The project 'For everyone saved a tree FOREST' is co-funded by the EU through the Interreg-IPA CBC Bulgaria-Serbia Programme.

Activity 4. 'Detecting and control of forest pests and assessment in the context of related ecosystem services'

SCIENTIFIC REPORT

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INTRODUCTION

According to the synthesis report of the Intergovernmental Panel on Climate Change (IPCC, 2014), in the period 1880-2012, the average global temperature increased by 0.85 °C. As a result of this increment, some environmental consequences are observed, such as droughts, increase in the frequency and intensity of floods, penetration of invasive alien species, threatening biodiversity, etc. Sustainable management of natural resources in changing climatic conditions would lead to a reduction in their negative impact on the environment and to the adaptation of forest ecosystems to them.

Over the last decades, massive forest decline has occurred in many countries because of prolonged periods of drought and anomalous climatic phenomena. Studies show that in most cases this is the result of a combination of unfavorable climatic conditions and impact of harmful biotic factors, mostly insect pests and fungal pathogens. Adverse phenomena such as prolonged droughts, floods, storms, etc. have been found in the climate changes observed in recent years. Under these conditions, there is a high probability that forest stands to be subject of more frequent and intense stresses due to climatic extremes. As a result of the physiological weakening of trees, diseases caused by invasive fungal pathogens and damages of insect pests could become devastating, covering vast areas of forest.

Some destructive diseases caused by the invasive pathogens - *Diplodia sapinea, Dothistroma septosporum*, *Dothistroma pini* and *Lecanosticta acicola* have the ability to change the functional structure of pine forests in Bulgaria (Georgieva, Hlebarska, 2018; Mullett et al., 2018; Georgieva, 2020). In the coniferous plantations, worsening of trees has been observed at lower altitudes. Insect pests, mainly bark beetles, were the most frequent causers of damages. Among the abiotic factors responsible for the deterioration of pine plantation, damages caused by wind, wet snow and ice have the most negative impact. Snow- and wind-throws damages often occurred provoking the bark beetle attacks.

The strong spread of invasive pathogens and pests violates the ecological role of forests in Bulgaria, as well as their economic function and recreational purpose. It is necessary to take into account the severity of the infection and the prevalence of pathogens, their interaction with other fungal pathogens and insect pests, as well as their specific impact on the affected forests. The monitoring of health status provides baseline data on the distribution, occurrence and harmfulness of biotic agents or damage factors. The assessment of harmful impact and spread of the most important insect pests and fungal pathogens causing damages in Bulgarian forests is essential for making decisions about their management. The identification of the pests and pathogens and the determination of their specific ecological features will allow the development of integrated measures for limiting their negative impact.

In terms of the national policies for protection of forests in good health conditions, since 1986 Bulgaria has been implementing the National Program for Monitoring of Forest Ecosystems, which is a part of the International Cooperative Program 'Forests'. The availability of information on biotic, abiotic and anthropogenic factors that negatively affect the state of forest ecosystems is one of the important circumstance for their sustainable management.

Unmanned aerial vehicle (UAV) remote sensing has great potential for vegetation mapping in complex landscapes due to the ultra-high resolution imagery acquired at low altitudes (Feng et al., 2015). UAVs have several benefits that make them suitable for forest health monitoring: high-intensity data collection and low operational costs (Tang and Shao, 2015). Specifically, UAV can be deployed easily and frequently to satisfy the requirements of rapid monitoring, assessment and mapping in natural resources at a user-defined spatio-temporal scale. The remote sensing technology in combination with terrestrial survey (in-situ) techniques and methods have a huge research potential, especially in protected forest areas with inaccessible and complex terrain (Dimitrov et al., 2018).

The gradual change in climate conditions alters the ecology of host tree species, the harmful effect of biotic agents and their vectors, that incidence the disturbance in forest stands. The use of remote sensing techniques provides information to detect the location of stressed forest stands induced by insect pests and diseases outbreaks. The satellite measurements and other remote sensing techniques directly cannot identify the biotic agents. They obtain information for land cover type, health status of vegetation that are conducive for breeding of vectors are used to identify and characterized the habitat in which pests and diseases are spreading out.

The assessment of health status of vegetation by UAV and terrestrial verification in urban and peri-urban area was carried out in Bulgaria (Dimitrov et al., 2018). The results showed that the implementation of this integrated approach was successfully used for remote monitoring of green systems in settlements with subsequent detailed investigation for calamities of insects and rapid detection of invasive pests and pathogens, in order to prevent their spreading in new areas. In recent years, a number of remote sensing techniques became available to forest resource managers, supporting the planning procedures and monitoring the health status of the forest ecosystems (Dimitrov et al., 2019). Remote sensing-based images indicating the presence of bark beetle attack could support the current monitoring practice by focusing the terrestrial search of infested trees to areas predicted as attacked.

The use of NDVI in vegetation monitoring and assessment of health status of forest ecosystems aim to improve the understanding, predictions, and impacts of disturbances such as drought, fire, flood, pests and diseases frost on global vegetation resources (Pettorelli et al., 2014).

Protecting ecosystems and biodiversity are key policy targets in the EU's biodiversity strategy for 2030 and the European Green Deal. EU and national policy makers require information on the extent and condition of ecosystems to improve their management. Habitat degradation, invasive alien species, climate change etc. are affecting ecosystems across the globe (Barnosky et al., 2011; Pereira et al., 2012). Biodiversity decline represents not only an irreversible loss to the planet but also threatens humanity's life support system. Ecosystem services are the many different benefits that ecosystems provide to people (MA, 2005). The high evaluation of biodiversity, including ecosystems, habitats, and species diversity, now is enriched with the understanding for importance of nature in the support of personal and social prosperity, for sustainable development of society and economy, in harmony with the Nature. Meanwhile the urban ecosystems are characterized with disservices provided by the sources of services. To this category belong the presence of allergens, diseases, secretion of disgusting volatile substances, appearance of invasive species, worsen aesthetical view, loss of biodiversity, etc. (Georgiev et al., 2017). The disservices of ecosystems could be described as 'functions or characteristics of ecosystems which are considered as negative for human prosperity' (Lyytimäki, Sipilä 2009) and frequently are related to significant economic costs (Lyytimäki et al., 2008). Implementing the ecosystem services approach effectively will require decision makers and other stakeholders to understand the trade-offs and synergies between multiple ecosystem services and biodiversity. Maps of ecosystem services are the first and most important tool in this process.

In forest ecosystems in Bulgaria, the economic damages are mainly caused by defoliating insect pests *Lymantria dispar*, *Thaumetopoea pityocampa*, leafrollers and geometer moths (Tortricidae and Geometridae), *Euproctis chryssorrhoea*, pine sawflies

(Diprionidae), (Mirchev et al., 2003). The ecosystem service pest and disease control is connecting to reducing the risk to crops and human health, and by protecting the environment. Natural enemies, such as predators, parasitoids and pathogens, are key regulators of pests.

In urbanized territories growing plants with larger growth expanse creates favourable conditions for development of heliophylic and thermophylic insects. On the other hand, the trade, transport and tourism facilitate the penetration of invasive species and formation of first populations in and around the settlements. In order to evaluate the insect harmfulness in urbanized territories and threats for plants the phytophages population density should be taken into account, as well as the place and time of damage caused and host health condition (Georgiev et al., 2017). During the last years introduced pathogens have turned into growing threat for the natural plant species disturbing the biodiversity and ecological dynamics in forest and urbanized ecosystems.

To implement a project Activity 4 'Detecting and control of forest pests an assessment in the context of related ecosystem services' of the Project 'For everyone saved a tree (FOREST)' No. CB007.2.32.170, a case study was carried out to assess the health status of different type of forest stands in the region of Botevgrad Municipality. The aim of this study was to assess the health status of forest stands in peri-urban areas by integrating remote sensing methods and terrain validation, to clarify the complex of main biotic stressors responsible for forest stands deterioration, assessing and mapping of the related ecosystem services, and developing solutions for improved management.

Objects and methods

Setting of sample plots

An area of 10.069 ha forest stands situated in Etropole and Pravets Municipalities (Sofia District) (Fig. 1) were selected in the period 16-17 September 2020 for studying the health status and treatment again forest pests and diseases.

Three different kind of forest stands were selected (Table 1): a coniferous plantation in bad health condition (near to Etropole town) (Fig. 2), a beech stand near to Etropole Monastery (Fig. 3) and an oak coppice stand in 'Nebesnite pasbishta' Forest park, Osikovitsa village (Fig. 4). These types of forest stands are the most typical in the cross-border region, and the concrete localities are situated in the peri-urban area of towns with a huge public importance and visited by many people.

