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DETECTION OF BARK BEETLE INFESTATIONS BY DRONE AND IMAGE ANALYSIS IN SPRUCE FORESTS

DETEKCIJA NAJEZDE POTKORNJAKA POMOĆU DRONA I ANALIZE SNIMAKA U ŠUMAMA SMREKE

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SUMMARY

Bark beetles, such as the eight-toothed spruce bark beetle (*Ips typographus* L.) and the six-toothed spruce bark beetle (*Pityogenes chalcographus* L.), cause extreme economic and environmental damage in forests, especially in areas dominated by Norway spruce (*Picea abies* L. Karst.). Fast detection and containment of bark beetle outbreaks are crucial in the battle against bark beetles, but unfortunately, the infestation detection system in Slovenia is somewhat outdated. As part of a research project, an experiment was conducted using a drone and a multispectral camera to search for bark beetle infestations. The experiment covered a forested area of 21.02 hectares, which was surveyed by the drone to capture images with the multispectral camera. By processing the collected data, an orthomosaic and NDVI indices were created. Based on the analysis of the NDVI index, potential locations of bark beetle infestations were identified. The actual conditions in nature were verified through physical inspection of the area. The results of the experiment revealed that in all three areas where bark beetle infestations were predicted, Norway spruce trees showed signs of attack by the eight-toothed spruce bark beetle were present.

KEY WORDS: Bark beetle, drone, multispectral camera, Norway spruce, orthomosaic

INTRODUCTION
UVOD

Slovenia is a land of forests, as it is one of the most forested countries in the European Union. As much as 58.2% of the entire country is covered by forests, and in the past practically the entire country was covered with it. For the first settlers in the country, the forest represented a source of food, building material for the construction of homes, heating, and a place for hunting, and by clearing it, they obtained areas for growing crops. A forest is a complex ecosystem that is home for many plants, animal species and microorganisms. Beech (*Fagus sylvatica* L.) and common spruce (*Picea abies* L. Karst.) dominate among the plant species in Slovenian forests (Ministry of Agriculture, Forestry and Food – Forestry, 2024).

Global warming and climate changes have a rather unfavourable effect on the functioning of the forest ecosystem. Milder winters, hot and dry summers and numerous extreme weather events put Slovenian forests to the test in the past. Natural disasters, such as snowdrifts, windbreaks and, above all, icefalls, severely damaged tree stands. The hot and dry periods in the past established favourable conditions for the multiplication of tree pests, which attacked the already weakened trees. The biggest problem was the rapid proliferation of bark beetles, especially the eight-toothed spruce beetle (*Ips typographus* L.) (Kolšek, 2017).

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According to the Statistical Office of the Republic of Slovenia, around 2.3 million cubic meters of wood trees were cut down in Slovenia in 2016 due to bark beetle attacks. Such a quantity of felled wood in a short period of time caused saturation of the market with forest wood assortments. Timber prices plummeted and economic damage was high. In places where the bark beetle attack was extreme, there were bare areas that would not regrow on their own and had to be artificially reforested. Thus, the costs of afforestation must also be added to the economic damage caused by the fall in wood prices. In addition to the economic damage, it is also necessary to take into account the fact that the forest in this place has lost its ecological and social function (Statistical Office of the Republic of Slovenia – SURS, 2023).

Bark beetles are beetles from the Scolytinae family. Different groups of bark beetles can be distinguished from each other by the burrows they dig under the bark of trees, from which they got their name. Depending on where they make their burrows, they are divided into Phloeophagous beetles (phloem feeders), Xylomycetophagous beetles (wood feeders) and Ambrosia beetles (fungus-associated wood feeders). To date, over 6,000 species of bark beetles have been discovered and described in the world, of which 90 can be found in Slovenia (Hulcr et al., 2015). Therefore, weakened stands of trees that have been damaged by natural disasters in the past, combined with long-lasting dry and hot weather, are excellent conditions for the mass multiplication of bark beetles. In recent years, the most affected tree species by bark beetles has been the common spruce (*Picea abies L. Karst.*), whose damage in the wood stands is most often caused by the eight-toothed bark beetle (*Ips typographus* L.) and the six-toothed berk beetle (*Pityogenes chalcographus* L.) (Bentz and Jonsson, 2015).

