возникновения и распространения пожаров на территории бореального подпояса Европейской части России. Выявлены тенденции пирогенного фактора в целом, а также по субъектам и ландшафтным зонам.
**Ключевые слова:** лесные пожары, бореальные леса, MODIS MCD45, тайга.

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**ВИКОРИСТАННЯ ДАНИХ MODIS MCD45 ДЛЯ ОЦІНКИ ПЛОЩ ВИГОРІЛИХ ТЕРИТОРІЙ БОРЕАЛЬНОГО ПІДПОЯСУ ЄВРОПЕЙСЬКОЇ ЧАСТИНИ РОСІЇ**
Дані про площі вигорілих територій є якісним матеріалом для ретроспективної оцінки ролі пірогенного фактора. Одним із джерел такої інформації є дані сенсора MODIS. У роботі була проведена оцінка якості даних MODIS MCD45. За задовільними результатами був проведений просторово-часовий аналіз осередків виникнення та поширення пожеж на території бореального підпоясу Європейської частини Росії. Виявлено тенденції пірогенного фактора в цілому, а також за суб'єктами і ландшафтними зонами.
**Ключові слова:** лісові пожежі, бореальні ліси, MODIS MCD45, тайга.

**Introduction**. Fire is an inevitable natural part of the functioning of many forest ecosystems. Fire is one of the natural forces that have influenced different ecosystems over time and as a natural process, it serves an important function in maintaining their health. In boreal ecosystems, fires play role of a natural driver of vegetation dynamics.

Boreal forest is a mosaic of species. It varies from pure deciduous through the mixed deciduous, coniferous to pure coniferous stands. The diversity of this mosaic has to do with numerous fires, which have occurred on different landscapes for a long period of time. These fires differed in severity, size, frequency, etc.

**Actuality**. Recently, forest fires have become more frequent and severe due to human activity and economic development. During the summer 2010, forest fires had enormous ecological and economic impact on the territories of the European part of Russia. Huge areas were burnt, including protected areas. An understanding of fire regimes can help in monitoring, preventing and protecting from forest fires in the future.

**Objectives**: The analysis of the MODIS burned area data in conjunction with secondary GIS data, such as administrative boundaries as well as land cover and protected areas, will provide fire statistics of the area burned per year and month (in square kilometers), administrative area, landscape zones. The results of the GIS analysis provide a basis of understanding of the fire occurrence, and its spatial and temporal patterns in European boreal forest and may help in defining important parameters of the existing fire regimes in forest of European part of Russia.

**Data and methods.**

MODIS burned area data. MODIS Burned area data (MCD45) were obtained as GeoTIFFs from the Server of the University of Maryland, and as HDF files from NASA (this is the official distribution). The two products differ in file format, extent, projection, and the amount of metadata and Quality Assurance (QA) information, as well as data processing. GeoTIFFs are easier to use to reach the current research goals, as GeoTIFFs can be easily ingested by standard GIS software [2]. Due to the data processing approach, the HDF data contain temporal overlaps between the different months, for instance, each monthly dataset contains burned area information from the last days of the previous, and the first days of the following months. These overlaps have been removed in the GeoTiff product [4]. We decided to base our analysis on the GeoTIFF files.

GIS Data. The GIS data were provided by Moscow State University or obtained from open sources. For the current analysis, the shape files of Administrative areas and landscape zones [1] were taken.

Methods. This section describes the methods which were applied to the data for extraction of the burned area statistics. These steps included projection, data quality analysis, complex of actions for intersection of data.

Data pre-processing. All data (MODIS MCD45) and GIS data were projected to Cylindrical Equal Area. These projections a bit distort the northern territories, but as these areas naturally have a small number of forest fires, so this won't alter the results heavily. There could be some overestimations which won't influence on overall statistics.

MODIS data analysis. Before conducting the spatial and temporal analysis of burned areas MODIS information was estimated and quality check was performed. These steps included:

— calculation of months without data retrieval due to clouds, aerosols or other problems for each pixel and year (no yearly data counted);

— calculation of months without data retrieval due to clouds, aerosols or other problems for each pixel and all year (no data count for temporal analysis window);

— calculation of months in a fire season without data retrieval due to clouds, aerosols or other problems for each pixel position and all year (no data count for analysis window in the fire season).

