MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____________ T. V. Dudar
«_____» ____________ 2022

BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM:
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Remote assessment of the mixed forest conditions in the north-eastern part of Ukraine»

Done by: student of EK-411 group Elyzaveta O. Zhmura
(student, group, surname, name, patronymic)

Supervisor: Dr. Eng. Sc. Professor of the Department of Environmental Science, Tamara V. Dudar
(academic degree, academic rank, surname, name, patronymic)

Standards Inspector: _____________ Andrian A. Iavniuk
(signature) (S.N.P)

KYIV 2022

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____________ Т. В. Дудар
«_____» ____________ 2022 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»
ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Дистанційне дослідження стану мішаних лісів північно- східної частини України»

Виконавець: студентка групи ЕК-411, Жмура Єлізавета Олександрівна
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КИЇВ 2022

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Environmental Science

Specialty, Educational and Professional Program: specialty 101 “Ecology”, Educational and Professional Program: “Ecology and Environment Protection”

(code, name)

APPROVED
Head of the Department
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«____» _________ 2022

BACHELOR THESIS ASSIGNMENT

Elyzaveta O. Zhmura

1. Theme: «Remote Assessment of the Mixed Forest Conditions in the North-Eastern Part of Ukraine» approved by the Rector on April 18, 2022, № 388/ст.

2. Duration of work: : from 23.05.2022 to19.06.2022.

3. Output work (project): data on the environmental conditions of the mixed forests of the Sumy oblast, space images of the Landsat 2000-2018.

4. Content of explanatory note: (list of issues): (list of issues): analytical review of the literature on the topic of the diploma. The assessment of environmental conditions of the mixed forests of the Sumy oblast using analytical review and the space images.

5. The list of mandatory graphic (illustrated materials): tables, figures, charts, graphs.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	08.04.2022	
2	Preparing the main part (Chapter I)	23.05-29.05.2022	
3	Preparing the main part (Chapter II)	30.06-01.06.2022	
4	Formulating conclusions and recommendations of the thesis	05.06.2022	
5	Making an explanatory note to the previous presentation of the department, consultation with the norms controller	05.06 - 07.06.2022	
6	Presentation of the work at the department	08.06.2022	
7	Taking into account the comments and recommendations and training to protect	09.06 - 13.06.2022	
8	Thesis defense at the department	14.06.2022	

7. Date of task issue: «23» __05____ 2022

Diploma (project) advisor: ________________ ___Dudar T.V.___
(advisor's signature) (S.N.P.)

Task is taken to perform: ________________ ___Zhmura E. O.________
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

Кафедра екології

Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»

(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
___________Дудар Т. В.
«____» _________ 2022 р.

ЗАВДАННЯ
на виконання дипломної роботи
Жмури Єлізавети Олександрівни

1.Тема роботи «Дистанційне дослідження стану мішаних лісів північно-східної частини України», затверджена наказом ректора 18 квітня 2022 р. № 388/ст.

2. Термін виконання роботи: з 23.05.2022 по 19.06.2022р.

3. Вихідні дані роботи: дані про екологічні умови мішаних лісів Сумської області, космічні знімки Landsat 2000-2018.

4. Зміст пояснювальної записки: аналітичний огляд літератури за темою диплома. Оцінка екологічного стану мішаних лісів Сумської області за допомогою аналітичного огляду та космічних знімків.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки, діаграми.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	08.04.2022	
2	Підготовка основної частини (Розділ I)	23.05-29.05.2022	
3	Підготовка основної частини (Розділ II)	30.06-01.06.2022	
4	Формулювання висновків та рекомендацій дипломної роботи	05.06.2022	
5	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	05.06 - 07.06.2022	
6	Представлення роботи на кафедрі	08.06.2022	
7	Урахування зауважень, рекомендацій та підготовка до захисту	09.06 - 13.06.2022	
8	Захист дипломної роботи на кафедрі	14.06.2022	

7. Дата видачі завдання: «_23__» ____05___ 20 22 р.

Керівник дипломної роботи (проекту): ________________ ___Дудар Т. В.__
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____________ ___Жмура Є.О.___
(підпис випускника) (П.І.Б.)

ABSTRACT

The explanatory note to the thesis «Remote Assessment of the Mixed Forest Conditions in the North-Eastern Part of Ukraine»: 39pages, 6 figures, 31 references.

An object of research – is an assessment of the mixed forest state using remote sensing data (for the north-eastern part of Ukraine).

Aim of work – to analyze and assess the state of the mixed forest using remote sensing data.

Methods of research: analytical, statistical, remote sensing methods.

This paper examines the state of mixed forests of Ukraine and Sumy region as a border area. The results of research can be used to monitor the forests of Ukraine and other studies.

MIXED FOREST ECOSYSTEMS, REMOTE SENSING, HANSEN GLOBAL FOREST CHANGE, IMPACT ON FOREST ECOSYSTEMS, HOSTILITIES

CONTENT

INTRODUCTION

Relevance of the work. Today, deforestation is an urgent problem of Ukrainian society. Forests cover a third of our country, so deforestation is indeed a catastrophe that will lead to ecological catastrophe: the loss of biodiversity, the death of terrestrial animals and birds, increasing the risk of avalanches, increasing floods, deteriorating soil quality and fertility. Due to the war in Ukraine, the condition of forests has deteriorated even more.

Aim and tasks of the diploma work

Aim of the work – to analyze and assess the state of the mixed forest using remote sensing data

Tasks of the work:

1.To overview and analyze the environmental conditions of the north-eastern part of the mixed forests (borderland Sumy region)

2. To assess the environmental conditions of mixed forests of the Sumy region according to remote data (Google Earth Engine, Hansen Global Forest Change)

3. To demonstrate the impact on forest ecosystems as a result of the 2022-hostilities

Object of research is assessment of the mixed forest state using remote sensing data (for the north-eastern part of the Ukraine)

Subject of research is remote sensing technique used for the forest state assessment

Methods of research **–** analytical, statistical, remote sensing methods

Personal contribution of the graduate: Conducted monitoring of forest changes in the period from 2000 to 2018, took satellite images with the help of Google Earth Engine, and analyzed the loss and growth of mixed forests, studied the state of forests in Sumy region during the war.

Approbation of results. The results were discussed at the conferences:

Екологічна безпека держави: Екологічна безпека держави: XIV Всеукраїнської науково-практичної конференції молодих учених і студентів, м. Київ, 23 квітня 2021 р., К. : НАУ, 2020

Екологічна безпека держави: Екологічна безпека держави: XIV Всеукраїнської науково-практичної конференції молодих учених і студентів, м. Київ, 22 квітня 2021 р., К. : НАУ, 2021

***Publications**:* The results were published in following papers:

1. Жмура Є. О. Екологічний стан лісів в Сумській області. ЕКОЛОГІЧНА БЕЗПЕКА ДЕРЖАВИ: Екологічна безпека держави: XIII Всеукраїнської науково-практичної конференції молодих учених і студентів, м. Київ, 23 квітня 2020 р., К. : НАУ, 2020. с. 71

2. Жмура Є.О. The state of forests in Chernihiv Polissya, Environmental audit as an important tool of control and management. ЕКОЛОГІЧНА БЕЗПЕКА ДЕРЖАВИ: Екологічна безпека держави: XIV Всеукраїнської науково-практичної конференції молодих учених і студентів, м. Київ, 22 квітня 2021 р., К. : НАУ, 2021. с. 23-24, с. 61

CHAPTER 1 MIXED FORESTS OF THE NORTH-EASTERN PART OF UKRAINE

1.1 General characteristics of mixed forests

1.1.1 Definition. Dissemination

Mixed forests are a natural zone of Ukraine, characterized coniferous-deciduous natural territorial complexes. It occupies the northern part of Ukraine and stretches for 750 km from the state border (west) to the Central Uplands (east). The southern edge of the zone covers most of the Volyn, Rivne, Zhytomyr, Chernihiv regions, partly Khmelnytsky, Kyiv and Sumy regions. The zone of mixed forests lies on different geostructures of the Eastern European platform: the Ukrainian Shield, the Volyn-Podilsky monocline, the Lviv Paleozoic depression and the Dnieper-Donetsk depression are represented in the figure 1.1.