Table 1. Characteristics of sample plots in forest stands

State Forestry		Assessed area (ha)	Tree species	Altitude	Geographical coordinates	
Etropole	153е$_1$	3.000	*Pinus sylvestris*	500	N 42.851452	E 24.005371
Etropole	153д$_1$		*Pinus sylvestris*	500	N 42.852404	E 24.004138
Etropole	139г	3.045	*Fagus sylvatica*	800	N 42.823162	E 24.035303
Botevgrad	552у	2.008	*Quercus frainetto* *Quercus petraea* *Quercus cerris*	400	N 42.925595	E 24.028846
Botevgrad	552я		*Pinus nigra*	400	N42.925933	E 24.031035
Botevgrad	552б$_1$	2.016	*Quercus frainetto* *Quercus petraea* *Quercus cerris*	400	N 42.927379	E 24.030166
	Total	**10.069**				

Etropole 153 е$_1$ 153 д$_1$

Etropole 139 г

Botevgrad 552 б$_1$

Botevgrad 552 у 552я

Fig. 1. Sample plots established for the assessment of health condition

Fig. 2. Sample plot in a Scots pine plantation

Fig. 3. Sample plot in a beech stand near to Etropole Monastery

Fig. 4. Sample plot in an oak coppice stand in 'Nebesnite pasbishta' Forest Park, Osikovitsa village

The established 40 circular sub-plots (each of them with an area of 0.25 ha) were defined by the coordinates of the centre and by a radius (Ferretti et al., 2017). Forty trees in each sub-plots for assessment of crown condition were selected around co-ordinates of grid intersections and following a standardized scheme (Fig. 5).

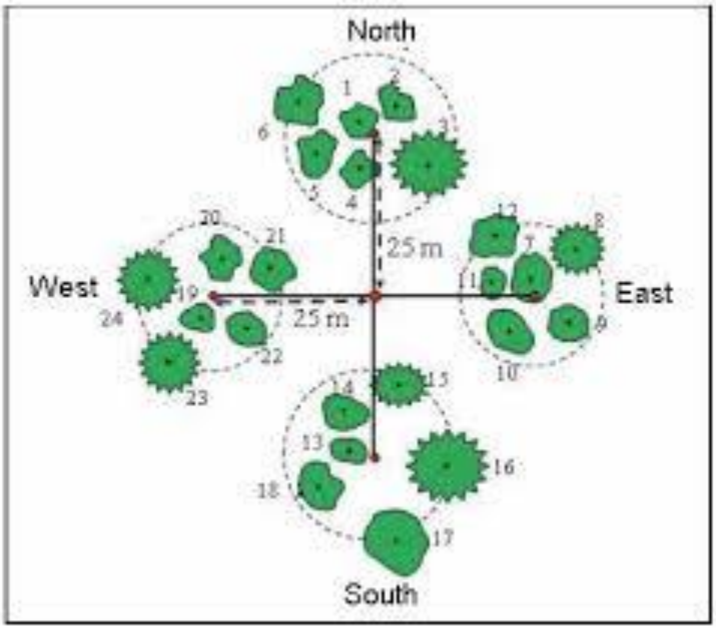

Fig. 5. Settings of sample plots (according the methodology of ICP 'Forests')

Information on the causes of damages to a tree and their influence on crown condition is essential for the study of cause-effect mechanisms. Without this information, data on defoliation and other crown parameters are extremely difficult to interpret. Data on leaf loss and discolouration caused by the actions of defoliating insects or other factors will also provide valuable information for interpreting e.g. litterfall measurements and phenological observations. These data may also contribute to other aspects relevant for forest policy like sustainable forest management (Eichhorn, 2016).

Assessment of health conditions

Crown condition is a fast-reacting indicator for many environmental factors affecting tree vitality. Field expeditions for terrestrial verification were conducted in the experimental sample plots (Fig. 6).

Fig. 6. Field expeditions for terrestrial verification of health status in the case-study areas

In the period 22-23 October 2020, *in-situ* studies were carried out in the selected case-study areas for evaluation of their health status, monitoring to assess the harmful effect of native pest and disease and identification of alien invasive species, assessing of related forest ecosystem services supplied by these areas.

The assessment of the general health status of trees was carried out according to the Manual of assessment of crown conditions of ICP 'Forests' (Eichhorn, 2016). Two physiological indicators were included in the complex assessment of the trees: defoliation and discoloration, characterizing the health of the trees, affected by several anthropogenic and natural factors. Defoliation of 1600 trees was estimated in 5% steps, ranging from 0% (no defoliation) to 100% (dead tree), grouped into five classes: '0' (0-10% - no defoliation), '1' (>10-25% - slight), '2' (>25-60% - middle, '3' (>60-<100% - severe) and '4' (100% dead trees).

The surveys were conducted in combination with detailed identifications of biotic and abiotic damage causes. A classification of damaged trees allowed us for reporting the reason why a tree had died or had been removed in broad categories only (e.g. biotic/abiotic reasons).

Remote sensing of health status

Earth Remote Sensing (ERS) data was used to increase the effectiveness of monitoring of forest areas. Unmanned aerial vehicle (UAV) remote sensing has great potential for vegetation mapping in complex landscapes due to the ultra-high resolution imagery acquired at low altitudes. In this study, remote sensing data were obtained using a Parrot Sequoia multispectral sensor (Green, Red, Red Edge and Near Infrared channels) with a resolution of 3.75 cm/pixel. The drone flew in October 21, 2020, at an altitude of 120 meters. The objects of the study were studied forests in the sample plots damaged as a result of attacks by invasive fungal pathogens or insect pest. Forests mainly consist of Scots pine - *Pinus sylvestris* (Fig. 7) near Etropole and oak stands - *Quercus cerris*, *Q. frainetto* and *Pinus nigra* near Osikovitsa village (Fig. 8). The satellite image of the selected sample plots is shown in Fig. 9.

The camera was equipped with a solar radiation sensor, which serves for calibration of the obtained reflex images. For accomplishment of the assessment, NDVI (Normalised Difference Vegetation Index) was used, obtained by digital mixing of imagery, captured in the red and near-infrared (NIR) range. The land cover database were integrated to infer landscape processes and patterns for monitoring vegetation health condition and changes across time and space.

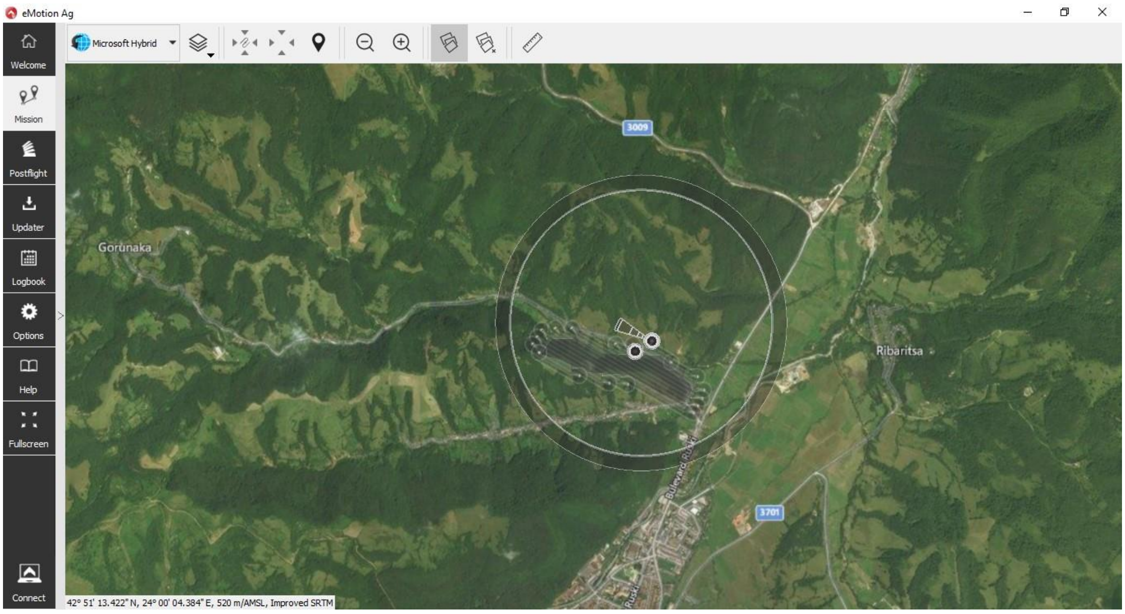

Fig. 7. Planned UAV mission above the Scots pine sample plot near to Etropole town