**Results.**

Data availability and quality. Data availability of the burned area data is restricted by clouds and haze. The analysis shows that amount of No Data pixels decreases from the north to the south. This indicates that especially in the northern part burned areas may be missed due to frequent cloud cover. The validity of the burned area analysis of these regions may therefore be compromised. However, this discrepancy is within 15–25%. During the fire season, the sum of the burned area can be underestimated by 10–15%.

Figure 1 shows the seasonal distribution of No Data. The analysis showed that the maximum number of No Data is detected during winter months and November. But these months have the lowest natural fire risk. So, this fact won't affect heavily the results. However, some information on burned areas can be compromised in August of 2011, 2008 and 2001. Also quite a decent gap in available data exists in September 2011, March 2007 and April 2002. For other months the data is reliable.

Burned area in boreal zone. Big areas of boreal forests in the European part of Russia are mapped as burned by MODIS MCD45 product. During the fire season these areas vary from 14 to 2115 square km. According to MODIS MCD45 data years with the highest fire risk and the largest burned areas are 2010, 2000 and 2002. Conducted analysis shows that more than 30% of the total burned areas occurred during the fire season of 2010.

Considering the seasonal distribution of burned areas, two types can be defined: spring and late-summer forest fires. Forest fires of the first type occur during spring, some time after the snow melts and till the moment when trees are leafed out. For the second seasonal type, forest fires occur during the summer, sometimes with the peak in August-September due to very dry spring and summer. The analysis shows that the largest burned areas are detected in August 2010 and 2002, in July 2000 and 2010, in June 2000 and in May 2006 and 2010.

The maximum average burned areas were detected in August, where mean yearly burned areas exceed 200 square km. The second month with the largest burned areas is July. During this month, the mean yearly burned area is 134 square km. The third and the forth months are April and May with average 85 and 60 square km burned every year correspondingly.

In addition, an analysis was conducted regarding the mean size of the fire. This is the ratio of the total burned area and number of forest fires. Mean fire size denotes the average size in units of area, of the individual fires that occur across a landscape of interest within the given period [3]. The mean fire size during the late-summer period is bigger than the one during spring fires. Thus, the mean fire size of spring forest fires varies between 0,32 and 0,48 square km. For the summer fires, the mean size is within the range of 0,54 and 0,57 square km.

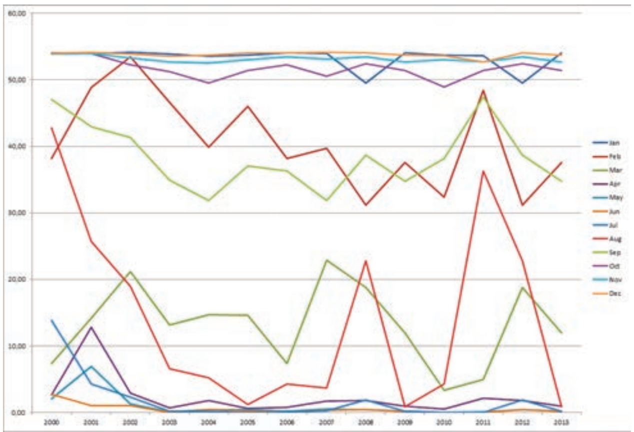

*Fig. 1. Area percentage of boreal forests in European part of Russia with no data from 2000–2013.*

Burned areas and administrative areas.The ost fire-affected regions are located in the south part of the target area. The most vulnerable territories for the forest fires are the areas of Smolensk and Pskov region. Mean yearly burned areas in these regions are 97,74 and 76,62 square km correspondingly. Decent burned areas are also detected in Ryazan', Nizhniy Novgorod and Kaluga regions. Mean burned areas of these territories are 50,94; 44,82 and 43,99 square km correspondingly. The distribution of mean burned areas across the regions is shown on Figure 2.