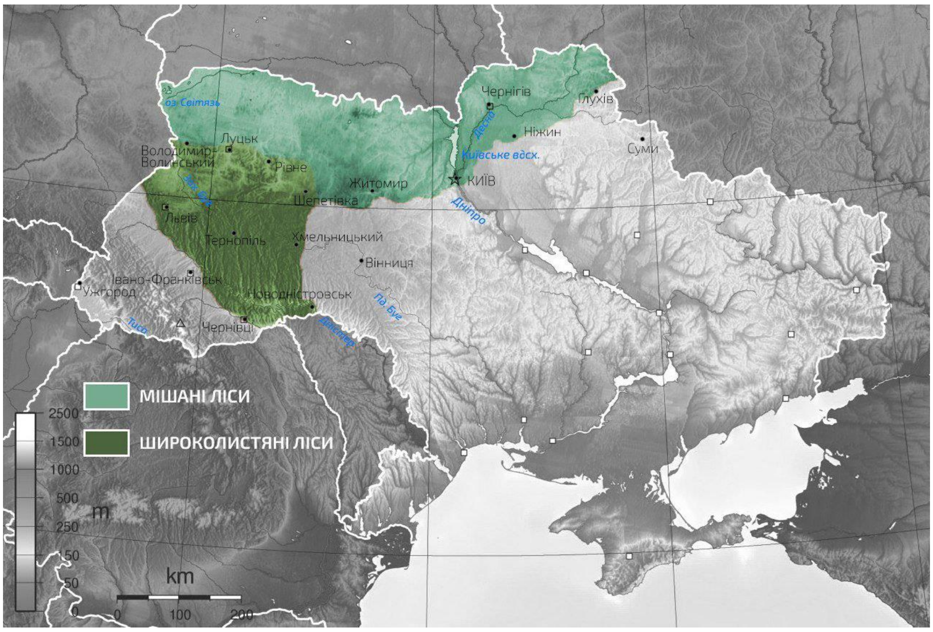

Fig. 1.1. Mixed forests

Characteristic features of the nature of the zone are low relief; sandy and loamy deposits. A temperate continental climate with a positive moisture balance contributes to a dense hydrographic network with wide swampy rivers and valleys, predominately coniferous-deciduous forests, meadows and swampy vegetation under which sod-podzolic and swamp soils were formed. The annual radiation balance is 3100–3200 MJ / m2. In January, the average temperature varies from West to East from -4.5 to -8.0, and in July - from Mon. to the South. from +17 to +19.5 ° C. The growing season lasts 190-205 days. The average annual rainfall is 600-680 mm; evaporation does not exceed 400-450 mm. Humidity coefficient 1.9–2.8. The average density of the river network is 0.29 km / km2, in bass. Gorin - up to 0.5 km / km2. The rivers belong to the Dnieper and Western Bug basins. There are many lakes, the largest of which are Svityaz, Pulemet Lake, Turkish Lake, and Luka. [1].

The zone of mixed forests is called Ukrainian Polissya. Rivers, lakes and swamps characterize the territory. In addition, there is a large artificial reservoir - Kyiv Reservoir.

In the area of mixed forests. Summer is warm and humid. In summer, the sun's rays warm the Earth well because the sun rises high in the sky. Autumn is rainy. Winter is snowy, not very cold, with thaws.

Due to the significant rainfall, the Polissya River is flooded. During the melting of snow on them in the spring, there are long floods. Rain and melt water slowly seeps into the soil, so swamps are formed. Groundwater comes to the surface in numerous streams. They feed rivers, lakes, and swamps. [2].

The river network of mixed and deciduous forests is well developed. In the Polissya lowland, they meander heavily due to the slight slope of the river surface. They have wide valleys. Old lakes are common. Roztocze Upland is a watershed between the Black and Baltic Seas rivers. Prolonged spring floods characterize the rivers of Polissya after melting snow with vast spills and winter lows. In addition to snow, groundwater is an essential food source for rivers, so rivers do not dry up even in the driest years.

The river valleys on the Podil Upland look like canyons, which cut through sedimentary rocks to a depth of 50-200 m. The major rivers are the right tributaries of the Pripyat, Desna, and Dniester, with numerous branches. Some rivers are navigable. The Dnieper crosses forest areas with a small section, on which the Kyiv Reservoir with an area of 922 km2 was established in 1964–1966 [3].

1.1.2 Vegetation and soils

The nature of the vegetation cover of the mixed forest zone coincides with the Polissya geobotany sub-province. The main types of vegetation in Polissya are forest, meadow and swamp. Forests occupy about 30% of the territorial zone. They are represented mainly by pine (forests - more than 60% of the total forest fund of the zone), as well as pine-oak (forests), pine-oak-hornbeam (chest) and alder (alder) forests. Birches are of secondary origin. forests (birches). About 10% of the territorial area is under meadows; they are distributed mainly in floodplains, terrestrial - in areas of felled forests. In the lowlands and transitional swamps - swamp vegetation, represented by grass and grass-moss associations. Upper bogs are insignificant and are occupied mainly by sphagnum cover and low-growing depressed pine. The largest wetlands of the zone are Perebrody (19.6 thousand hectares), Syra Pohonya (10 thousand hectares), Koza-Berezina (9 thousand hectares) and others.

In the forests there is a clear layering. The upper tier is formed by trees, the middle, undergrowth - bushes, the lower - herbaceous plants, mushrooms. In the northern part is dominated by Scots pine and oak. Hornbeam, birch, linden, aspen, maple, and alder have become more common in forests to the south. There are blackberries, dog rose, barberry, hazel, and raspberry among the undergrowth. Cranberries and blueberries are common in wetlands. In the spring in the woods, the first to bloom are snowdrops, snowdrops, rust, anemone. Later - lilies of the valley, violets, bushes, sleep-grass. Only moisture-loving, shade-tolerant plants - ferns, mosses, ungulates - grow under the trees in summer. Other herbaceous plants grow on lawns and edges. Among them: St. John's wort, yarrow, valerian, chamomile, ivan tea. There are many mushrooms in mixed forests. In autumn, the trees drop their leaves, most herbaceous plants die. Fallen leaves and dead plants form forest litter, which retains moisture in the soil.

Herbivores are found in the area of mixed forests: bison, elk, red deer, roe deer, hare, mouse. Predators - wolf, fox, lynx, black ferret, forest marten. Omnivores: wild boar, badger, squirrel, hedgehog. Beavers, otters, and muskrats settle near forest reservoirs. Most birds arrive in the spring: nightingales, cuckoos, starlings, flycatchers, common viper, white stork, gray crane, waders, swans. Permanent inhabitants of the mixed forest zone are woodpecker, capercaillie, black grouse, gray owl, woodpecker. Reptiles are home to vipers, snakes and lizards. There are many frogs and newts in the reservoirs. Rivers and lakes are rich in fish. Many insects live on plants in the forest floor, under the bark of trees. [4].

Typical zonal soils of mixed forests are sod-podzolic, and deciduous forests - gray forest and chernozem podzolic. Several azonal soil types have formed in areas of mixed and deciduous forests. Peat-swamp and meadow soils with productive hayfields were formed in the floodplains of rivers and near lakes. Wetlands are used for arable land after reclamation activities. The most fertile are humus-carbonate soils, common in the southern and southwestern Volyn region on Cretaceous rocks. These soils have from 3 to 12% humus.