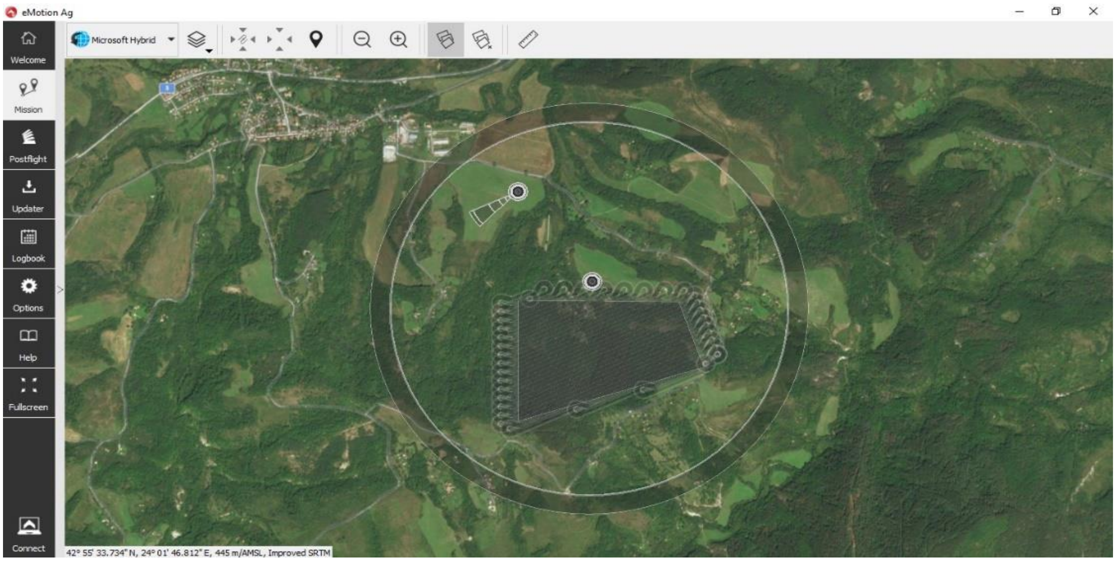

Fig. 8. Planned UAV mission above the sample plot in oak stands near to Osikovitsa village

Advances in close-range and remote sensing technologies drive innovations in forest resource assessments and monitoring at varying scales. Data acquired with airborne and spaceborne platforms provide higher spatial resolution, more frequent coverage, and increased spectral information. Satellite images provided 3 meter multispectral image resolution for a variety of mapping applications including environmental applications were used form Planet Labs Inc. (Fig. 9).

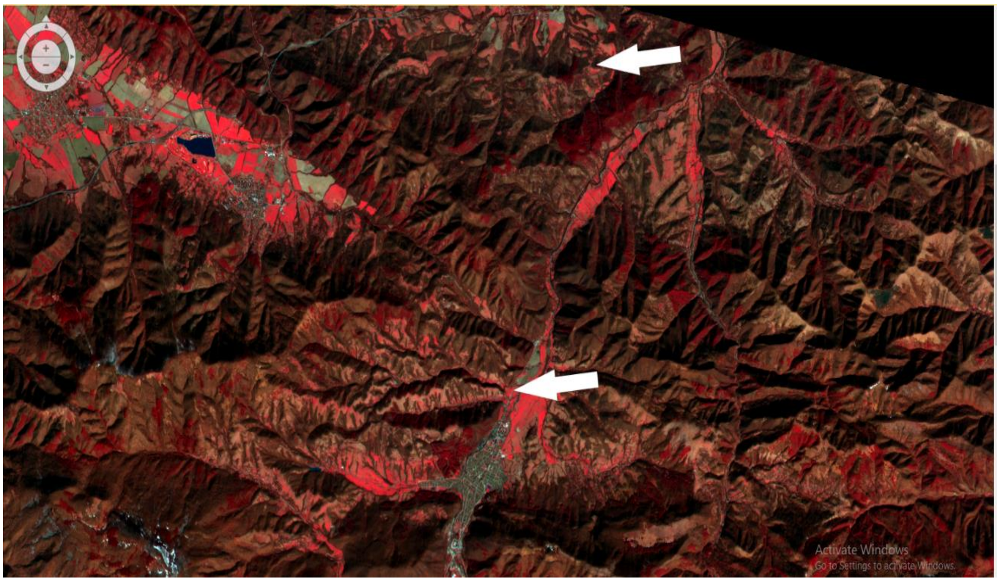

Fig. 9. Satellite image of the established sample plots in Scots pine stand near to Etropole and oak stands near to Osikovitsa village

Assessment of ecosystem services

Ecosystem services (ES) provided by the studied area were categorized according to the CICES classification (Haines-Young, Potschin, 2013.). These ES were selected in order to reflect representatives from each of the key ES categories for provisioning services, regulation and maintenance services, cultural services, as well as for biodiversity protection, pest and disease control etc. Following the same principle as the MAES working group (Maes et al., 2016), a set of potential indicators for each identified services that helped the valuation, and management of the delivered services was indicated.

For the ecosystem services assessment, common steps for evaluating the supply capacity of ES based upon the land-cover approach in the investigated area were used. The capacities of the identified units were assessed on a relative scale ranging from 0 to 5 (Burkhard et al., 2009). A 0-value indicates that there is no relevant capacity to supply regulating services and a 5-value indicates the highest relevant capacity for the supply of these services in the case study regions. Values of 2, 3 and 4 represent respective intermediate supply capacities. Of course it depends on the observer’s estimation and knowledge which function–service relations in general are supposed to be relevant. But, this scale offers an alternative relative evaluation scheme, avoiding the presentation of monetary or normative value-transfer results.

Urban and peri-urban ecosystems are characterized by a high degree of harmfulness: the presence of allergens, diseases, release of unpleasant volatile substances, the emergence of invasive species, deteriorating aesthetic appearance, loss of biodiversity and others. The set of indicators that were chosen in this study included the indicators for the assessment of the condition of the green infrastructure to control pest and diseases dissemination, namely:

- type of host plants, pcs/ha;
- area of healthy plantations (quality indicator), ha;
- area of areas affected by pests and diseases, ha;
- number of pests and diseases, number/ha;
- area of affected areas of invasive species, ha;
- number of invasive species/ha.

RESULTS

Assessment of health conditions

A serious deterioration of Scots pine (*P. sylvestris*) health status was noticed in sample plots established (Fig. 10).

Fig. 9. Deterioration of health status in Scots pine case-study area

Mean defoliation degree varied from 3.5 (severe damaged) to 4.0 (dead) in the studied sub-plots (Fig. 11). The value of mean defoliation is 89.5%, which was indication for deteriorated health status of all Scots pine trees.

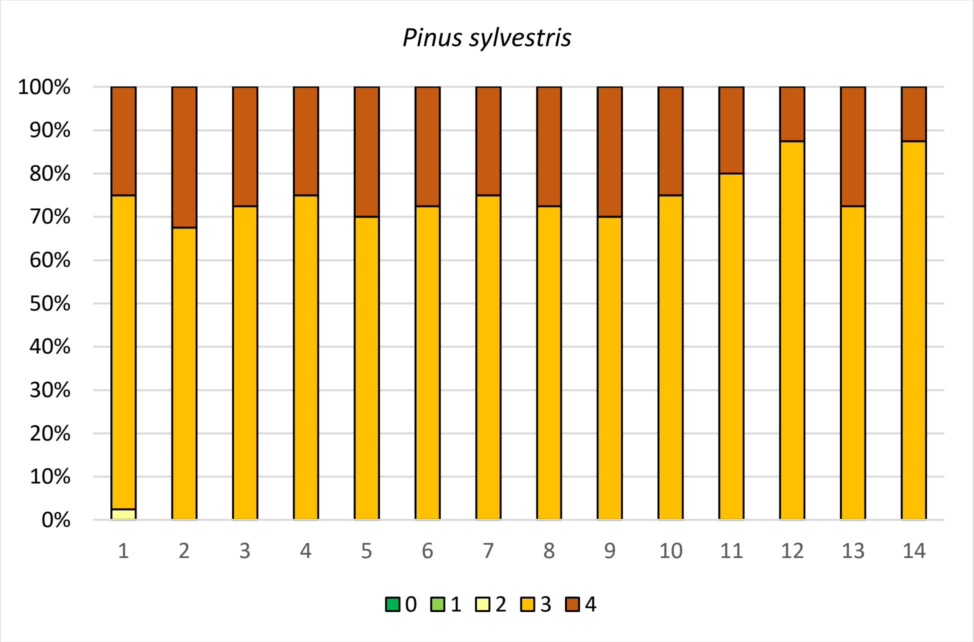

Fig. 11. Health status of *Pinus sylvestris* trees in observed sample plots

Numerous factors determine the health condition of pine forests. These include climatic conditions, disease and insect damages as well as other biotic and abiotic factors (Georgieva et al., 2019). The ecological problems were particularly manifested in plantations. Some of pine plantations were planted for the restoration of degraded lands, in atypical habitats at lower altitudes where early pine mortality was registered (Popov et al., 2015, 2016). A process of incremented damages by biotic and abiotic factors contributes significantly to the rapid destruction of pine plantations.

Among the abiotic factors responsible for the deterioration of pine plantation, damages caused by wind, wet snow and ice have the most negative impact. Damages from natural anomalies are regularly observed in Bulgarian forests on larger or more limited areas. However, their frequency and strength are increasing, creating prerequisites for appearance of xylophagous pest calamities and disease development. Among xylophages, the most dangerous and economically harmful for pine trees is *Ips acuminatus*, and among diseases - root rot caused by the fungus *Heterobasidion annosum* (Mirchev et al., 2016).

The health status of *Fagus sylvatica* forests was assessed in 13 sample sub-plots established in a large-scale monitoring plot under the International Cooperative Programme 'Forests' (Fig. 12).

Fig. 12. Field expeditions for terrestrial verification of health status in the case-study areas

For the study period, the health status of most monitored trees was classified as 'very good'. Defoliations were not exceed 25%, the predominant degree of defoliation varied between 0 and 20% (Fig. 13). Mean defoliation was assessed between 10.4% and 25.8%.