To combat bark beetles, a system of measures divided into 3 groups has been established in Central Europe, from preventive measures (prevention), to preventive and suppressive measures (prophylaxis), and repressive measures (curative). All three measures have in common the timely detection of a beetle attack (Jurc et. al., 2016).

UAV (unmanned aerial vehicle) is a general abbreviation for unmanned aircraft, also known by the general name "drone". It is an unmanned aircraft that was initially developed for military use, but in recent years has become a general purpose device. Unmanned aircraft first included vessels that flew freely (without control), until the development of remote control. Today, unmanned aircraft include small-dimension and low-mass aerial robots that are capable of flying autonomously along a certain route and performing their function (e.g. collecting data). Unmanned aerial vehicles are divided into airplanes or fixed-wing drones (similar to standard aircraft), which reach higher speeds and are able to fly longer distances, and copters or rotor drones (usually with four or more upward-facing propellers), whose advantage is take-off and landing in areas with limited space (Bitenc, 2014). Drones can also be divided according to the way they are powered. They are divided into electric drones and internal combustion drones. In recent years, drones powered by electricity have mostly been used, as they are more suitable for use in remote sensing due to their economy and lower vibrations. Technological developments, especially in the field of sensors, remote sensing and software, have led to the fact that the need to use drones in everyday life has increased even more. New applications have been developed that enable the use of drones in various fields, such as geodesy, construction, precision agriculture, forestry, as well as certain indoor solutions. Depending on the purpose of use, the drone is equipped with various cameras and sensors, such as a RGB camera, multispectral camera, hyperspectral camera, lidar sensor, etc., and with other devices that allow them to perform their function (e.g. sprayers) (Aru et. al., 2019; Chen et. al., 2021; Sassu et. al., 2021; Tang et. al., 2018).

With the help of satellite images and aerial photographs, sustainable planning and management of forests, and the assessment of the structure, composition, volume and growth of forests have already been possible in the past. In recent decades, the need for remote sensing in forestry has increased. Compared to satellites, with drones it is possible to achieve more accurate images of forest areas and individual trees and even leaves. Drones are widely used around the world to map forests and determine biodiversity, since this technology saves time, costs and manpower. Drones are also more often used for precision forestry. It was found that with the help of an unmanned aircraft with an added LiDAR sensor, it is possible to determine the amount of trees and the amount of biomass in a plantation of fast-growing trees. It was also found that with the help of an unmanned aircraft and an installed multispectral camera, it is possible to determine the disease state and vitality of trees based on the light radiation from the leaf surface. With the help of a drone and remote sensing equipment, damage to the canopy caused by windbreaks and snowdrifts has also been discovered in the past. In doing so, they also obtained data on the variety of damage according to the stands and growth stages of individual trees. Information on the height of individual trees is also important in forest management. Until recently, the measurement of these trees took place with the help of field measurements, which involved a large number of workers and lasted several days. LiDAR technology allows us to measure the height of individual trees in a forest stand with the help of a drone. In order to collect data, the unmanned aircraft only has to fly over the forest stand, and the accuracy of the measurement depends on the density of the parallels during the flight. The use of drones in forestry, despite a large number of attempts, is still in its initial phase, as the development of modern technologies in sensorics opens up completely new areas of application (Banu et. al., 2016).

The main goal of a research study by Stoyanova et al. (2018) was to identify the affected forest areas in a forest region in Bulgaria. In the study the authors obtained similar results compared to our research. The NDVI index in the range of 0.7 to 0.95 characterizes green tree vegetation. Affected forest subjected to stress has lower NDVI index values of 0.65. The NDVI index of damaged areas ranges from 0.45 to 0.5.

