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Remote Sensing Based Vegetation Analysis in Parangalitsa Reserved Area

*Miroslav A. Ivanov**, Konstantin A. Tyufekchiev*

South-West University of Neofit Rilski,
66 Ivan Michailov Str., Blagoevgrad, BULGARIA
*Corresponding author: m_ivanov@swu.bg

Abstract. In the last decade the remote sensing and the Unmanned Aerial Vehicles (UAV) become a very popular technology for observing the spatial distribution of different objects and processes. Generating a point cloud, extracting DSM and DTM from a photogrammetric mosaic and analyze the change of the canopy are the main features of the remote sensing ground monitoring applications. This study is focused on the feasibility and adaptability analysis of the UAV techniques and the satellite images processing software as instrument for interpretation of the vegetation health in Parangalitsa reserve area. The area of interest that is subject of investigation in this research is situated in Rila National Park, South-West Bulgaria. To analyze the canopy in the reserve have been used two types of remote sensing information the first one is a rapid eye satellite picture with a 5 m spatial resolution as the second one is a photogrammetry mosaic extracted with a fix wing E-bee UAV equipped with a high resolution 20 MP S.O.D.A and multispectral Parrot Sequoia cameras. The main idea of this study was to use the high resolution images captured by the UAV as a benchmark and to extract the NDVI values of the pixels that represent vegetation in very bad shape and after that to search for pixels with the same NDVI values on the low resolution satellite images in order to find areas on the satellite pictures with dead or dying vegetation and also to analyze the dynamics in the health status of the forest vegetation inside the reserve for 8th Years period between 2009 and 2017.

Key words: remote sensing, satellite images, NDVI, forest ecosystems.

Introduction

Parangalitsa reserve area is the second oldest reserve in Bulgaria. It is known with its etalon forests of *Picea abies* L./H, *Abies alba* M., *Fagus sylvatica* L. and has an enormous influence over the biodiversity preservation in Bulgaria and Europe as well. But recently due to the whirlwinds activity and vermin infections the old forests in the reserve are constantly dying. Because of that, the dynamic changes in the health status of the forest vegetation inside the boundaries of the reserve area, represent a big scientific interest.

The main goals of this research are to be analyzed the changes in the vegetation health on the territory of the Parangalitsa reserve area between 2009 and 2017 by remote sensing methods including satellite images and UAV data. As a bench mark area for more detail observation has been chosen the North-Western corner of the reserve between Blagoevgradska Bistritsa River and Haidushka River (Fig. 1) which will be referred bellow as a small area of interest. Thirty years ago this particular part of the reserve had been known with its large volume of wood growing stock which according some estimations were more than

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1000 m^3/ha. Today the forest ecosystems in this part and in the reserve as a whole are in very bad condition and huge numbers of ill, dry and fallen trees can be observed. The main reasons for this change probably are the large numbers of fallen trees due to the whirlwind activity in the area. These whirlwind spots and the fallen trees that were left inside, served as a food base for vermin which consequently affected the living trees around. The same methodology after that was applied to the bigger area of interest which coincide with that area of the reserve which is covered by forest vegetation.

Materials and Methods

To achieve the main goal of this research have been used two sources of remote sensing information - multi spectral satellite images captured by Rapid Aye satellites with spatial resolution of 5 m and a high resolution, multi spectral orthophoto mosaic with a spatial resolution of 11 cm.

The satellite images are captured on 13.07.2009 and on 20.07.2017 by Rapid aye satellites that are operated by Planet Labs Inc.. These satellites are equipped with a multi-spectral push broom imager sensors that are capable of capturing the spectral bands shown in Table 1. The satellite images where processed with an image processing software Erdas Imagine 2018.

Table 1. Spectral resolution of Rapid Aye satellites.

Type	Wavelength (nm)
Blue	440 - 510
Green	520 - 590
Red	630 - 685
Red Edge	690 - 730
NIR	760 - 850

The orthophoto mosaic has been assembled from 365 pictures captured by E-Bee UAV equipped with a multispectral Parrot Sequoia camera, the technical specification of the last are presented in Table 2. All the UAV pictures were process by an image processing software - Pix4D.

Based on the spectral information that is incorporated inside the satellite images and the orthophoto mosaic a NDVI index for each image has been built. The Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The mathematical formula that stands behind the NDVI index is (NIR-Red)/(NIR+Red). The values of the NDVI can be between -1 and +1, but in the scientific literature there is no consensus about the boundary between the values of unhealthy or dead vegetation and healthy vegetation. Because of that in order to achieve reliable values of NDVI for the forest vegetation in the reserve area and also to distinguish dry or unhealthy from healthy vegetation, in this research we used a combination of high resolution RGB orthophoto mosaic and NDVI of the same mosaic. This approach is very useful when the precise location of the dry wood stock (in White on the Fig.2-left side) have to be determined and more over the values of the NDVI that represent a Dry wood stocks (in Black on Fig. 2- right side) can be extracted (Fig.2.).

NDVI values from the high resolution orthophoto were extracted in an image processing Erdas Imagine 2018 Software. Additional unsupervised classification has been executed and these values after that where separated in 36 classes. This unsupervised classification was used as an instrument which helped to distinguish a healthy from unhealthy and dry vegetation. Classes with the same values of the NDVI were also determined for the same area of interest on the two satellite images (Fig. 3).

This approach to extract NDVI values from the high resolution images and compared these values with the NDVI values extracted from the satellite images leads to precise determination of the areas occupied with dry woods and healthy or unhealthy vegetation even on the satellite pictures with a spatial resolution of 5 m. Taking in consideration the works of Eigemeier *et al.* (2012), Gospodinova & Kandilarov (2018) and Xiao & McPherson (2005) the defined 36 classes were additionally combined in 10 classes (Appendix 1, 2, 3, 4). This is more suitable for the purposes of this research due to the resolution of the satellite pictures and the size of the Parangalitsa reserve area.