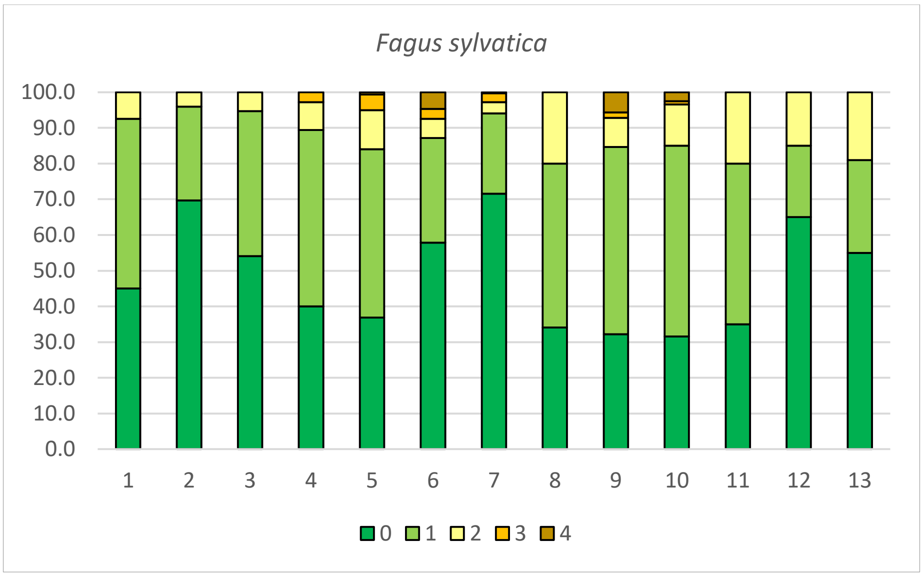

Fig. 13. Health status of *Fagus sylvatica* trees in observed sample plots

The impact of biotic factors was within the normal functioning of the stand, but more significant are the damage of abiotic factors. Rotting of wood caused by wood-destroying fungi have developed in the lower part of the stems.

The health condition of *Quercus cerris* trees was surveyed in 13 sample sub-plots based on the assessment of defoliation and damages caused by biotic and abiotic factors (Fig. 14). It was established that *Q. cerris* stand was not in good condition. Decline of single mature trees due to stem decay was observed. A persistent tendency for deterioration of tree health status was recorded.

Fig. 14. Field expeditions for terrestrial verification of health status in the oak case-study areas

The mean defoliation varied from 1.45 to 2.73 (Fig. 15). The decline of single trees was observed under consideration that it was caused mainly by biotic factors. The results showed that fungal pathogens and insect pests caused the most significant impact on the process of drying. Among the abiotic factors, the most significant were the frost cracks in the result of low winter temperatures.

Within this agent group of insects, the alien insect pests had a significant influence on the process of deterioration of trees. They are the major potential threat for *Q. cerris* stands causing the severe damages. A complex of fungal pathogens were the responsible for tree decline.

Symptoms of infected trees included crown dieback, yellowing of leaves, bark cankers, reduced growth and tree mortality.

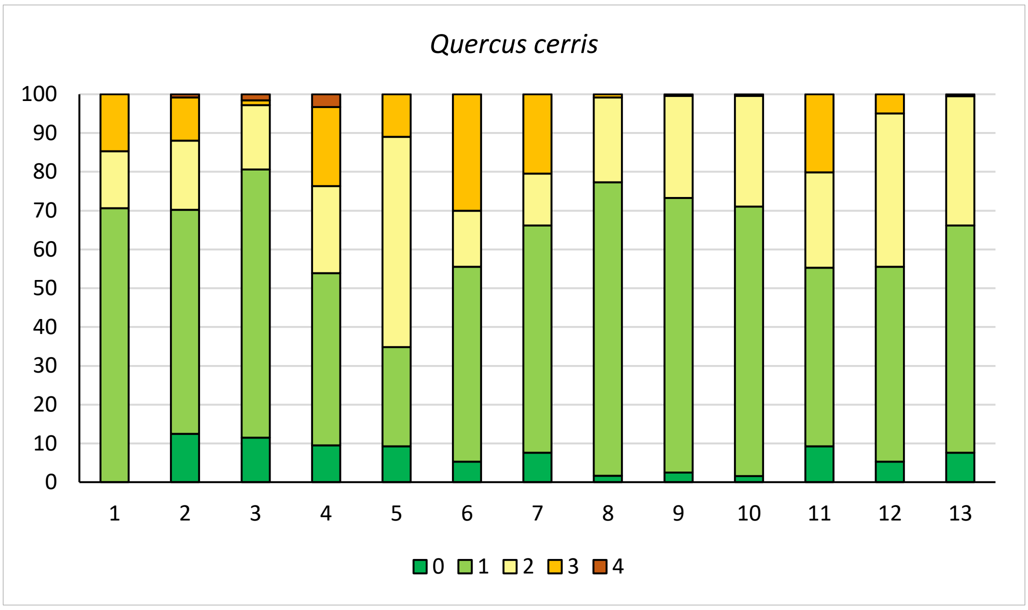

Fig. 15. Health status of *Quercus cerris* trees in observed sample plots

Among abiotic agents – more symptoms were attributed to frost cracks, snow and drought. Besides the significant role of droughts that determine the drying process, it was also found that the increase in their age is an essential reason for the worsening of their growth and vitality. The findings in both studies on the role of insects are similar - they have a limited influence on the drying process, but are considered as a major potential hazard in their calamity development. Combining damages caused by the severe droughts and the extend rate of defoliated stands, could increase the drying process that would spread in large areas.

Remote Sensing of health status

Use of satellite images

The evaluation of the health status of the vegetation in the two selected localities by remote sensing methods was conducted during the autumn months of 2020 and the winter months of 2021. This is the period of the vegetation pause and the health status of the broadleaf vegetation cannot be determined accurately with a NDVI extraction and classification. Because of that inside the two localities were selected areas occupied predominantly with coniferous vegetation. This areas are referred as area of interest (AOI).

The location and shape of the evaluated objects on satellite images in the area of Etropole and the village of Osikovitsa is shown in Fig. 16 and Fig. 17.

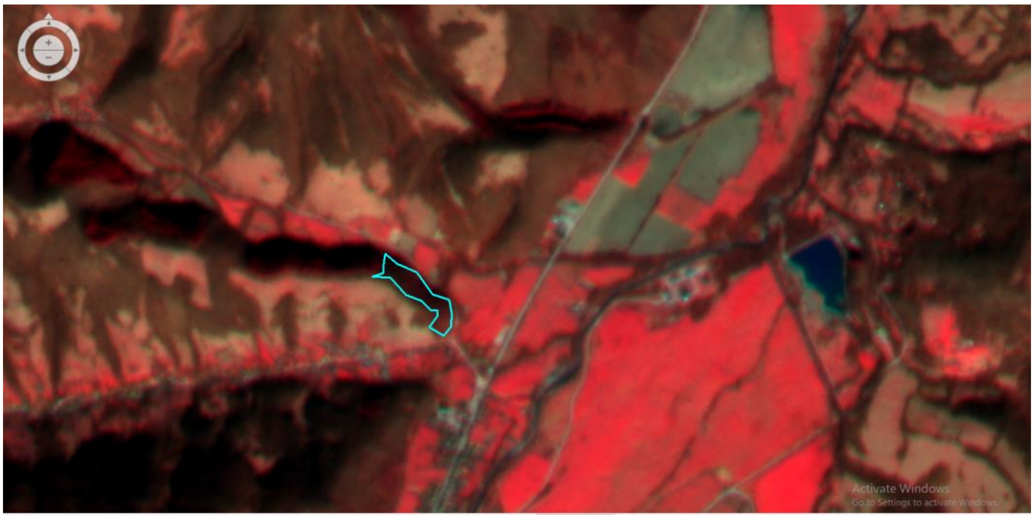

Fig. 16. Sample plots near town of Etropole

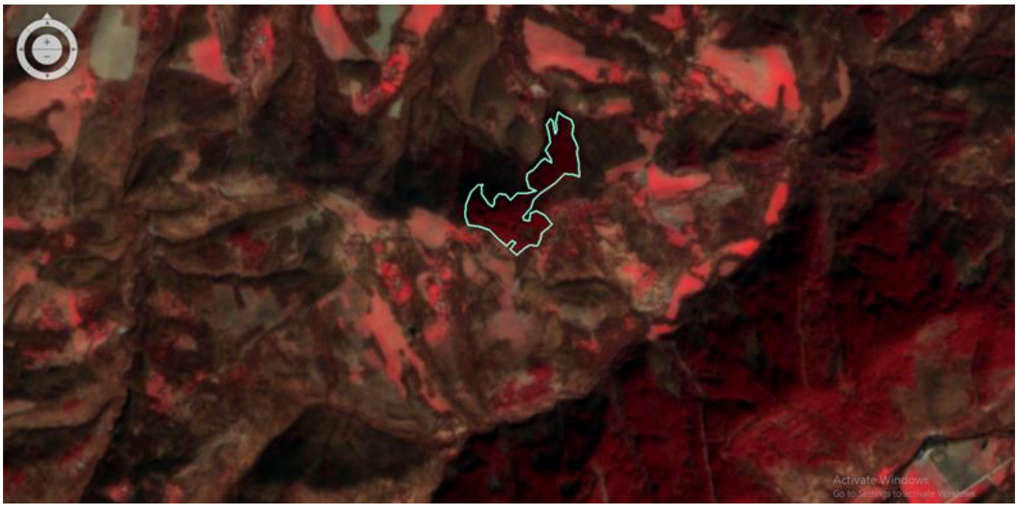

Fig. 17. Sample plots near Osicovitsa vill.