The aim of the research is to determine, based on the results of the experiment, whether the use of a drone in combination with a multispectral camera is effective in finding bark beetle attacks and how this method affects the speed of detection, especially in hard-to-reach areas.

Figure 1. DJI Phantom 4 drone with a built-in Parrot Sequoia multispectral camera
Slika 1. DJI Phantom 4 dron s ugrađenom Parrot Sequoia multispektralnom kamerom

MATERIAL AND METHODS
MATERIJAL I METODE

Description of the equipment used in the experiment – *Opis opreme korištene u istraživanju*

In the experiment, we used the DJI Phantom 4 drone (Figure 1), developed by the Chinese company DJI. It is a copter that is mainly used for aerial photography and recording. Its technical characteristics are:

1. Dimensions:

– diagonal: 350 mm
– weight (with battery and propellers): 1380 g

2. Flying:

– maximum speed (horizontal): 20 m/s
– maximum climbing speed: 6 m/s
– maximum descent speed: 4 m/s.

3. Battery:

– type: LiPo 4S
– capacity: 5350 mAh
– maximum flight time: 28 minutes
– voltage: 15.2 V.

4. Camera:

– resolution: 12.4 MP
– sensor: 1/2.3″CMOS
– shooting mode: single shot / sequential shooting / time lapse.

The PIX4Dfields software helped us process the captured data. It is a software that enables the analysis and processing of images (Figure 2). It was developed by the Swiss company PIX4D for use in precision agriculture, where images

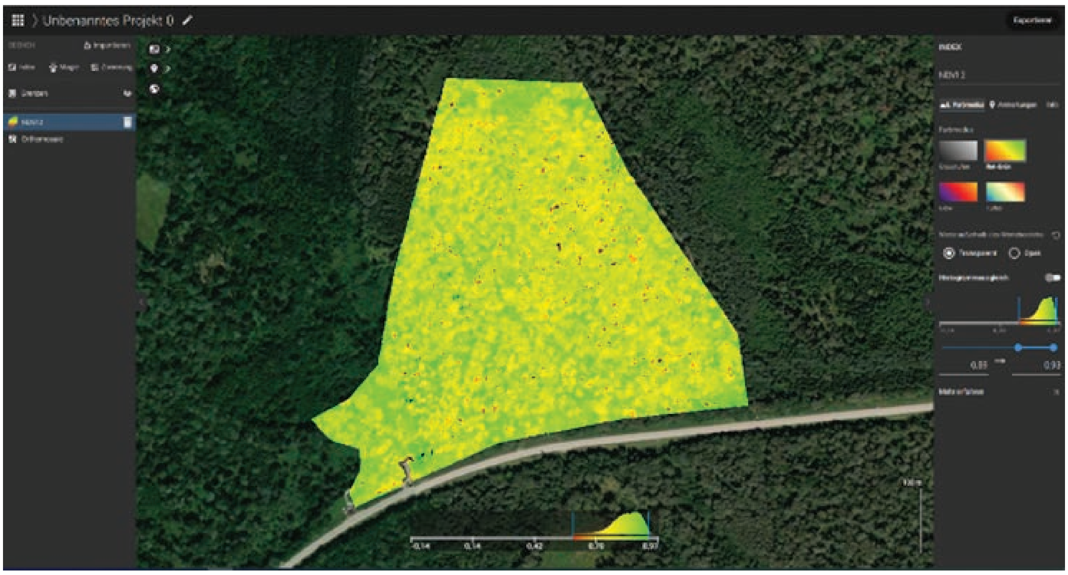

Figure 2. PIX4Dfields software during the experiment
Slika 2. PIX4Dfields softver tijekom eksperimenta

captured by drones or satellites are analysed and processed. The results of the analyses enable farmers, agronomists and other experts to gain insight into the state of agricultural land and subsequently adjust agricultural production (PIX4Dfields, 2024).