The forest cover of the mixed forest zone was 42%, and deciduous forests - were almost 90%. Due to timber harvesting and deforestation, forests now occupy about 25% of Polissya and 13% of Podillya. The main forest-forming species of trees are pine, oak, birch, alder, aspen, and hornbeam. There are also linden, maple, spruce, poplar, and elm. Pine forests (forests) predominate on sod-podzolic sandy soils, and pine-oak (forests) predominate on more fertile sandy and loamy soils. Oak-hornbeam (chest) and beech-oak forests are widespread on fertile grey forest soils. They are mixed with gum and sycamore. Oak-linden forests occur in some places. Alder forests grow in wetter areas. Secondary birch forests have been formed on the fellings of pine and oak-pine forests. Rowan, brittle buckthorn, warty buckthorn, hazel, hawthorn, thorns, black and red elder, and honeysuckle grow in the undergrowth. [2].

The zone of mixed forests by the nature of the soil cover forms the Polissya agro-soil zone. Zonal types of soils are sod-podzolic and swampy, they make up about 95% of the territorial zone. There are humus-carbonate, gray forest soils and podzolic chernozems. The formation of mixed-forest natural-territorial complexes (localities, tracts and facies) is mainly due to the flat relief, surface deposits and the balance of heat and moisture. The following landscape areas play a significant role in the landscape structure of the zone: moraine-zander lowlands, flat and slightly undulating, with sod and sod-podzolic soils under pine and pine-oak forests; sandy lowlands, flat undulating and wavy, with sod and podzolic soils under pine and pine-oak forests; alluvial-zander lowlands, flat undulating and wavy, with sod-podzolic soils under pine-oak forests; sandy terraces, hilly-wavy with sod-podzolic soils under pine forests, with lowland swamps; forest and meadow-swamp floodplains. Natural territorial complexes are characterized by unfavourable physical and geographical processes of varying intensity (wetlands, coastal erosion, deflation, karst). [1].

1.2 Natural state of mixed forests of the north - eastern part of Ukraine

1.2.1 State of forest ecosystems

Forests are one of the largest ecosystems in terms of capacity, biodiversity, duration of development, carbon deposition, and the scale of biosphere functions. At the local level, forests are the main stabilizing element of the landscape, which prevents the degradation of all its components: vegetation, fauna, water, soil. Forest cover in different natural areas has significant differences and does not reach the optimal level at which forests have the most positive impact on climate, soils, water resources, counteract erosion processes, as well as provide more wood. The age structure is dominated by medieval plantations, the share of mature and overripe plantations18.7%. Although the average age of forests is over 60 years, there is a gradual ageing of forests, which leads to the deterioration of their sanitary condition.

According to operative data, in 2019 the total area of deforestation according to the State Forest Agency was 270 thousand hectares, which indicates a decline in outbreaks of bark deforestation due to timely measures to improve the sanitary condition of forests (sanitary felling).

Last year, forest pests and diseases affected artificial forests in eastern Ukraine the most. Still, recently, due to favourable climatic conditions, forest pests and diseases have spread throughout Ukraine. Forest protection works are carried out by the specialized forest protection service, which is organized based on 7 state technological forest protection enterprises. The priority of the forest protection service is the development and implementation of biological means of forest pest control. Such standards are not harmful to humans and the environment and are used in densely populated areas of Ukraine and in forests where the use of chemical pesticides is prohibited. [5].

Manifestations of climate change affect all-natural ecosystems of our planet, and Ukrainian forests are no exception. Foresters have been talking for many years about increasing the area of drying and weakened pine and oak forests. Drying of swamps and wetlands due to prolonged droughts is becoming more frequent, even in Polissya, a traditionally swampy region that has been ruthlessly reclaimed in the last century.

And the mass fires of 2020, which, against the background of a long drought and almost snowless winter, covered more than 150 thousand hectares of forests from Zhytomyr to Sumy, have already shown everyone the vulnerability of our forests and ourselves to the climate crisis.

In general, further intensification of the climate crisis in the coming decades threatens the following consequences for Ukraine's forests:

• Decreased forest productivity and, consequently, carbon sequestration due to more frequent and prolonged droughts;

• Increasing deforestation areas, especially monocultures in unfavourable climatic and forest conditions - for example, spruce plantations in the lowlands of the Carpathians, where beech and fir forests have traditionally grown, or pine crops on rich soils, which are naturally characterized by deciduous forests;

• Increasing the likelihood of mass spread of forest pests and invasive species;

• More frequent and powerful forest and peat fires and prolonged smoking of settlements;

• Increasing the probability of windstorms due to more frequent storms;

• Disappearance of a number of forest biotopes, such as small forest swamps and wetlands, island spruces in Polissya, and as a result - a significant reduction in forest biodiversity.

At the same time, forests, like all other productive natural ecosystems, have great potential to mitigate the negative impact of our society on the climate, as they absorb a significant share of carbon dioxide emissions.

Due to this, the overall balance of emissions in the sector "land use, land use change and forestry" has been negative for a long time - absorption prevailed. Unfortunately, the situation has worsened in recent years, and in 2018, greenhouse gas emissions in this sector exceeded their absorption for the first time. [6].

1.2.2 Environmental problems of mixed forests

According to their purpose and location, forest areas perform mainly water protection, protection, sanitation, health, and meet the needs of society in forest resources. They are located very unevenly on the territory of Ukraine - in Polissya and the Ukrainian Carpathians. Of course, coniferous forests predominate - spruce and pine occupy 41.9% of the total area, 27.5% - oak, 8.9% - beech. In addition, grow aspens, hornbeams, ashes, birches and larch. In some places you can find related species of trees, but this is not often, because they simply do not survive in our climate.

In Ukrainian forestry, the division of forests into young (up to 40 years old), middle-aged (40-60 years old), arriving (60-80 years old) and mature and overripe (over 80 years old) has been preserved. This division is because it is economically viable. However, unfortunately, Ukraine's forests are liquefied and characterized by the uneven distribution of forest plantations by age groups. As a result, young and medieval trees predominate (70-80% of the total area) and the number of mature and overripe trees is insufficient (6-15%).

According to the State Agency of Forest Resources of Ukraine, illegal logging has been steadily declining for a long time, during 2003-2007. However, in 2008 it amounted to 20.1 thousand cubic meters, 2.2 thousand more than in the previous year, 2007. However, these statistics are mainly about illegal logging by the local population, so it reflects very small volumes.

As an example, in 2010, 8,047 cubic meters of wood were destroyed in the region, and the figures are not standing still. By December 1 of this year, it is planned to install GPS trackers on cars that carry wood. This will help not only to monitor fraud and the passage of wood, but also to monitor the use of cars during working hours and evaluate workers' work.

In winter, logging increases. After all, closer to the winter holidays and mass holidays, there are also unauthorized felling of trees, which no one records. "These are small fellings that are not recorded anywhere. No one even knows the extent of those feelings. Everything is measured on a large scale, and no one controls some people who cut down 10 fir trees. In general, in the regions with the greatest forest cover, the number of fellings decreases over the years. Compared to 2013, in 2014 the volume of illegal logging decreased by 20%. However, the figures remain high. "In principle, if you look globally, logging is minimized. In general, the estimate is made for a quarter, not specifically for one feeling, as represented in Figure 1.2.