Based on the spectral information of the satellite images with a spatial resolution of 3 m (provided by Planet Labs Inc.), NDVI values of the AOI were calculated by ERDAS Imagine image processing software. The values of NDVI index of the AOI close to the town of Etropole (a) (0.04-0.38) and of the research site (AOI) close to the village of Osikovica (b) (0.02-0.46). Based on the NDVI values an unsupervised classification of the NDVI values was conducted and the values were combined in 36 classes distributed between the lower and the higher NDVI values. This approach first highlight the mosaic structure of the forest cover in the selected AOI and the presents of deciduous trees and second it also was used as instrument that visualize the health status of the vegetation in the sections occupied by coniferous vegetation (Fig. 18).

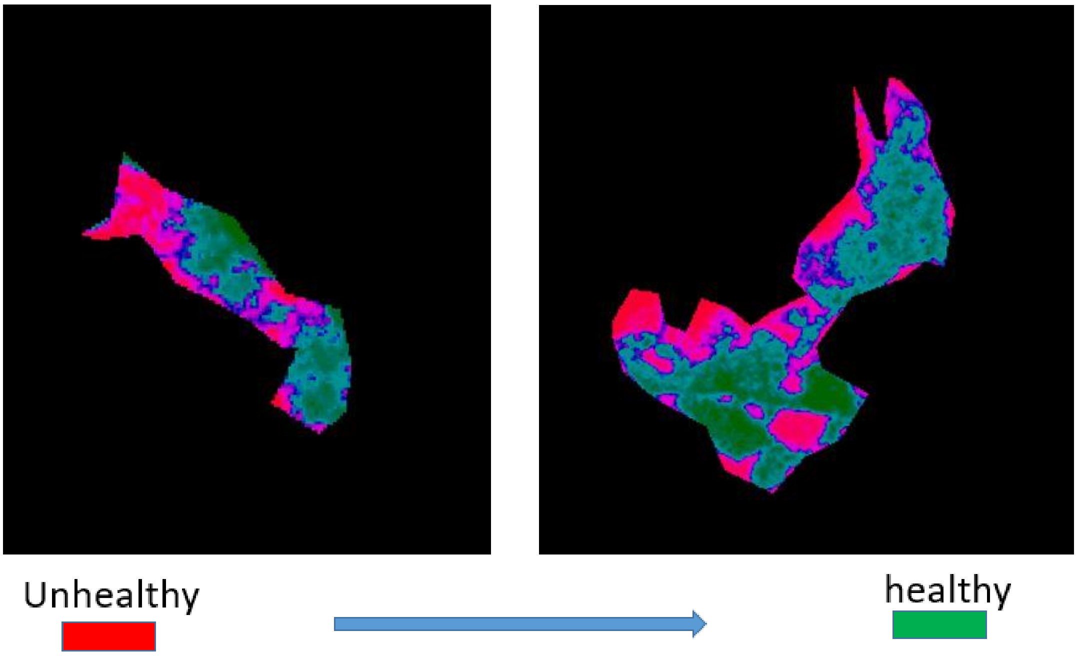

Fig. 18. Unsupervised classification based on the NDVI values of the research site close to the town of Etropole and Osikovica village

The lower values indicate unforested spaces (fields, meadows, pastures, etc.), and the higher - forest stands. Based on the NDVI values calculated from the satellite images could be concluded that the coniferous vegetation is in better condition in the AOI which is close to the village of Osikovica (Fig. 18, Right), were the maximum NDVI values reach 0.42 opposite to the maximum values of 0.38 that can be observed along the AOI which is close to the town of Etropole (Fig. 18, Left).

Use of UAV equipped with a multispectral camera

The flights with the UAV were conducted on 15th October 2020 and again because of the vegetation season smaller AOI which are the same as the AOI extracted on the satellite images were defined. Although the area of interest are the same the NDVI values are different and this difference comes from the different radiometric resolution of the instruments used on the UAV and Satellites. The results of mapping the research site close to the town of Etropole with UAV equipped with a multispectral camera is pointed in Fig. 19.

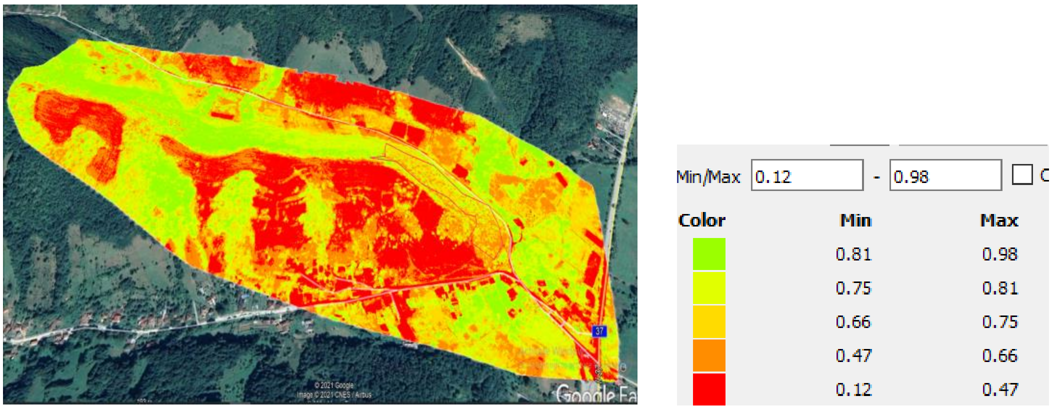

Fig. 19. Map of the sample plot close to the town of Etropole

The red spots on the map are exposed, unforested areas. The forest areas are colored green, with NDVI values mainly between 0.66 and 0.81. There are areas of deciduous stands in the surveyed area, which are in relatively good health condition (NDVI between 0.75 and 0.98). The trees in the pine plantation are weakened, having NDVI values most often between 0.66 and 0.75. It is obvious that inside the AOI occupied with pine plantation there are many orange spots with NDVI values most often between 0.47 and 0.66. On the ortofoto picture can be visualised only this values that are inside the interval between 0.47 and 0.67.

The differentiation in the health condition of pine trees and deciduous stands is shown in Fig. 20 after that by combining high resolution RGB pictures and Index map (NDVI) can be notice that this diapason of NDVI represent either deciduous vegetation in vegetation pause or coniferous trees in bad health condition.

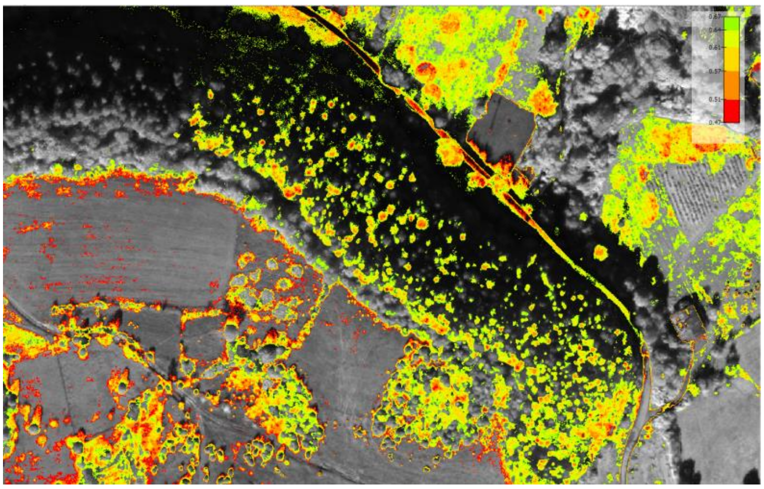

Fig. 20. Health condition differentiation of deciduous and coniferous trees near town of Etropole

Opposite to the AOI which is close to the town of Etropole the AOI near Osikovica (red line poligon) have NDVI values between 0.69 - 0.98 (Fig. 21) which is higher than the values inside the first AOI 0.47- 0.75. The unforested areas, coloured in red and orange have NDVI values between 0.50 and 0.69. The image in RGB color clearly shows that the individual spots are essentially single dead trees or biogroups of drying trees with reduced vitality.

Fig. 21. Biogroups of drying trees and single dead trees near town of Etropole

It can be noticed that inside the AOI (red line polygon) there are few spots colored in orange with values between 0.6-0.69. On the ortofoto picture can be visualised only this values that are inside this interval between 0.6 – 0.69 (Fig.21). By combining high resolution RGB pictures and Index map (NDVI) can be notice that this range of NDVI represent individual spots with essentially single dead trees or biogroups of drying trees with reduced vitality (Fig. 22).