When processing the data in our experiment, the software enabled the calculation of the vegetation index, more precisely the NDVI index. The advantage of this software is that, in combination with a portable device such as a laptop or tablet, it allows us to analyse data in the field. It does not even need an internet connection to calculate some indices and create maps. This feature is crucial when used in forests, as signal coverage is poor in certain areas in Slovenia and, as a result, internet connection is not possible. In addition, data analysis in the field can significantly speed up the process of detecting hotspots.

NDVI index

NDVI (Normalized Difference Vegetation Index) or normalized vegetation index is the most popular index for assessing the state of vegetation and also one of the first analytical data used in remote sensing. It has become so widespread mainly for this reason, because for the calculation of the index it is necessary to obtain information from only two spectra of light, namely the red spectrum (RED) and the near infrared spectrum (NIR). Data on NDVI is thus captured with the help of multispectral cameras, which, due to the need to capture only two light spectra, are quite simple and affordable (PIX4Dfields, 2024).

In mathematical form, the calculation of the normalized vegetation index can be expressed as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where:

NDVI – Normalized Difference Vegetation Index

NIR – Light reflected in the near-infrared spectrum

RED – Light reflected in the red range of the spectrum

According to the equation above, NDVI is therefore calculated as the difference in intensity between the NIR and RED wavelength ranges, divided by the sum of the NIR and RED wavelength ranges. The NDVI value always ranges between 1 and -1. The higher the NDVI result, the denser and healthier the vegetation, or the lower it is, the weaker the plants. In cases where the NDVI result is close to zero, it is mostly related to rocks, sand or concrete surfaces, and when the NDVI is negative, it is the case of water areas (Huang et. al., 2021).

Due to its versatility, NDVI is used for:

- Controlling plant growth: with the help of NDVI, we monitor the growth and health of plants, and consequently adjust the implementation of measures in agriculture;
- Sowing planning: with the help of NDVI results, we can optimally determine the time of sowing plants according to their needs for nutrients, moisture, temperature;
- Forest management: NDVI allows us to monitor the state of the forest (degree of damage, disease state, pest attack...);
- Pollution detection: NDVI can be used to detect soil, water and air pollution;
- Climate change research: with the help of NDVI, we can monitor the effects of climate change on vegetation and the environment.

Despite the versatility of NDVI, it is necessary to pay attention to the accuracy of the index measurement and quality data processing. In the case of multispectral cameras installed on satellites, the atmospheric effect must be taken into account when calculating the NDVI, which can have an impact on the final results. In the case of measurements made with the help of UAVs, there are often problems, because due to increasing needs, examples with sensors of poorer quality appear on the market, the measurement of which varies slightly according to the actual situation (Huang et. al., 2021).

Multispectral camera

A multispectral camera (Figure 1) is a device for capturing images in different light spectrums of electromagnetic radiation. In addition to the visible spectrum (380 – 780 nm), with the help of a multispectral camera with a suitable filter, images can also be captured in the range of gamma rays (up to 0.01 nm), X-ray waves (0.01 – 10 nm), ultraviolet light (10 – 380 nm), infrared light (780 nm – 1 mm), microwave (1 mm – 1 m) radiation and radio waves (above 1 m). Multispectral cameras are built from a lens that captures light. With the help of a filter, only light of a certain spectrum is allowed through, which is then captured by sensors (CMOS, CCD). The sensors convert the captured light into an electrical signal, which is then converted into digital form. Each sensor converts a specific spectrum of light, and the digital data is then combined into a multispectral photo. In most cases, each sensor in a multispectral camera has its own filter, but there are multispectral cameras with only one sensor and several filters that move to let in light of a certain spectrum at a given moment. Such cameras are cheaper, but capture of footage is usually slower due to moving filters. Multispectral cameras, which are intended for specific use, only contain sensors and filters for capturing certain wavelengths (Morales et. al., 2020).