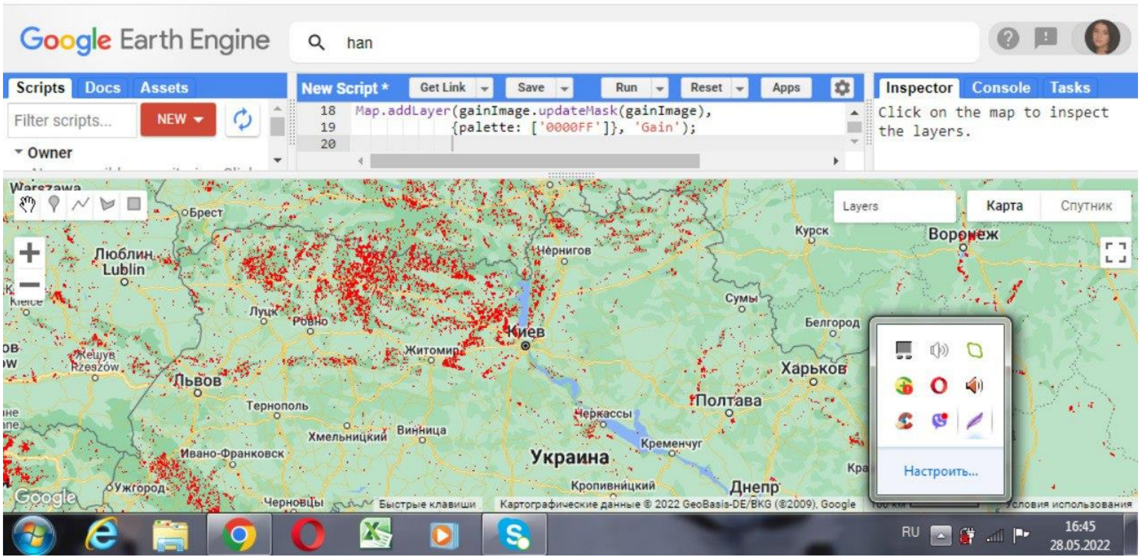

Fig. 1.2. Deforestation as of 2021.

We must not forget about forest fires. The situation is agitated in the eastern and southern regions, where there are the most artificial forests. A significant increase in fire danger contributes to the constant rise in recreational load on forests. There are also more and more mass violations of fire safety requirements by the population. More than 98% of fires occur for this reason. [7].

1.3Conclusions to chapter 1

Mixed forests occupy the northern part of Ukraine. Sod-podzolic soils characterize this natural area with 3 to 12 per cent humus, coniferous-deciduous forests, swampy vegetation and a temperate climate. Forests cover about 30% of the entire forest area of the northeast. In this natural area, the layering of vegetation is distinguished. Mixed forests have a great variety of animals and plants listed in the Red and Green Books of Ukraine. Currently, the state of forest ecosystems is not in perfect condition, primarily due to large areas of bark drying, deforestation and fires, which leads to reduced forest productivity, increased insect pests and the disappearance of several forest habitats. Therefore, the priority now is the development of biological methods for the reproduction of mixed forests.

CHAPTER 2 METHODS OF REMOTE FOLLOW-UP

2.1 Type of remote sensing

2.1.1 Google Earth Engine

Earth Engine is a cloud-based platform for geospatial data analysis on a planetary scale. Earth Engine is unique because it empowers Earth remote sensing scientists and a broader audience that lacks the technical capabilities to use traditional big data processing tools. In addition, earth Engine is a multi-petabyte data integrated with a high-performance server cluster for parallel computing.

The Earth Engine contains many publicly available geospatial datasets:

-Space and aerial photographs were taken in different ranges of the electromagnetic spectrum

-Weather forecasting models and climate parameters

-Land cover maps

-Topographic and socio-economic datasets

-Various environmental parameters (for example, soil moisture or the outgoing thermal radiation of the Earth).

Users can request and analyze data from a public catalog, or upload their own. Most of the catalog consists of Earth remote sensing images, including the entire archive of the Landsat mission, as well as complete archives of data from the European satellites Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P with various levels of processing, climate forecasts, data on the Earth cover, geophysical, ecological and socio-economic datasets.

The Google Earth Engine (GEE) portal provides enhanced opportunities for undertakingearth observation studies. Established towards the end of 2010, it provides access to satellite and otherancillary data, cloud computing, and algorithms for processing large amounts of data with relativeease. [25].

2.1.2 Hansen Global Forest Change

In partnership with Global Forest Watch, the Global Land Analysis and Discovery Laboratory at the University of Maryland provides annually updated global forest loss data from Landsat time-series images. These data, available here, are a relative indicator of the Spatio-temporal trends in the dynamics of forest loss worldwide. However, discrepancies exist due to the following factors:

Differences in Landsat sensor technology include Thematic Mapper, Enhanced Thematic Mapper Plus, or operational ground image data. For example, Operational Land Imager (2013) on board the Landsat 8 spacecraft uses pressure sensor technology, which increases the time spent on observation compared to previous whiskey systems. The result is a signal-to-noise ratio much higher than that of Landsat 7 Enhanced Thematic Mapper Plus sensor. The increased signal provides better ground change detection capabilities.

The Hansen et al. (2013) The Global Forest Change dataset in Earth Engine represents a forest change with a resolution of 30 meters globally between 2000 and 2014. The global acquisition strategy has improved over time: acquisitions have grown from less than 150,000 per year in the early 2000s to more than 250,000 per year in recent years. In addition, Landsat 7 was the only input for the original product from 2001-2012, and has been affected by a malfunction of the scan line corrector in Enhanced Thematic Mapper since 2002, when nearly a quarter of each scene's fingerprint was not collected. In addition, the gap between the decommissioning of Landsat 5 in 2011 and the launch of Landsat 8 in 2013 led to a total global collection of 2012 with less than 100,000 Landsat 7 images.

The Hansen Global Forest Change use the collect of Landsat images from 2000 to 2021 year. Automatic satellites "Landsat" are designed to study the natural resources of the Earth or solve the problems of geography in the broadest sense of the word. The first of the five satellites of this series was launched from the United States in July 1972. It was established not to take pictures of the Earth during the orbital flight but to collect material suitable for computer processing with its multi-zone and periodically repeated long-term surveys. For example, it was solving agriculture and forestry issues, geological mapping and prospecting and exploration of mineral deposits, spatial planning of territories, and oceanography. [26].

Algorithm adjustments, including modification of training data and input function space. For example, the original map of forest losses in 2001-2012 was created using a single algorithm, compared to subsequent years, which were added separately. In addition, the models have been redesigned to improve performance since 2012. Such changes in the display method can lead to inconsistencies from year to year.

Although the cartographic data obtained are largely a viable relative indicator of trends, caution should be exercised when comparing changes at any interval. The use of a temporary filter, such as a 3-year moving average, is often useful for identifying trends. However, the final estimate of the area should not be made by counting pixels from forest loss layers.

The Intergovernmental Panel on Climate Change guides reporting on land area and land and land use change, requiring the use of estimates that do not exceed or underestimate the dynamics as much as possible and have known uncertainties. Maps provided by GLAD do not have these properties. However, maps can be used to facilitate appropriate probability-based statistical methods to obtain statistically valid forest areas and changes. In particular, maps can be used as a stratifier to target forest area and / or change sampling probabilities. The GLAD team demonstrated the following approaches using GLAD forest loss data when estimating the area based on a sample (Tyukavina et al., ERL, 2018, Turubanova et al., ERL, 2019, and Potapov et al., RSE, 2019, among others).

Using Landsat 8 OLI data for 2013,

Reprocessing of data, starting in 2011, to measure losses,

Improved training data to calibrate the loss model,

Improved quality assessment models for each sensor for filtering input data and

Improved input spectral characteristics for the construction and application of the loss model.

These changes lead to different and improved detection of global forest loss. However, the years before 2011 have not yet been re-processed in this way, and as a result, users will notice discrepancies. It should also be noted that a full verification of the results using Landsat 8 was not performed. Such an analysis may reveal a more sensitive ability to detect and map forest disturbances using Landsat 8 data. The integrated use of data version 1.0 2000-2012 and updated data version 1.9 2011-2021 should be performed with caution.