The deciduous forest stands in the area of Osikovitsa vill. are in better health condition. With the exception of the unforested areas, colored in orange and red (NDVI between 0.50 and 0.69), the forest areas have NDVI mainly 0.79-0.98 (Fig. 22).

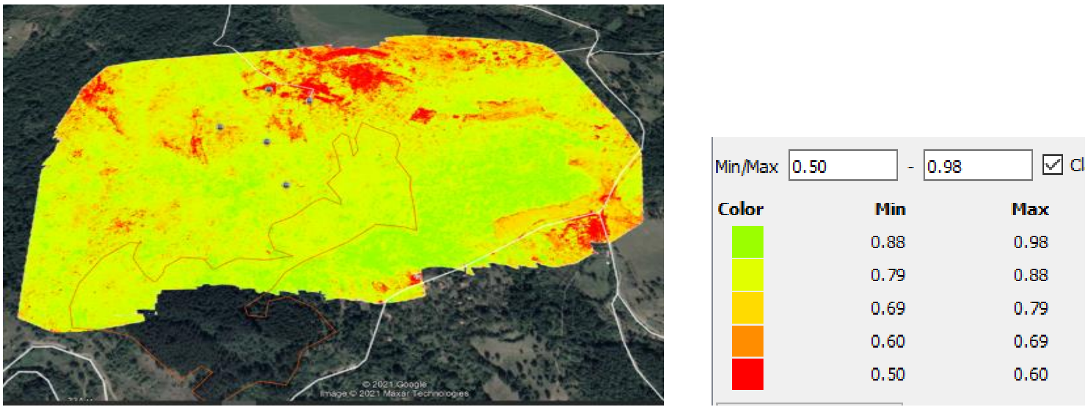

Fig. 22. Map of the sample plot close near Osikovica village

The unforested areas and the drying trees are clearly visible on the map (Fig. 23).

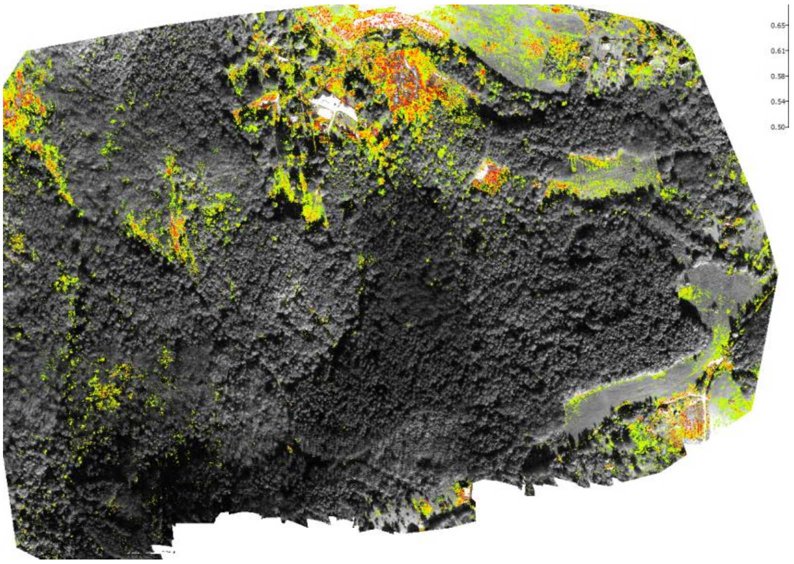

Fig. 23. Health condition differentiation of forest stands near Osikovica village

It is clear that the NDVI values extracted from the satellite images and the ones from the images taken by the UAV in the area of interest which is close to the town of Osikovica shows, that the coniferous vegetation in this AOI is in better health conditions than the vegetation inside the AOI which is close to the town of Etropole.

In-situ verification

With regards to the determined the biotic factors affected Scots pine plantations, infections with the fungal pathogens *Dothistroma septosporum*, *Cyclaneusma minus* and *Diplodia sapinea* dramatically increased and caused serious damage to the Scots pine stands in the monitored sample plots (Table 2). The presence of the fungus *H. annosum* caused root rot disease was also observed in the *P. sylvestris* plantations. These pathogens cause damage to needles and shoots, and therefore pose a threat to the monitored tree stands.

The alien fungal pathogen D. septosporum caused the most pathogenic damages in the sample plots (Fig. 23). The parasitic fungus caused needle blight disease; red coloured bands strips forming across the needles' length and brownish tips of needles; acervuli appearing on the red bands; prematurely dropping of diseased needles. The symptoms were found on needles of all branches and the pathogen affected the whole crown. It was established that in the result of infectionsevere disease development and premature defoliation in successive years resulting in decreased growth and, in extreme cases, death of the tree.

Table 2. Fungal pathogens causing damages of studied sample plots

Pathogens	Tree species	Affected parts	Origin	Significance
Cyclaneusma minus	*Pinus sylvestris* *Pinus nigra*	needles	alien	***
Dothistroma septosporum	*Pinus sylvestris* *Pinus nigra*	needles	alien	***
Lophodermium pinastri	*Pinus sylvestris*	needles	native	*
Lophodermium seditiosum	*Pinus sylvestris*	needles	native	*
Sclerophoma pythiophila	*Pinus sylvestris*	needles	native	*
Cenangium ferruginosum	*Pinus sylvestris*	shoots	native	**
Diplodia sapinea	*Pinus sylvestris* *Pinus nigra*	shoots	alien	***
Pholiota aurivella	*Fagus sylvatica*	stem	native	**
Fomes fomentarius	*Fagus sylvatica* *Quercus* spp.	stem	native	**
Trametes versicolor	*Fagus sylvatica*	stem	native	**
Nectria spp.	*Fagus sylvatica*	stem	native	**
Pholiota adiposa	*Carpinus betulus*	stem	native	**

Significance: *** - high; ** - medium: * - low



Fig. 24. Damages caused by *Dothistroma septosporum* in Scots pine plantations

Dothistroma septosporum is a parasitic fungus causing damages mainly on species from *Pinus* genera. Wide brick-red bands appearing on infected needles and persisting after the needles have withered and turned brown. The red coloration is due to the presence of a mycotoxin, dothistromin. Generally the red zone is distinctly marked off from the rest of the needles; roughly spherical black fruiting bodies erupting in the red infected band. Adjacent to the red band are bands of yellow necrotic needle tissue. The end of the needle dieing beyond the point of infection and extensive necrosis (browning) developing on the whole needle 2-3 weeks after the first appearance of symptoms.

The second important pathogen responsible for the deterioration of studied pine plantations was *Diplodia sapinea* (Fig. 25). Damages were caused at the tip of pine shoots, needles and on second-year cones. Withering of young needles altering the external portion of the crown, death of shoots and buds occured in severe affected trees.

Diplodia sapinea is a parasitic fungus infecting mainly the species of *Pinus* genus as well as of *Abies*, *Arucaria*, *Cedrus*, *Chamaecyparis*, *Cupressus*, *Juniperus*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Thuja*, *Sequoiadendron* (Zlatković et al., 2017). The fungus has been recognized as endophytes, and weak or latent pathogens on healthy and dead cones, twigs and needles. It is an opportunistic pathogen, colonizing in stressed by drought, weakened, injured or dying woody tissues. Young shoots become infected when rain coincides with warm temperatures at the onset of growth.

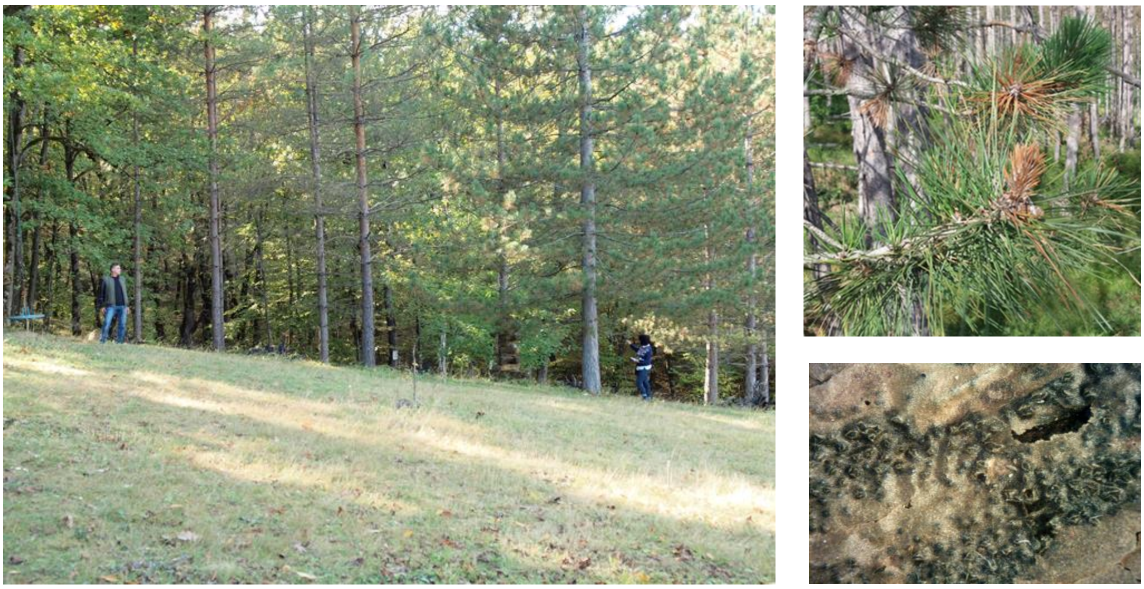

Fig. 25 Damages caused by *Diplodia sapinea* in *Pinus nigra* plantations near Osicovitsa

The results from the investigation the beech forest stand in second sample plot near Etropole Monastry showed damages caused by wood destroying fungal pathogens *Fomes fomentarius* (Fig. 26).