Burned areas and boreal landscapes. Across the territory of the northern taiga under the study period, the largest burned areas are detected in 2011 and 2013. The areas burned during these years make up more than 56% of the total burned area in the northern taiga.

In the middle taiga, the most affected year was 2010. During this year, the forest fires blighted more than 50% of the total burned area.

In the southern taiga, there were a many years with a high fire risk. Approximately 10–15% per each year of the total burned area in this zone is divided between 2002, 2003, 2006, 2007, 2008, 2009 and 2010.

In the mixed coniferous forest, the biggest burned areas are detected in 2010, 2009 and 2002. These years make up more than 75% of the total burned area in this zone.

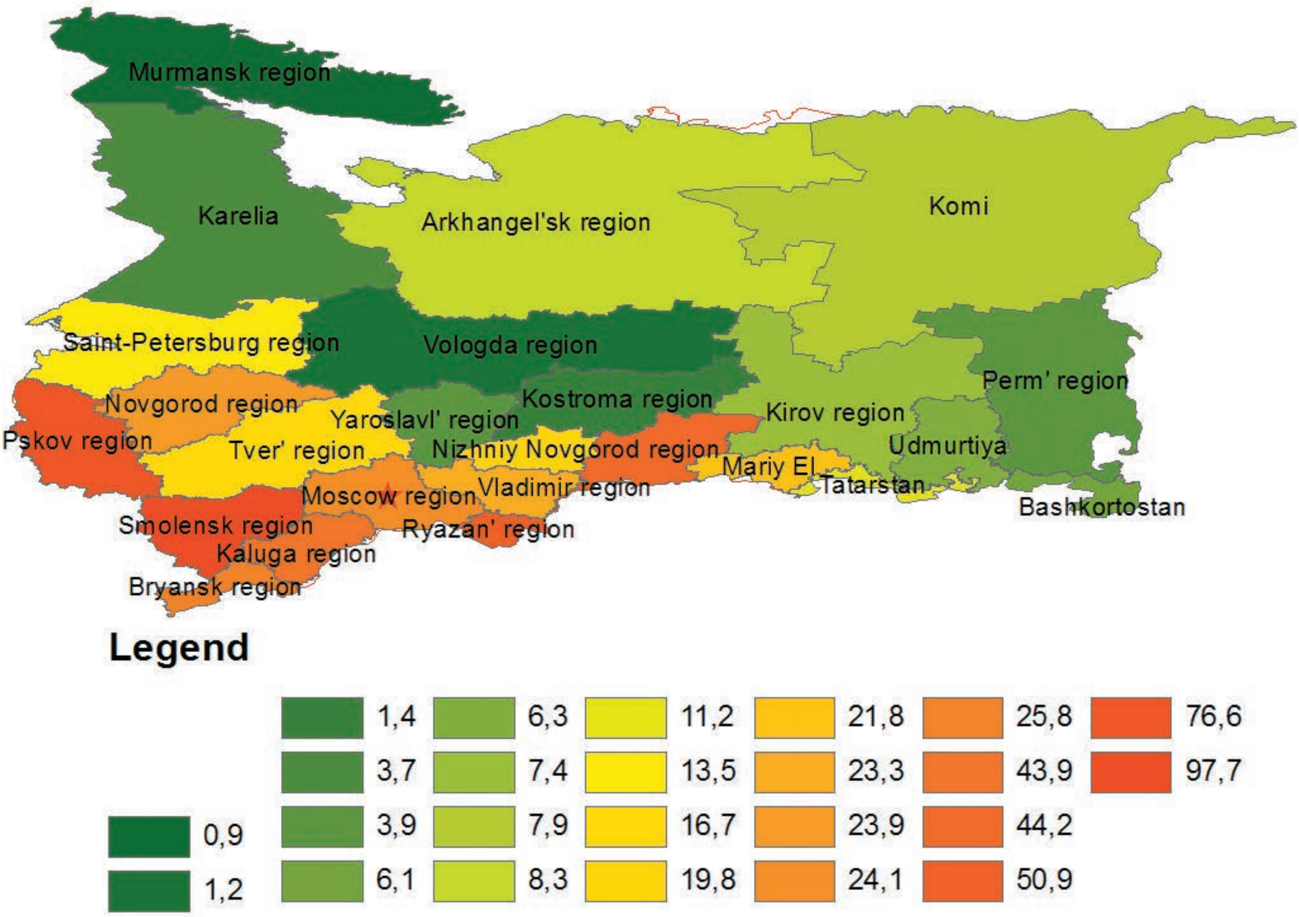


*Fig. 2. Mean yearly burned area per region.*

**Conclusions**. Forest fires are an important factor of functioning and dynamics of many natural ecosystems. Forest fires occur across all territories of the boreal zone. After analysis of remote sensing data, the most affected by fires region in the study area are Smolensk and Pskov regions. The largest burned areas are detected on the territory of mixed coniferous forests and southern taiga.

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# ЦИФРОВЕ МОДЕЛЮВАННЯ РЕЛЬЄФУ ДНА АКВАТОРІЙ У РАЙОНІ УКРАЇНСЬКОЇ АНТАРКТИЧНОЇ СТАНЦІЇ «АКАДЕМІК ВЕРНАДСЬКИЙ»

У статті викладено досвід розробки цифрових моделей рельєфу (ЦМР) дна акваторій у районі української антарктичної станції «Академік Вернадський». Оглядові цифрові моделі створено із використанням існуючих навігаційних та батиметричних карт, згодом їх деталізовано на основі даних ехолотної зйомки, здійсненої під час сезонних експедиційних досліджень 2014 р. При обробці та візуалізації даних застосовані геоінформаційні та веб-технології. ЦМР слугують основою для комплексного вивчення підводного біорізноманіття та обґрунтування ідеї створення морських охоронних районів у протоках Stella Creek та Skua Creek поблизу станції «Академік Вернадський».