Some examples of improved detection of changes in the 2011-2021 update include:

Improved detection of boreal forest losses due to fire.

Improved detection of small-scale agricultural felling in dry and wet tropical forests.

Enhanced detection of sample registration.

Improved detection of short-cycle plantation cleanup in subtropical and tropical ecozones. [25].

2.1.3 Spectral characteristics of growth

Much of the land is covered with vegetation. For the most part, geological mapping and other studies are forced to be carried out in areas with vegetation cover. Often in such areas, geological mapping is simply impossible without surveying and analyzing regional and local vegetation communities. For geological aspects, spatial changes in the type, composition and density, as well as in the height of vegetation, are essential since, above all, in areas where there is no cultivated agriculture, there is an experimentally established close relationship between vegetation, soil profile and substrate geology. Vegetation, in this case can serve as a direct indicator of lithofacies and structural varieties of the geological substrate or base. For the formulation of geological problems, even the localization of landscape areas in which plants are under unfavorable conditions, for example, a raised or lowered groundwater level, an anomalous concentration of salts or metals (in reservoirs and wastewaters) or an anomalous ratio of them in the soil profile, which may indicate on the location near the surface of the outputs of oxidized sulfide ores or other deposits.

Differences in vegetation cause convective movement of air, and on multispectral images of multispectral imaging systems lead to changes depending on the properties of vegetation, tonality and texture of images. In the geological interpretation of panchromatic black-and-white and color aerial photographs and color infrared photographs, one almost always works with relative tonal and textural differences in neighboring areas covered with vegetation. With the introduction of multi-zonal imaging methods, which involve simultaneous imaging of the same area in different spectral ranges, it has become possible to more accurately distinguish meadow grasses, groups of shrubs or forests based on the wavelength-dependent reflective, absorbing and thermal characteristics of plants (primarily their communities). Then black and white and even colour infrared aerial photographs.

Currently, they are studied using numerical methods for recording and processing spectral and multi-zone images, which represent the differences in the spectral characteristics of plant communities in the form of an image with increased contrast. Here, first of all, of interest are such methods that allow the correlation and combination of spectral data over two or more channels.

To select the necessary spectral channels for surveying areas covered by plants and, based on the spectral intensity recorded by the sensors, to conclude the uniformity or mixed species composition of vegetation or anomalous conditions for their growth, the user-interpreter of remote sensing data must have basic ideas about the physical and physiological causes of differences spectral characteristics of plants and their communities. First of all, it is necessary to know the external factors that make up the interaction of the incident solar radiation flux and the plant and affect the spectral signal of plants or their communities. In recent years, in remote sensing, the spectral characteristics of vegetation have been studied by many working groups both in laboratories and on the ground.[10].

2.2 The state of mixed forests of Sumy region according to remote data

Patterns of historical deforestation of the mixed forest of Ukraine

The algorithm uses training datasets of continuous forest cover and annual phenological metrics obtained from global datasets to build up a regression tree algorithm that generates a tree cover map. The ‘phenological yearly metrics’ consist of information about phenological variations in terms of annual means, maximum, minima and amplitude of spectral data. The metrics are built up for different bands (red, NDVI and surface temperature). The global 30-m spatial resolution dataset quantifies changes in forest extent and height, cropland, built-up lands, surface water, and perennial snow and ice extent from 2000 to 2020.

In recent decades, the rapid development of remote sensing technology has enabled the mapping of deforestation using satellite images to become the primary approach for monitoring mixed forests. This technique allows large-scale monitoring of forest resources, particularly in remote and difficult-to-reach areas or where there is a need to fill information gaps expeditiously and automatically.

This research work has been done by applying slight variations of the algorithm to produce a region-specific mixed forest map of the Sumu region.

Gross forest loss producer’s and user’s accuracy >88% and 89% respectively were found over Ukraine. In addition, the maps captured changes in forest cover from 2000 to 2018 over this region (fig. 2.1.).

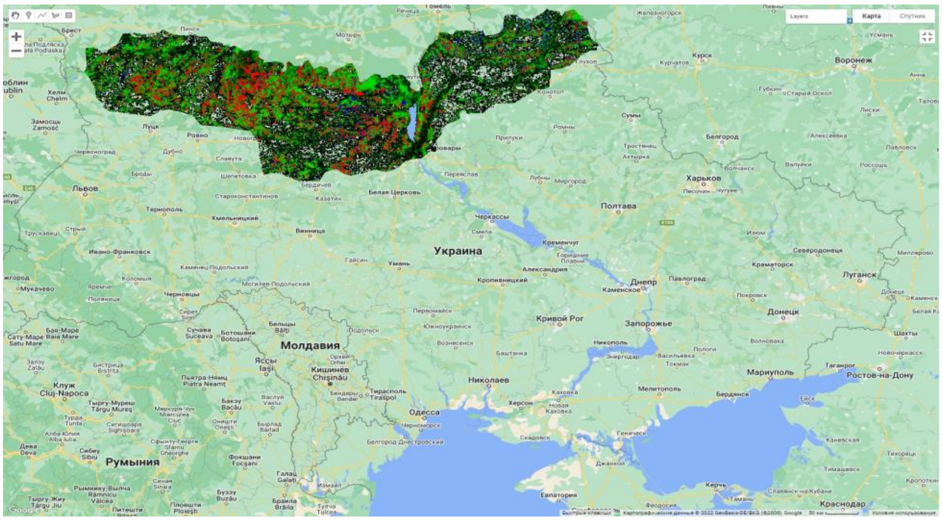

Fig. 2.1. Forest change was estimated by Hansen et al. (2013). Ukraine mixed forest

This results in an image that is green where there's forest, red where there's forest loss, blue where there's forest gain, and magenta where there's both gain and loss. A closer inspection, however, reveals that it's not quite right. Instead of loss being marked as red, it's orange. This is because the bright red pixels mix with the underlying green pixels, producing orange pixels. Similarly the pixels where there's forest, loss, and gain are pink - a combination of green, bright red and bright blue.

The global forest loss and disturbance pattern (Figure2.2.) highlights agricultural expansion frontiers, timber production regions, and the effects of stand-replacement wildfires.

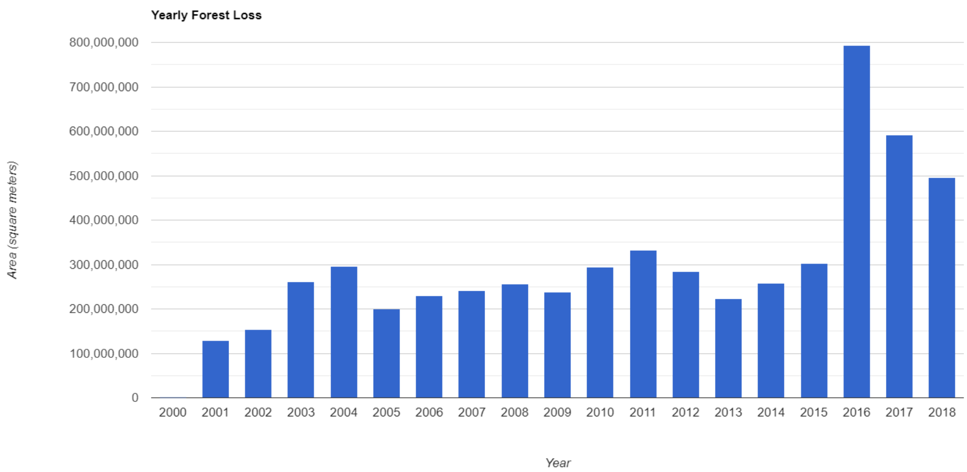

Fig. 2.2. Yearly Forest Loss of mixed forest in Ukraine

As a result, net forest loss area is highest for 2000 and 2001 year and the minimum start from 2016 to 2018 year.