Description and location of the experiment

The attempt to search for the bark of attacked trees was carried out on a forest land (Figure 3) which is located directly on the border between Zgornji Razbor and Šentvid at Zavodnje in Slovenia. The location of the experiment thus lies on the border between the municipalities of Slo-

Figure 3. The area of the experiment
Slika 3. Područje eksperimenta

Table 1. Flight parameters and data acquisition
Tablica 1. Parametri leta i prikupljanje podataka

Horizontal airspeed (km/h)	25
Flight altitude (m)	150
Adjusting the flight height to the terrain	YES
Direction of parallels	default
Data capture	time – every 2 seconds
Overlay footage (%)	80

venj Gradec and Šoštanj and on the border between the Koroska and Savinjska statistical regions. The forest land of 21.02 ha is located on rugged steep terrain, with the lowest point at an altitude of 835 m and the highest point at an altitude of 1100 m. The tree stand on the forest land is dominated by spruce, which represents more than 80% of the total stand. In addition, there is also a small number of young beech trees and some other deciduous trees, as well as individual larch trees.

en filming areas where the terrain is highly undulating, it is important that the drone follows the height of the terrain and thus captures images at the same distance from the vegetation. In cases where dense vegetation is recorded, such as in our case a forest, it is also important to set a sufficiently large percentage of the overlap of individual images to obtain sufficiently detailed results. When determining the direction of the parallels along which the drone flies over the area, the program itself determines the direction that allows capturing the entire surface by the shortest route. If necessary, the direction of these parallels can be changed.

After setting the flight parameters, we saved and transferred the data to the drone and connected it to the RTK network. According to the set parameters, the flight of the drone over the area lasted 10.93 minutes, during which it flew a 4554 m long route and captured 328 images.

After the flight, we transferred the data to the computer using a micro SD card.

RESULTS WITH DISCUSSION
REZULTATI I RASPRAVA

In order to determine the presence of bark beetles in the spruce forest, we flew over the area with a drone and captured images with the help of a multispectral camera. In order to obtain the results, we loaded the recorded images into the PIX4Dfields program, which processed and created the ort-

Figure 4. Orthomosaic of the recorded area
Slika 4. Ortomozaik snimljenog područja

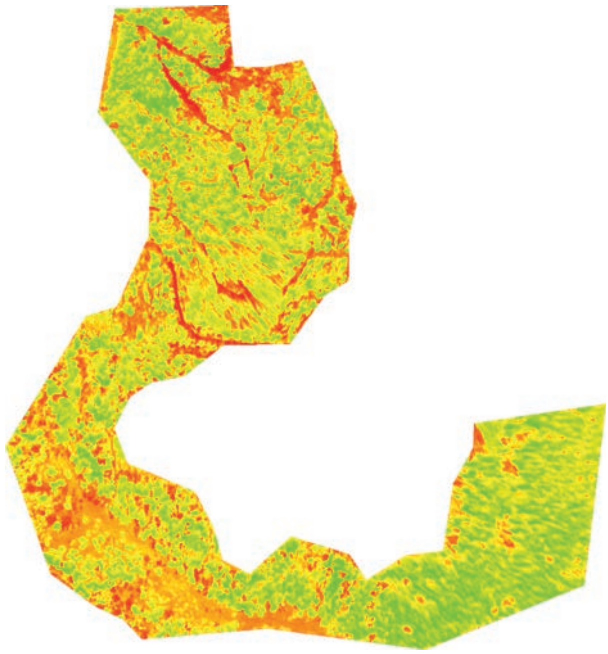

Figure 5. Graphic display of the NDVI index of the recorded area
Slika 5. Grafički prikaz NDVI indeksa snimljenog područja

homosaic (Figure 4) and the NDVI index (Figure 5). The processing of the captured data itself took about half an hour.

Both obtained results were compared with each other. We looked for red areas on the NDVI index, which were colored if the areas were covered with trees. In this search, it was necessary to exclude areas that are not covered with trees, and on the NDVI they were colored red due to the lack of vegetation. These were, for example, forest roads, traffic roads, areas of water depressions, areas intended for the manipulation and storage of wood, and bare areas where logging was carried out. In the areas where, according to the results of the comparison, the possibility of the presence of the bark beetle was found, we carried out a field inspection with the help of GPS location. In these areas we looked for trees that showed symptoms of bark beetle attack and based on the symptoms we determined whether it was a focus or not.