Fig. 26. Fruit bodies of *Fomes fomentarius* on beech stem

Species of the genus *Pholiota* was the most frequent decay fungus, detected in mature trees *Pholiota aurivella* (Fig. 27a) and on beech stems and *Pholiota adiposa* (Fig. 27b) on the common hornbeam stems in the same sample plot. No decay was detected in trees less than 60 years old. In recently fallen and felled beech trunks, however, the basidiomycete *Fomes fomentarius* appeared most frequently, and was the likely contributor to tree windthrow in most of these cases. Decay fungi identified were mostly of the Basidiomycota, which is reflective of this taxonomic group being the main agents of wood decomposition (Boddy, Watkinson, 1995). Likewise, the majority of these were white rot fungi, which corresponds with general observations on the decay type seen in standing beech trees.

The most serious damages responsible for single tree deterioration were necrosis developing on branches and stems, wounds and rottenness resulting after the impact of some abiotic factors (ice, snow-fall etc.). Necrosis was caused by the pathogens of genus *Nectria*.

Fig. 27. Damages caused by *Pholiota aurivella* (a) and *Pholiota adiposa* (b)

On oak stems in sample plots in 'Nebesnite pasbishta' Forest Park, Osikovitsa village fruit bodies of *Fomes fomentarius* were detected (Fig. 28).

Fig. 28. *Fomes fomentarius* on oak stems in 'Nebesnite Pasbishta' Forest Park

Canker, caused by bacteria was noticed on oak stems. Symptoms included round-to-irregular sunken, swollen, flattened, cracked and dead areas on the stems (Fig. 29). Cankers girdled branches and stems. They were most common on plants weakened by cold or drought stresses or root rot.

Fig. 29. Canker caused by bacteria on oak stems in 'Nebesnite Pasbishta' Forest Park

Eleven insect pests were found in the surveyed sites: 7 on *Pinus sylvestris*, two on *Fagus sylvatica* and two on *Quercus cerris, Q. frainetto* and *Q. petraea* (Table 3). Six are xylophagous (affecting tree trunks) and the rest are phyllophagous, feeding on leaves and needles.

With the exception of one species, *Corythucha arcuata* (Say) (Hemiptera: Tingidae), which is invasive, all other insect pests are native.

Two species are of high importance as pests (*Ips sexdentatus* and *Corythucha arcuata*) (Table 3). Three species (*Tomicus piniperda*, *Orchestes fagi* and *Dryomyia circinans*) and one group (*Pissodes* spp.) are of medium importance as pests, and the rest do not cause significant damages to the host plants.

Table 3. Insect pests causing damages of studied sample plots

Insect pests	Tree species	Affected parts	Origin	Significance
Ips sexdentatus	*Pinus sylvestris*	stem	native	***
Pissodes spp.	*Pinus sylvestris*	stem	native	**
Tomicus piniperda	*Pinus sylvestris*	stem	native	**
Spondylitis buprestoides	*Pinus sylvestris*	stem	native	*
Asemum striatum	*Pinus sylvestris*	stem	native	*
Rhagium inquisitor	*Pinus sylvestris*	stem	native	*
Cinara pini	*Pinus sylvestris*	needles	native	*
Orchestes fagi	*Fagus sylvatica*	leaves	native	**
Mikiola fagi	*Fagus sylvatica*	leaves	native	*
Corythucha arcuata	*Quercus cerris* *Quercus frainetto* *Quercus petraea*	leaves	alien	***
Dryomyia circinans	*Quercus cerris*	leaves	native	**

Significance: *** - high; ** - medium: * - low

Ips sexdentatus is one of the most dangerous bark beetles in pine plantations (Fig. 30). The species usually develops on trees attacked by *Ips acuminatus*, which is the most aggressive xylophagous pest on *Pinus sylvestris*. At the time of the study, *I. acuminatus* was not found in the area, but it will undoubtedly appear in the near future, and will cause a dramatic drying of pine plantations.

Fig. 30. Damages caused by *Ips sexdentatus* and *Pissodes* spp. in Scots pine plantation near town of Etropole

The results from the investigation the beech forest stand in second sample plot near Etropole Monastry showed damages caused by insect pest (*Orchestes fagi*) (Fig. 31) and *Mikiola fagi* on leaves (Fig. 32).

Fig. 31. ***Orchestes fagi***

Fig. 32. ***Mikiola fagi***

The larvae of *O. fagi* mine the leaves, and the adults feed by making holes in them. The species is found throughout the country and periodically causes damage in beech forests, which is easily compensated by the reserve capacity of host plants. As concerns *M. fagi*, the insect causes galls on leaves, but the damages are insignificant.

In sample plot near Etropole Monastry, exit holes of xylophagous insects have been found on the trunks of felled beech trees (Fig. 33). Many saproxylic insects develop in the dead and rotten wood, including species of high conservation importance – *Morimus asper funereus* Mulsant, 1862, *Rosalia alpina* (Linnaeus, 1758) (Coleoptera: Cerabycidae), etc.

Fig. 33. Exit holes of xylophagous insects on felled beech tree

Among the insect pests, *Corythucha arcuata* (Say, 1832) (Heteroptera: Tingidae) and *Dryomyia circinans* (Giraud, 1861) (Diptera: Cecidomyiidae) were the most numerous in oak coppice stand in 'Nebesnite pasbishta' Forest park near Osikovitsa village.

D. circinans caused strong damages on studied *Quercus cerris* sample trees. The leaves were totally coved by galls worsening the aesthetic qualities of the infested trees and causing decrease of growth and physiological weakness (Fig. 34).

Fig. 34. Galls of *Dryomyia circinans* on *Quercus cerris*

The oak lace bug, *Corythucha arcuata* (Say, 1832) (Heteroptera: Tingidae) is of North American origin widely distributed in United States and southern part of Canada. It is an invasive species first recorded in Europe in Italy (Bernardinelli, Zandigiacomo, 2000) and Switzerland (Forster et al., 2005). In 2012, the oak lace bug was found for first time on Balkan Peninsula in Plovdiv City and Zlati dol village near town of Simeonovgrad (Dobreva et al., 2013). Five years after the first record on the Balkan Peninsula, the oak lace bug had penetrated almost all over Bulgaria.

In this study, *C. arcuata* was established mainly on *Quercus cerris* and *Q. frainetto* (Fig. 35), and rarely on *Q. petraea*. It was found as larvae, nymphae and adults on the host plants. Finding of single adults on *Carpinus betulus* leaves could be considered as occasional records (Fig. 36).

In Bulgaria, the oak lace bug is widespread mainly in the lowland and hilly area of the country, in the belt of xerothermic oak forests, up to about 600-700 m a.s.l. (Simov et al., 2018). The invader was found on 8 oak species (*Quercus robur*, *Q. petraea*, *Q. pubescens*, *Q. cerris*, *Q frainetto*, *Q. hartwissiana*, *Q. pedunculiflora*, *Q. polycarpa*), chestnut (*Castanea sativa*) and 5 species of occasional hosts (*Lysimachia punctata*, *Rosa canina*, *Rubus caesius*, *Rubus* sp., *Acer platanoides*). In Europe, the oak lace bug feeds on 11 oak species, but the calamities of the pest most often occur in stands of *Quercus robur*, *Q. frainetto*, *Q. petraea* and *Q. cerris* (Csóka et al., 2019).

Fig. 35. Damages caused by *Corythucha arcuata* on *Quercus cerris* (a) and *Q. frainetto* (b)

Fig. 36. Occasional record of *Corythucha arcuata* on *Carpinus betulus*

In strongly attacked trees, feeding activity of *C. arcuata* results in earlier discolouration of the leaves (Fig. 37). In the case of heavy infestation, the oak trees turn yellow in the middle of the summer and lose the leaves earlier than usual.

Fig. 37. Discolouration of *Quercus cerris* leaves caused by feeding of *Corythucha arcuata*

Measures for improving the health status of the studied plots

The main management objective in urban and peri-urban forests is to protect the stands in stable health condition and biodiversity. These forests are exposed under the huge public access and the management objective for nature protection is prevented in the protected area. Activities as: game control; control of diseases and insect outbreaks, public access; fire intervention. As studied forests are managed, harvesting, silvicultural prevented in the protected area.