**Ключові слова:** цифрові моделі рельєфу (ЦМР), Антарктика, біорізноманіття, морські охоронні райони, ГІС.

**Е.И. Сенная, А.Ю. Утевский, В.С. Попов**
**ЦИФРОВОЕ МОДЕЛИРОВАНИЕ РЕЛЬЕФА ДНА АКВАТОРИЙ В РАЙОНЕ УКРАИНСКОЙ АНТАРКТИЧЕСКОЙ СТАНЦИИ «АКАДЕМИК ВЕРНАДСКИЙ»**
В статье изложен опыт разработки цифровых моделей рельефа (ЦМР) дна акваторий в районе украинской антарктической станции «Академик Вернадский». Обзорные цифровые модели созданы с использованием существующих навигационных и батиметрических карт, в последствии модели детализированы на основе данных эхолотной съёмки, осуществлённой во время сезонных экспедиционных исследований 2014 г. При обработке и визуализации данных применены геоинформационные и веб-технологии. ЦМР служат основой для комплексного изучения подводного биоразнообразия и обоснования идеи создания морских охранных районов в проливах Stella Creek и Skua Creek вблизи станции «Академик Вернадский».
**Ключевые слова:** цифровые модели рельефа (ЦМР), Антарктика, биоразнообразие, морские охранные районы, ГИС.

**O.I. Sinna, A. Yu. Utevsky, V.S. Popov**
**DIGITAL SIMULATION OF THE SEA-BOTTOM RELIEF NEAR THE UKRAINIAN ANTARCTIC STATION «ACADEMIC VERNADSKY»**
The article describes the experience of the development of the digital terrain models (DTM) of the sea-bottom near the Ukrainian Antarctic Station «Academic Vernadsky». Survey digital models were created by using existing navigation and bathymetric maps; later, models were based on detailed data of the echolocation survey that was conducted during the seasonal field research in 2014. During the processing and visualization of data, GIS and web technologies were used. DTMs provide the basis for a comprehensive study of underwater biodiversity and support the idea of the establishment of marine protected areas in the Stella Creek and Skua Creek straits near the station «Academic Vernadsky».
**Keywords**: digital elevation model (DEM), Antarctica, biodiversity, marine protected areas, GIS.