In the process of comparing the orthomosaic and the NDVI index, 3 areas of potential occurrence of bark beetle foci were determined. These were the areas covered with trees, and the NDVI in these areas was colored red, indicating low vegetation activity of plants. The locations of these areas are shown in Figure 6.

The individual coordinate points of the focus and the average numeric values of NDVI are listed in Table 2.

In the middle of July, when the study was conducted, the vegetation development phase was such that the NDVI index was below or around 0.7-0.8 (Figure 5).

Table 2. Coordinates of areas of potential occurrence of bark beetles
Tablica 2. Koordinate područja potencijalne pojave potkornjaka

Area designation	Coordinates	Numeric value of NDVI on area
AREA 1	46.4565210, 14.9673077	0.45-0.5
AREA 2	46.4579585, 14.9662712	0.35-0.39
AREA 3	46.4531149, 14.9702519	0.5-0.6

The NDVI index in the range from 0.7 to 0.95 characterizes green tree vegetation or very healthy plants. We selected three areas where the index was smaller and deviated from the green areas (Table 2). The results of numerical values of the NDVI index are comparable to the study by Stoyanova et al. (2018).

Area 1 overview

For each area of possible bark-beetle attack, we obtained coordinates that brought us to the individual area. The numeric value of the index varied from 0.45 to 0.5 and deviated from the value in green areas.

On physical examination of area 1, we found adult spruce trees showing signs of attack by the eight-toothed spruce bark-beetle (*Ips typographus* L.). One of the attacked trees, which shows obvious symptoms, is the spruce tree in Figure 7.

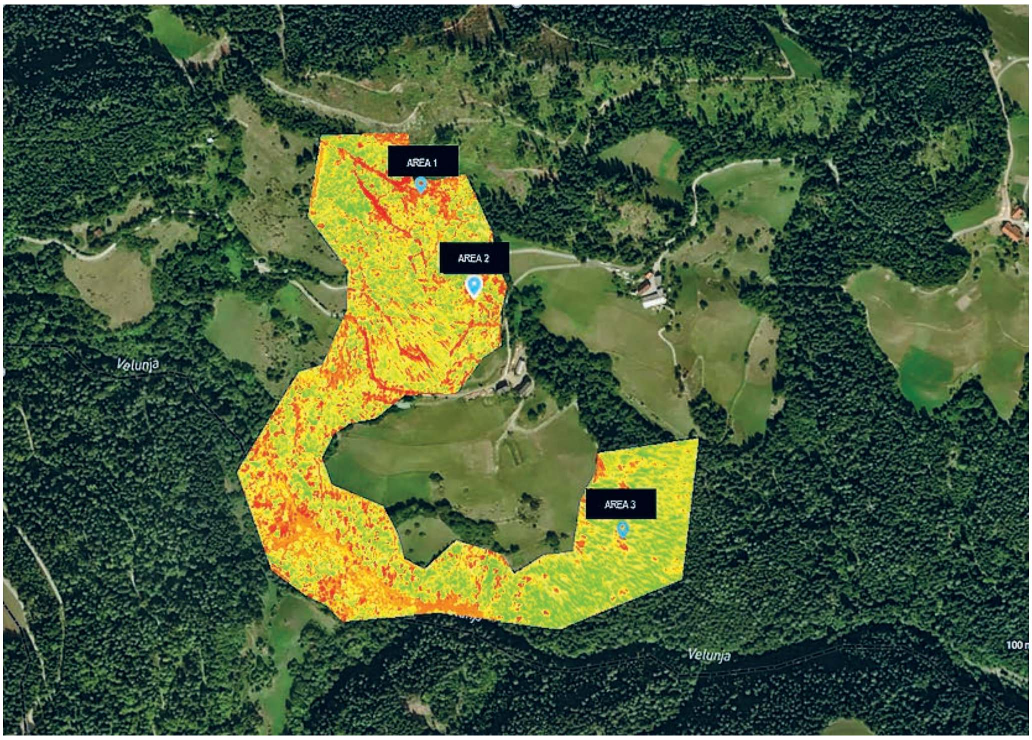

Figure 6. Graphic display of the NDVI index of the recorded area with locations
Slika 6. Grafički prikaz NDVI indeksa snimljenog područja s lokacijama