Forests provide a multitude of benefits to society. To maximize these benefits an inventory is often needed for planning and management purposes. Urban and peri-urban forest inventories are a valuable asset to planners and decision makers and can provide needed information about the quality, quantity and location of natural resources in urban areas. Identifying changes in species composition cover types, and presence of invasive pest and pathogens will provide insight to maintain healthy urban forests.

Interventions are clearly directed to achieve the management goals landscape diversity, cultural, aesthetic, spiritual and historical values, recreation, specific natural elements. The use of forest resources is restricted. A clear long-term commitment and an explicit designation as specific protection regime, defining a limited area exists. Activities negatively affecting characteristics of landscapes or/and specific natural elements mentioned are prevented in the protected area.

In recent years, a deterioration in the health status of *Pinus sylvestris* plantations has been observed in Bulgaria. By increasing the age of plantations, a decrease in their vitality and resistance to biotic factors occurred. Among the xylophagous, the most dangerous is the *Ips acuminatus*, and among the pathogens the root rot fungus (*Heterobasidion annosum*). *Ips acuminatus* calamites occur after long-term periods with droughts and physiological weakening of trees. Other three species of bark beetls (*Ips sexdentatus*, *Tomicus minor*, *Tomicus pinipera*), as well as an aggressive species of the Buprestidae - *Phaenops cyanea*, also contribute to the deterioration of Scots pine plantations. In this regard, the monitoring of bark beetles using traps baited with synthetic pheromones will provide reliable information on the population density of the pests and the forthcoming threats to pine plantations from attacks by the three most aggressive species: *Ips acuminatus*, *I. sexdentatus* and *Tomicus pinipera*. On the other hand, it is necessary to strictly apply the basic preventive measures in pine plantations (rapid removal of freshly broken or uprooted trees from abiotic impacts, as well as felled wood) in order to prevent pest attacks.

The invasive species *Corythucha arcuata* is a serious threat to oak forests and should therefore be subject to permanent monitoring in studied area. This is even more true for the most dangerous insect pest in deciduous forests, the gypsy moth (*Lymantria dispar*), which forms calamities every 8-10 years. Monitoring with pheromone traps would allow early biological control to be applied using the specific and highly effective fungal pathogen *Entomophaga maimaiga*.

During the last years, introduced pathogens have turned into a growing threat for the natural pine species, disturbing the biodiversity and ecological dynamics in forest and urban ecosystems. The distribution and population size of disease vectors is heavily affected by local climate. Because the spread of the pathogens facilitated by movement of free-living hosts or vectors, the risk of spread of *Dothistroma septosporum*, when accounting for heterogeneous landscape features, could be estimated. The high pathogenicity of the diseases strongly suggests that these newly emerging in Bulgaria pathogens have the potential to cause severe damages and are a serious threat to species of *Pinus* throughout the country.

Assessment of ecosystem services

Ecosystem services are the benefits humans derive either directly or indirectly from ecosystems (Table 4). People are entirely dependent on ecosystem services for their wellbeing and economies and indeed survival (Díaz et al., 2005).

Table 4. Ecosystem services

Provisioning services	**Regulating services (human time scale)**	**Supporting services (long time scale)**
• Food - Human (land/fresh water/marine) - Forage • Biochemicals - Medicines - Other • Raw materials - Timber - Fibre - Stone - Minerals/ores • Fuel/energy - Biomass - Solar - Hydro - Other	• Pollination and seed dispersal • Biological control - Pest regulation - Invasive species resistance - Disease regulation • Climate regulation - GHG regulation - UV protection - Moderation of temperature • Prevention of disturbance and moderation of extremes - Wind/wave force modification - Mitigation of flood/drought - Erosion control • Decomposition	• Soil - Formation - Retention - Renewal of fertility - Quality control • Fixation of solar energy - Primary production/ plant growth • Nutrient cycling - Regulation of biogeochemical cycles - Retention of nutrients • Habitat provision - Shelter and resource - Reproduction space

• Fresh water • - Consumption - Irrigation - Industrial processes • Genetic information	- Waste removal • Purification - Water/air/soil	• Species maintenance - Biodiversity - Natural selection - Self organisation

Among regulating services, pest regulation is one of the important processes in the functional diversity of forest ecosystems and can play a critical role in their long term durability (Andersson et al., 2007). However, pest regulators are threatened by habitat loss and fragmentation due to urban development and expansion. To manage these services sustainably over time, a deeper understanding of how they operate and depend on biodiversity is crucial (Nelson et al., 2009).

Recently emerged invasive species, both pathogens and insect pests, could become more established with extended drought or other disturbances. Expansion or strengthening of disease pathogens could threaten locally important species such as predators of insect pests, which in turn could increase the number of the specific pest species. Winter warming and absence of cold waves will benefit certain species of insect pests and diseases that are sensitive to prolonged periods of cold; other invasive species may be able to respond more readily to warmer winterand spring-time temperatures.

The selected forest area on the territory of the Etropole and Pravets municipalities was situated near the urban territories. The land cover data showed that most of studied forests were deciduous, represented mainly by beech and oak forests. Coniferous forests were predominantly plantations planted around the Etropole and Osicovitsa village. Studied forest ecosystems were characterized by a high degree of harmfulness: presence of allergens, diseases, emergence of invasive species, deteriorating aesthetic appearance, loss of biodiversity and others.

The changes in the distribution of pathogens and pests are assessed and whether these changes occurred simultaneously with the regulation of the root causes that led to the change of green areas. Natural enemies, such as predators, parasitoids and pathogens, are key regulators of pests' distribution. The provision can be carried out through preventive or mitigating functions.

• preventive - the service is provided mainly by maintaining forest areas in good health. Changes in abiotic conditions, including changes in humidity, have the greatest impact on pathogens that spend much of their life cycle outside their vectors, transmitted by vectors or by water currents. Biotic processes, such as genetic and species diversity of plant species, spatial distribution of individual landscape units, reduce the density of hosts that are sensitive to specialized pests and pathogens, thus reducing their ability to spread.

• mitigation - forest areas can be regulated or maintained below harmful levels in green areas through a specific combination of: (*i*) biotic factors, such as predators, pathogens, competitors or the absence of hosts; (*ii*) abiotic factors, such as changes in environmental conditions; and (*iii*) socio-economic factors, such as disease and pest control.

For the territory of the Etropole and Pravets municipalities, the service is identified as recommended in view of the great importance for maintaining the green areas in good condition, which is related to the provision of the ecosystem services identified as priority for the municipality. The emergence of new invasive diseases and pests in green areas is defined as a negative effect that increases in frequency, impact, geography or range of the host. Both emerging and identified pests and diseases are important for the aesthetic vision and good health and social status of residents and visitors.

To the main elements of green infrastructure in the studied peri-urban forest area included: pine forest plantations in the peripheral urban areas of Etropole town, forest beech stands near Etropole Monastery, forest park 'Nebesnite pasbishta' included oak species, hornbean, pine plantations etc.; natural and semi-natural urban green spaces - forests, shrubs and grasslands, wetlands in urban areas, children's facilities etc.;

The need to maintain green areas in good health is greatest in highly urbanized and densely populated areas. The movement of plants and their products between different biogeographical zones is perceived by humans as the main way through which new pests and pathogens are introduced into new regions. Most people appreciate the beauty or aesthetic value of different ecosystems, which is reflected in the widespread interest in visiting green areas for recreation and tourism. Pest and plant pest control can be used as a successful means of maintaining sustainable green infrastructure, which plays a role in mitigating the effects of air pollution and climate change, and in stabilizing the effects of functional diversity on human sustainability.

During the field inspections of the forest vegetation, attacks of several dangerous pests were found. In oak sample plots, severe damages was caused by the invasive species *Corythucha arcuata*. Severe damages by the invasive pathogen *Dothistroma septosporum* on the needles of Scots pine (*Pinus sylvestris*) and Austrian pine (*Pinus nigra*) showed strong virulence in recent years and cause serious damages to local and introduced coniferous tree species.

The average assessment of the health condition of the trees in the assessed sample plots varies from category 2 (presence of stable disturbances or changes in the structure and functionality of the forest ecosystems) to category 4 (small changes in individual parts of the assessed sites that are not related to degradation and significant effects on ecosystems). Despite the large predominance of local over foreign representatives of harmful entomofauna, determining the damage caused by invasive alien species were observed. Among them the most harmful are insects that damage non-renewable and difficult-to-renew tissues and organs (phloem, young shoots, branches, stems). The assessment identified pathogens causing damage on needles, deteriorating the health and decorative qualities of the trees used for landscape.

The supply of the service can be expressed both through the preventive and through the mitigating function. The service is provided mainly by green areas in urban, suburban and forest ecosystems, which are maintained in good health and forestry and protection approaches and measures are taken to control pests and invasive diseases. Service provision is most needed in vulnerable central green areas, where population flows are highest and the use of introduced plant species and their landscaping products is most widespread, often leading to the emergence of new pests and pathogens.

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