While forest area has declined, human populations have increased, which means that per capita forest area is reducing – a trend that has existed for many millennia.

Forests and forest management have changed substantially over the past 25 years. But, overall, this period has seen a series of positive developments. For example, even though the extent of the world’s forests continues to decline as human populations continue to grow and demand food and land increases, net forest loss has been cut by over 50 percent.

In 2000 Ukraine had 3043 million ha of mixed forest; by 2018 this area had decreased to 2631 million ha.

This is a change from 31.6 percent of global land area in 1990 to 30.6 percent1 in 2015. Yet deforestation, or forest conversion to other land use, is more complicated than that. Forest gains and losses occur continuously, and forest gains are particularly difficult to monitor even with high-resolution satellite imagery. The dynamics of natural and planted forest area differ across national circumstances and forest types, figure 2.3

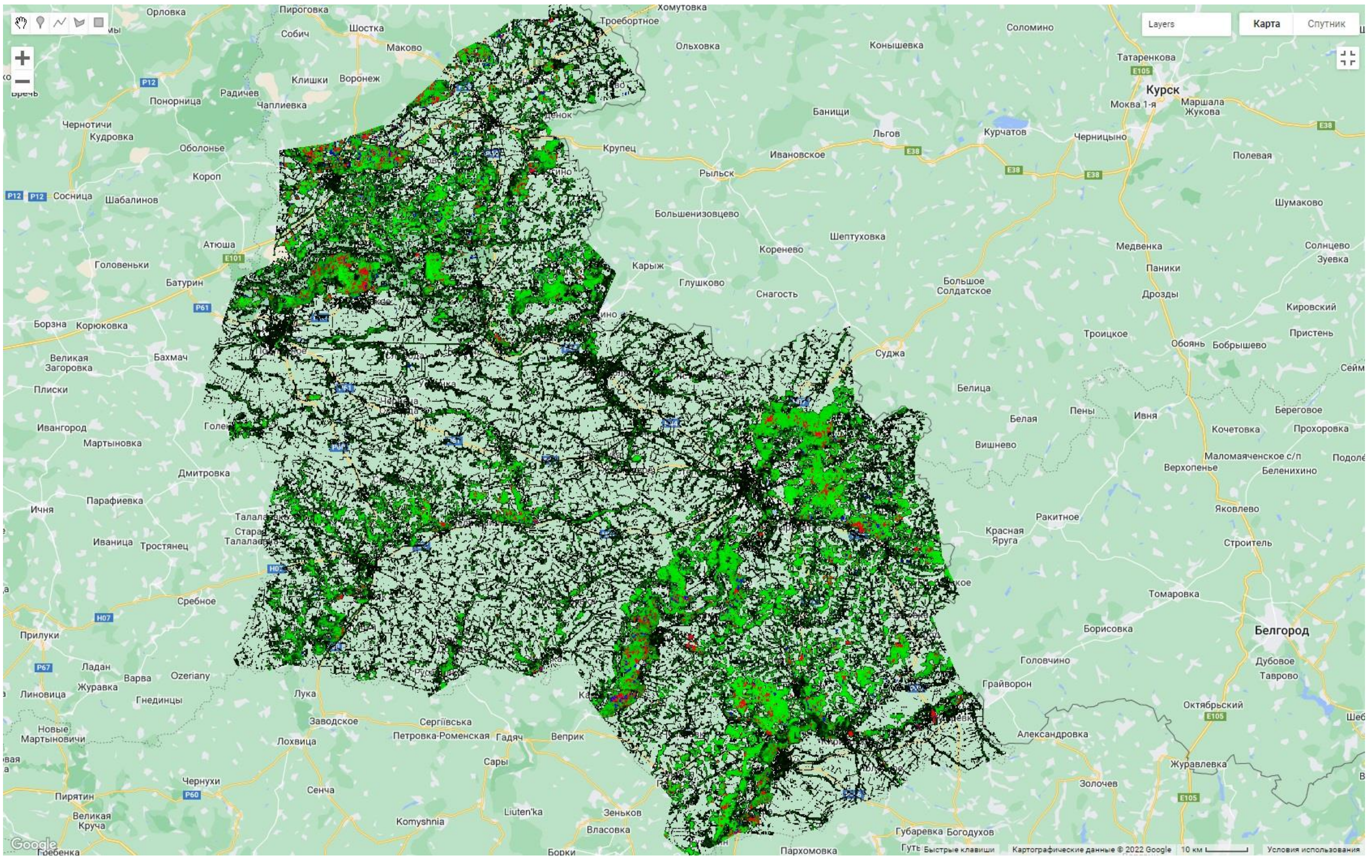

Fig. 2.3. Forest change in Sumy Oblast

Forest resource data have improved in recent years. Ukraine now has more and better information about their forest resources than ever before, and as a result, we have a better picture of global forest trends,figure 2.4.

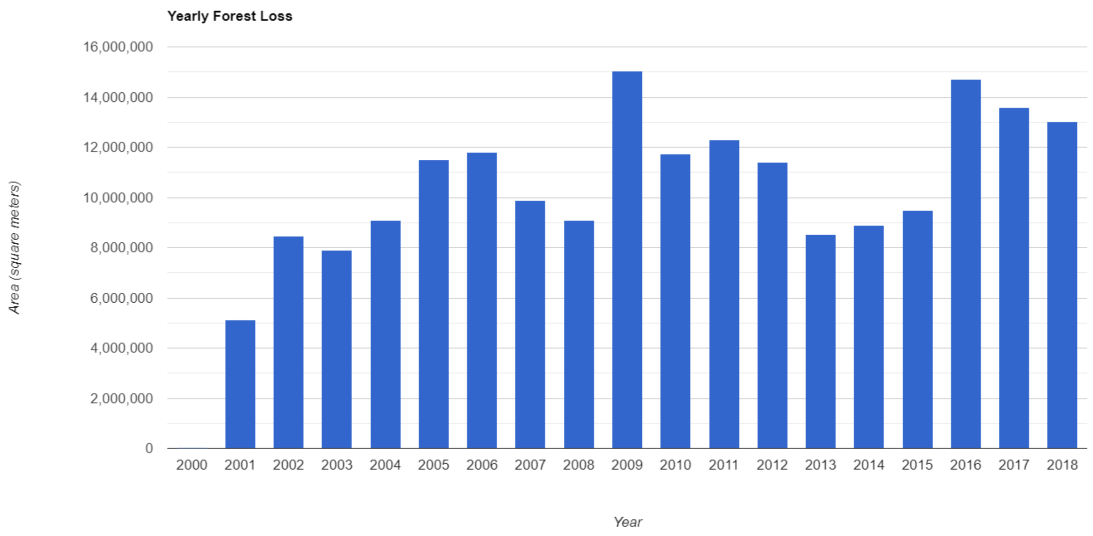

Fig. 2.4. Yearly Forest Loss of mixed forest in Sumy Oblast

The situation with the development of forests in the Sumy region is homogeneous. However, a sharp decline in their quantity and quality was recorded only in 2001 and 2013-2015. The period from 2009 to 2012 and 2016 to 2018 are characterized by an increase in the number of mixed forests. In recent years, in the north of Sumy region, pine plantations have significantly prevailed, and in the south of the region - oaks and spruces. In general, seedlings of maple, maple, white linden, ash and many other plant species were planted throughout the territory. Measures have also been taken to preserve the plants listed in the Red and Green Books of Ukraine, which has increased their number.

2.3 Impact on forest ecosystems as a result of hostilities

It is not even possible to fully assess the impact of the war on the environment due to a lack of accurate information. There are two reasons for this. First of all, even collecting this data is dangerous for specialists as active hostilities continue. Second, not all information can be made public for tactical purposes.