Figure 7. Attacked spruce tree in area 1
Slika 7. Napadnuto stablo smreke na području 1

Figure 8. Tunnel system of the bark beetle
Slika 8. Tunelski sustav potkornjaka

Under the tree, we can see a bunch of green needles, which are the result of the drying of the tree. In the lower part of the crown, a marked deviation of the bark is visible. In the places where the bark beetle has already given way, it is possible to see the tunnel system of the bark beetle (Figure 8).

In the case shown in Figure 7, we can already speak of a strong attack of the bark beetle. This is the July attack of the eight-toothed spruce bark beetle from the previous year, as the needles on the treetop are still colored green, and we can already see the deviation of the bark. Bark shedding is present on the half of the tree trunk where the woodpecker inhabits. In such a case, we are talking about moderate economic damage, since the market price drops significantly in places where the bark falls off and the resulting greyish-blue discoloration of the wood due to fungi appears. The wood is healthy in the lower part of the trunk, where the bark beetle has not yet settled, and consequently its value is equal to the market price of healthy spruce wood. If the forest manager did not rehabilitate such a tree for some time, the activity of the bark beetle would increase with the rise of temperature, and as a result the bark beetle would spread throughout the entire trunk, which would further destroy the wood and cause greater economic damage.

Area 2 overview

In area 2, we discovered a stronger attack by the eight-toothed bark beetle. This is also shown by the NDVI, since in this area the red spot is larger and more pronounced than in area 1. The value of the index varied from 0.35 to 0.39. In this area, one of the attacked trees is also the spruce tree in Figure 9.

Figure 9. Attacked spruce tree in area 2
Slika 9. Napadnuto stablo smreke na području 2

In the example above, we can observe symptoms quite similar to those in area 1 (Figure 7). In this case, too, it is a July attack of the bark beetle, where, most likely, due to the faster infection and higher temperatures, the activity of the bark beetle was slightly higher. This is evident in the damage to the trees, which was more pronounced than in area 1. In this case, the loss of needles is very strong, and the crown of the tree has already almost completely dried out. Only a small part of the crown is greenish. Bark shedding is very intensive and is present along the entire length of the trunk, practically up to the stump.

Just like in area 1, we can also observe a strong attack of bark beetles here, which caused fairly high economic damage as well. As the borer developed over the entire trunk area and damaged the wood there, the value of the whole wood fell. Despite the damage caused to the wood by the bark beetle, such wood is still worth more than if the bark beetle had died completely due to late rehabilitation. At that time, the bark on the trunk would completely fall off and the value of such wood is equal to the value of cellulose wood.

Area 3 overview

Area 3 was smaller in size of the numeric NDVI, and was colored with a less pronounced red color. The value of the index varied from 0.5 to 0.6. At this site, we found only one tree that showed obvious symptoms of a bark beetle attack (Figure 10).

Figure 10. Attacked spruce tree in area 3
Slika 10. Napadnuto stablo smreke na području 3

The tree shown in Figure 10, like the trees in areas 1 and 2, is attacked by the eight-toothed spruce bark beetle, but in this case it is a fresh May attack in its early stages. It can be noticed that the tree is really attacked only by the yellowing of the crown and the drying of the needles, which is also characteristic of the spring attack of the bark beetle. Since the tree is in the early stage of attack, the bark is not yet falling off, which can be seen in Figure 10. It is likely that the ruffed grouse also attacked some of the surrounding spruces, but they do not show any visible signs of attack so far.

In area 3, the focus of the bark beetle attack was discovered in time, since only one tree was heavily attacked. In case of a good condition and favorable weather conditions, the surrounding trees are still able to resist the attack of the bark beetle. Such a focus does not cause significant economic damage to the owner of the forest with timely remediation, as the trunk of the spruce tree (Figure 10) is mostly undamaged. In this case, the value of the wood is exactly the same as the value of healthy spruce wood.

CONCLUSIONS
ZAKLJUČCI

We relied on the operation of modern technology when conducting an experiment to detect bark beetle-infested trees in a spruce forest. A drone with an installed multispectral camera flew over the rugged area of the spruce forest. Based on the obtained data, with the help of the software, we determined 3 areas of potential occurrence of bark beetle. After a physical inspection of the condition at the locations, we found that in all three areas the bark beetle really attacked the spruce trees. In two cases, we found a July attack from the previous year, and in one case we encountered a fresh spring attack.

According to the results of the experiment, we can confirm the goal of research, in which we asked whether it was possible to find the focus of the attack of the bark beetles using a drone and a multispectral camera. It is also necessary to take into account the saving of time and physical effort, since with the help of a drone we recorded an area of 21.02 ha and for this we spent 10.93 minutes for flying and an additional half an hour for data processing. If we tried to inspect such a surface in a standard way on foot, it would take much more time, and it would be necessary to take into account the error of the human factor. Such a search method shows its advantage especially in hilly areas, which can be easily flown over with a drone, but which are physically very difficult to access.

The problem with finding trees affected with bark beetle in the way shown in the experiment is that it takes experience to study the results, and this could be facilitated by developing a software that would analyze the obtained index and eliminate the disturbing areas. In this way, the system could become generally usable and the user would not need special training to operate it. These are also some further guidelines for the continuation of the research.

With the development of this technology, the work of foresters and forest owners could be made easier in the future, because with a faster and less laborious search for hotspots, they could inspect a larger area of forests at the same time and with less effort, and thus also improve the process of fighting with bark beetles. In addition, faster detection of hotspots would also mean shorter remediation, as only individual trees would be remedied, but not the entire infested areas. With incremental improvements, the technology could be developed to the point where a physical examination of the condition would not be necessary at all.

Timely rehabilitation would prevent the spread of bark beetles, preserve the value of the wood and prevent economic damage. It would preserve the forests and the cultural landscape, which is the basis of sustainable forest management. In addition, a healthy forest also has a positive effect on the cleanliness of the air and people's health.

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SAŽETAK

Potkornjaci, kao što su osmerozubi smrekov potkornjak (*Ips typographus* L.) i šesterozubi smrekov potkornjak (*Pityogenes chalcographus* L.), uzrokuju iznimnu ekonomsku i ekološku štetu u šumama, posebno u područjima gdje dominira obična smreka (*Picea abies* L. Karst.). Brzo otkrivanje i suzbijanje žarišta potkornjaka ključno je u borbi protiv potkornjaka, međutim, nažalost, sustav otkrivanja zaraze u Sloveniji pomalo je zastario. U sklopu istraživačkog projekta proveden je eksperiment pomoću drona i multispektralne kamere za traženje štete od potkornjaka. Eksperiment je obuhvatio šumsko područje od 21,02 hektara koje je pregledano dronom kako bi se snimile slike multispektralnom kamerom. Obradom prikupljenih podataka izrađeni su ortomozaik i NDVI indeks. Na temelju analize NDVI indeksa identificirana su potencijalna mjesta najezde potkornjaka. Fizičkim pregledom terena utvrđeno je stvarno stanje u prirodi. Rezultati eksperimenta pokazali su da su na sva tri područja u kojima je bila predviđena najezda potkornjaka stabla obične smreke pokazivala znakove napada smrekovim osmerozubim potkornjakom.

KLJUČNE RIJEČI: potkornjak, dron, multispektralna kamera, obična smreka, ortomozaik