However, it is clear that the longer the war lasts, the more damage it will do to the environment and the more consequences we will have in the future.

Russian troops moved within the existing infrastructure in the first days of the full-scale invasion. However, military action has dragged on - and so the Russians are changing tactics and preparing for long confrontations. To do this, they form bases and fortifications. This means that they are moving deep into natural areas: they occupy forests and areas of nature reserves. The movement of heavy equipment, construction of fortifications and hostilities damage the ground cover. This leads to the degradation of vegetation and increases wind and water erosion.

As a result of hostilities, part of the forests in Kyiv, Chernihiv, Sumy, Luhansk, Donetsk and Kherson oblasts are currently under the control of the occupiers. Therefore, it is not yet possible to estimate property and forestry losses. However, there are already many fallen missiles in the forests, as well as unexploded ordnance. As practice shows, this will pose a potential danger to people for many decades.

The direct damage to the forest ecosystem is about $ 135.5 million. The area of forested areas covered by hostilities is 2907 thousand hectares (average reserve per 1 hectare - 202 cubic meters), then their total stock is 588 million cubic meters. m. Given that hostilities will be destroyed 0.5% of the stock (the cost per cubic meter of depersonalized wood is 1337 hryvnia) we get 588 * 0.005 * 1337 = 3 930.78 million hryvnia or 135.5 million dollars.

Indirect damage to the forest ecosystem, ie delayed in time, amounts to $ 53.6 million. The area of forested areas covered by hostilities is 2,907 thousand hectares (the average annual change in stock per 1 hectare in the forests of the State Forest Agency is 4 cubic meters). Considering that as a result of hostilities the annual change of stock for 10% of the area will be stopped (the cost of a cubic meter of depersonalized wood is 1337 UAH) we get 2907 * 0.1 * 4 * 1337 = 1554.7 million hryvnias or 53.6 million dollars.

The damage to forest ecosystem services is $ 185 million. According to international experts, the amount of forest ecosystem services is estimated at $ 37 billion a year. Given that as a result of hostilities will be destroyed 0.5% of the stock, which produces ecosystem services, we get 37 * 0.005 = 185 million dollars.

The total amount of damage inflicted by Russian troops is 438.3 million dollars or 12.7 billion hryvnias. [27].

About 200 territories of the Emerald Network with an area of 2.9 million hectares are under threat of destruction. The Emerald Network is a network of protected areas created to preserve species and habitats that need protection at the European level, but are located in non-EU countries. All these are habitats for thousands of species of plants and animals. These areas play an important role in protecting biodiversity and preserving the climate. Habitats of some rare and endemic species and settlements are in the zone of active hostilities, which threatens their existence, such as virgin unploughed steppes, Cretaceous slopes in the Donetsk region, coastal settlements in the southern areas, swamps in the north are represented in the figure 2.5.

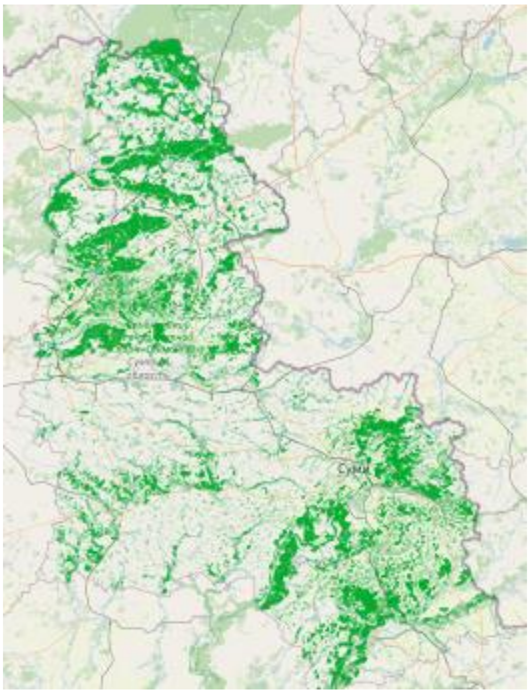

Fig. 2.5. Sumy forests

As a result of hostilities, part of the forests in Kyiv, Chernihiv, Sumy, and oblasts are currently under the control of the occupiers. It is not yet possible to estimate property and forestry losses. There are already a large number of fallen missiles in the forests, as well as unexploded ordnance. According to the practice and regular reports of the same SES with information about accidentally found World War II bombs, this will be a potential danger to people for many decades.

Also, Russian troops, destroying our forests, use wood to build fortifications, build infrastructure, heat and cook.

With the onset of spring, the fire season begins and the risk of fires in ecosystems due to shelling increases. After the snow melts, last year's grass dries up, which can quickly flare up. In dry conditions, fires spread instantly and over large areas. SES services will not be able to work and eliminate fires in the territories occupied by Russian troops. Also favorable conditions for fires spread in monocultural pine plantations in northern and eastern Ukraine.

In addition to forests, wetland ecosystems and peatlands are widespread in the north of the country, where active hostilities are taking place. Most of Ukraine's peatlands are drained, so there are favorable conditions for peat fires. Such fires are difficult to extinguish and, as usual, the continuation of hostilities in the northern regions will have serious consequences for both the environment and human health. Toxic substances such as carbon monoxide and dioxide, fine dust with a particle diameter of 2.5 microns (typical of combustion), volatile organic compounds containing acrolein and formaldehyde are released into the air during the combustion of peatlands.

Forests in the territories temporarily occupied by Russia, or in the war zone. Planned deforestation, which was carried out in peacetime by state and municipal forestries, is currently almost non-existent. Sell felled wood to anyone and nowhere. And the occupiers are stealing forestry equipment - both cars and trucks and tractors.

The occupiers themselves are also unable to carry out logging on an industrial scale. And will not have in the coming months.

Many foresters are now at the front or in the guerrillas, control by other authorities is limited. Therefore, the protection of forests in the occupied territories is a problem.

As a result, locals chaotically cut down trees for heating near many settlements. But the scale of such felling is much smaller than the scale of planned felling carried out by forestries in peacetime.

There are also cases of the individual trees being cut down by the occupiers to equip fortifications, the use of forestry forests to equip their bases, and so on.

Thus, in the short term, logging will not significantly impact Ukraine occupied forests. But this does not mean that forests are not threatened.

In peacetime, forest fires were extinguished by foresters and firefighters. But not now, because the occupiers are blocking the activities of Ukrainian structures. In addition, it is becoming warmer and drier, so in the coming months in the occupied forests may be fires of unprecedented proportions. No one will put them out. Ukraine could lose hundreds of thousands of hectares of forest in a few months.

The only way out of the situation is the complete de-occupation of the territory of Ukraine. Almost everyone is working on this now. [24].

2.4 Conclusion to chapter 2

During the study, continuous forest cover data platforms and phenological indicators were used to build a tree regression algorithm. In recent years, remote sensing technologies have become the main approach to monitoring mixed forests. Thanks to the Earth Engine platform, it is possible to perform geospatial analysis of data on a planetary scale, calculation by pixel and spectral decomposition analysis of structures. It is used for statistical calculations, time series of images. This platform uses Landsat satellite imagery. The research was conducted on the basis of scientific ideas and allows to use the obtained criteria for the study of mixed forests. Thanks to him, pictures of mixed forests of Ukraine in the period from 2000 to 2018 were taken, and the change in forest cover during this period was shown. Global Forest Watch provides annual access to information on forest loss. An analysis was carried out with the help of Hansen Global Forest Change, which revealed mass deforestation of mixed forests. Which in the subsequent analysis was not authorized. As a result of fires, forests were destroyed.

CONCLUSIONS

1) Analyzing the ecological conditions of the north - eastern part of mixed forests, we can conclude that this natural area is characterized by low relief; sand deposits; temperate continental climate. In this area there are wide swampy river valleys; mainly coniferous-deciduous forests, meadows and swampy vegetation, under which sod-podzolic and swamp soils were formed. Several azonal soil types have formed in areas of mixed and deciduous forests. There are many rivers in this natural area. In the forests there is a clear layering. The upper tier is formed by trees, the middle, undergrowth - shrubs, the lower - herbaceous plants, mushrooms. Herbivores, carnivores and omnivores are found in the area of mixed forests. Most birds arrive in the spring. Reptiles are home to vipers, snakes and lizards, under the bark of trees, many insects live on plants. For natural - territorial complexes are characterized by unfavorable physical and geographical processes of varying intensity (wetlands, coastal erosion, deflation, karst).

The forest is a product of the natural ecosystem, which has great potential to mitigate the negative impact of our society on the climate, as it absorbs most of the carbon dioxide emissions.

Due to this, the overall balance of emissions in the sector "land use, land use change and forestry" has been negative for a long time - absorption prevailed. In recent years, the situation has deteriorated, and in 2018, for the first time, greenhouse gas emissions in this sector exceeded their absorption.

2) Remote sensing technologies have become the main approach to monitoring mixed forests in recent years. Thus, in the study of the state of mixed forests of Sumy region, a cloud platform was used for geospatial analysis of data on a geoplanetary scale Google Earth Engine. This technique allows for large-scale monitoring of forest resources, especially in remote and hard-to-reach areas or where information gaps need to be filled quickly and automatically. The research part of the work was performed by applying small variations of the algorithm to create a region-specific map of mixed forests of Sumy region. Forests and forestry management have changed significantly over the last 25 years.

As a result, the net area of forest losses is the largest in 2000 and 2001, and the minimum - from 2016 to 2018. In 2000, Ukraine had 3,043 million hectares of mixed forests; by 2018, this area has decreased to 2,631 million hectares. Forest gains and losses occur continuously. Forest growth is particularly difficult to control, even with high-resolution satellite imagery. In recent years, data on forest resources have improved. Ukraine now has more and better information about its forest resources than ever before, and as a result we have a better idea of global forest trends. The situation with forest development in Sumy region is homogeneous. However, a sharp decline in their quantity and quality was recorded only in 2001 and 2013-2015. The period from 2009 to 2012 and from 2016 to 2018 are characterized by an increase in the number of mixed forests. This study shows the state of forests up to and including 2018. Given the current events, the condition of mixed forests in Sumy region has deteriorated and their number has decreased. Research on this issue is a topical issue for the future.

3) Today the problem of the impact of hostilities on forest ecosystems is acute. The movement of heavy equipment, construction of fortifications and hostilities damage the ground cover. This leads to degradation of vegetation and increases wind and water erosion.

As a result of hostilities, part of the forests in Kyiv, Chernihiv, Sumy, and oblasts were under the control of the occupiers. Forests already have large numbers of missiles, as well as unexploded ordnance, which could pose a potential threat to the forest ecosystem for decades. About 200 territories of the Emerald Network with an area of 2.9 million hectares are under threat of destruction.

Habitats of some rare and endemic species and habitats are in the zone of active hostilities, which threatens their existence, such as virgin unploughed steppes, Cretaceous slopes, swamps in the north.

With the onset of spring, the fire season began and the risk of fires in ecosystems due to shelling is growing.

At the moment, there is no planned felling of trees due to the fact that many foresters are now defending our country. This led to uncontrolled deforestation by both the occupiers and the locals. The occupiers are blocking the activities of Ukrainian structures. In addition, it is becoming warmer and drier, so in the coming months in the occupied forests may be fires of unprecedented proportions. No one will put them out, Ukraine could lose hundreds of thousands of hectares of forest in a few months. The only way out of the situation is the complete deoccupation of the territory of Ukraine.

APPENDICES

Appendix A.

Script Google Engine

```
var shape_file= table.geometry();
//var shape_file= table2.geometry();
//var shape_file= table3.geometry();
//var shape_file= table4.geometry();

var gfc2018 = ee.Image('UMD/hansen/global_forest_change_2018_v1_6').clip(shape_file);

//Whole script
var treeCover = gfc2018.select(['treecover2000']);
var lossImage = gfc2018.select(['loss']);
var gainImage = gfc2018.select(['gain']);

// Add the tree cover layer in green.
Map.addLayer(treeCover.updateMask(treeCover),
    {palette: ['000000', '00FF00'], max: 100}, 'Forest Cover');

// Add the loss layer in red.
Map.addLayer(lossImage.updateMask(lossImage),
        {palette: ['FF0000']}, 'Loss');

// Add the gain layer in blue.
Map.addLayer(gainImage.updateMask(gainImage),
        {palette: ['0000FF']}, 'Gain');

var gfc2018 = ee.Image('UMD/hansen/global_forest_change_2018_v1_6');
var lossImage = gfc2018.select(['loss']);
var lossAreaImage = lossImage.multiply(ee.Image.pixelArea());

var lossYear = gfc2018.select(['lossyear']);
var lossByYear = lossAreaImage.addBands(lossYear).reduceRegion({
  reducer: ee.Reducer.sum().group({
    groupField: 1
    }),
  geometry: shape_file,
  scale: 30,
  maxPixels: 1e9
});
print(lossByYear);

Export.image.toDrive({
  image: gfc2018.select(['treecover2000', "loss", "gain" ]), // канали, які будуть збережені
  description: 'gfc2018', // назва файлу

  region: shape_file, // область, по якій буде обрізано зображення

});

var Tree_cover_url = gfc2018.clip(shape_file).getThumbURL({

  bands: ['treecover2000'], //канали, які будуть відображені
  palette: ['000000', '00FF00'], max: 100,
  'dimensions': '1000', //вибір розміру в пікселях найбільшої сторони зображення (в данному випадку - довжини)
  'region': shape_file, //визначення території дослідження
  'crs': 'EPSG:3857' //визначення системи координат за кодуванням EPSG (https://epsg.io/?q=)
});
print('Tree_cover',Tree_cover_url);
```

```
var Loss_url = lossImage.updateMask(lossImage).clip(shape_file).getThumbURL({

  bands: ['loss'], //канали, які будуть відображені
  palette: ['FF0000'],
  'dimensions': '1000', //вибір розміру в пікселях найбільшої сторони зображення (в данному випадку - довжини)
  'region': shape_file, //визначення території дослідження
  'crs': 'EPSG:3857' //визначення системи координат за кодуванням EPSG (https://epsg.io/?q=)
});
print('Loss', Loss_url);

var Gain_url = gainImage.updateMask(gainImage).clip(shape_file).getThumbURL({

  bands: ['gain'], //канали, які будуть відображені
  palette: ['0000FF'],
  'dimensions': '1000', //вибір розміру в пікселях найбільшої сторони зображення (в данному випадку - довжини)
  'region': shape_file, //визначення території дослідження
  'crs': 'EPSG:3857' //визначення системи координат за кодуванням EPSG (https://epsg.io/?q=)
});
print('Gain', Gain_url)

var statsFormatted = ee.List(lossByYear.get('groups'))
  .map(function(el) {
    var d = ee.Dictionary(el);
    return [ee.Number(d.get('group')).format("20%02d"), d.get('sum')];
  });
var statsDictionary = ee.Dictionary(statsFormatted.flatten());
print(statsDictionary);

var chart = ui.Chart.array.values({
  array: statsDictionary.values(),
  axis: 0,
  xLabels: statsDictionary.keys()
}).setChartType('ColumnChart')
  .setOptions({
    title: 'Yearly Forest Loss',
    hAxis: {title: 'Year', format: '####'},
    vAxis: {title: 'Area (square meters)'},
    legend: { position: "none" },
    lineWidth: 1,
    pointSize: 3
  });
print(chart);
```

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