The values of these 10 classes are presented on colored maps (Fig. 4) with the health status of the forest vegetation in the small area of interest and the whole forest area of the reserve as well. Based on the NDVI values the forest vegetation was divided on five categories - dead or dry with NDVI values under 0.1; vegetation in bad shape, with values between 0,1 and 0.41; in generally good condition, between 0.42 and 0.69; in very good condition, between 0.7 and 0.89 and in excellent health with NDVI values above 0.9.

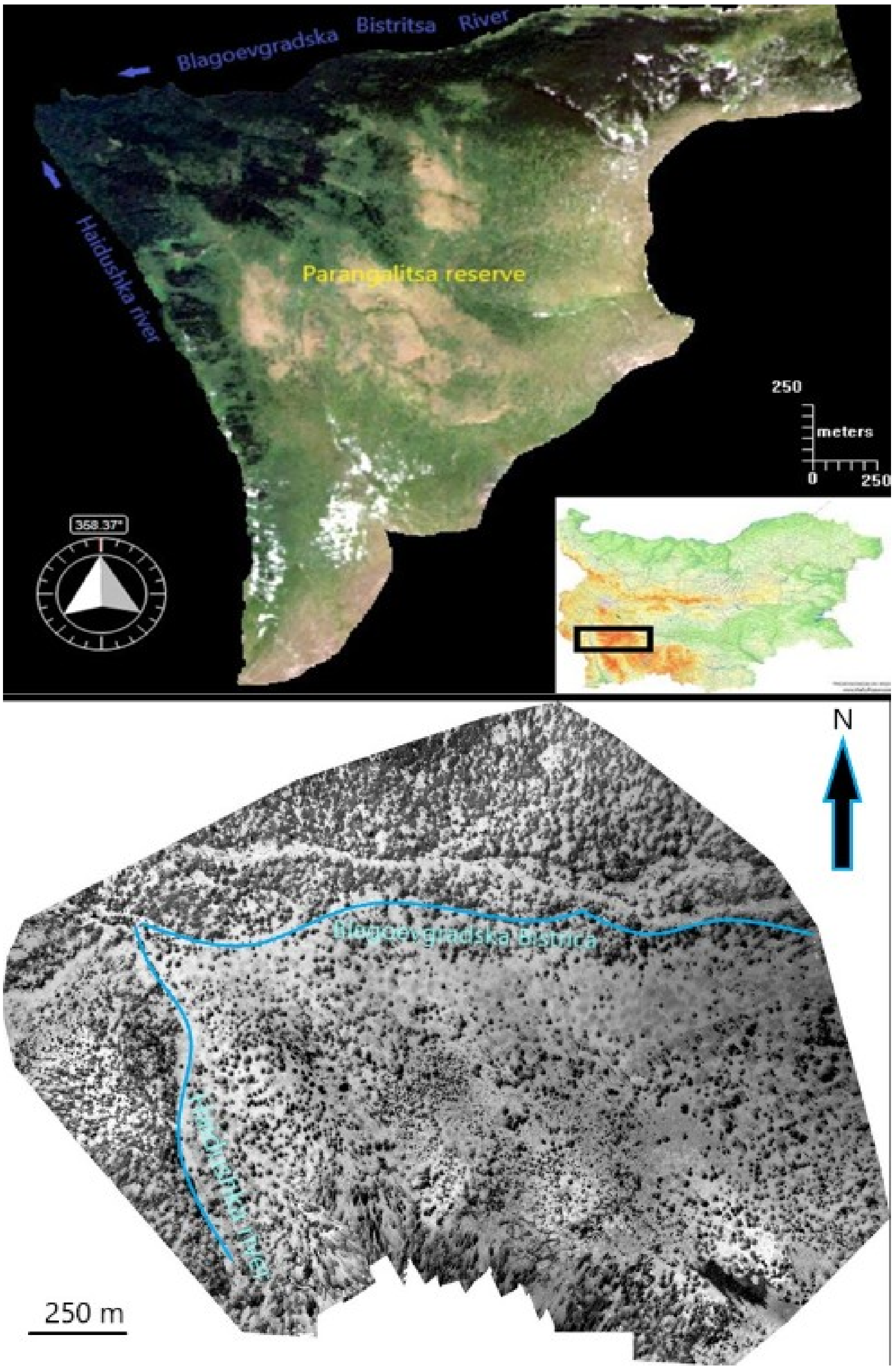

Fig. 1. Map of Parangalitsa reserve (above) and Orthophoto mosaic with NDVI (bellow) of the western corner of the Parangalitsa reserve with a pixel size of 11 cm.

Table 2. Technical specifications of Parrot Sequoia multi-spectral camera.

Sensor	Multispectral sensor + RGB camera
Multispectral sensor	4-band
RGB resolution	16 MP, 4608 x 3456 px
Single-band resolution	1.2 MP, 1280 x 960 px
Multispectral bands	Green (550nm ± 40 nm) Red (660nm ± 40 nm) Red edge (735nm ± 10 nm) Near infrared (790nm ± 40 nm)
Single-band shutter	Global
RGB Shutter	Rolling
RGB FOV	HFOV: 64° VFOV: 50° DFOV: 74°
Single-band FOV	HFOV: 62° VFOV: 49° DFOV: 74°
Calibration	Automatic radiometric calibration
Support RTK/PPK	Yes

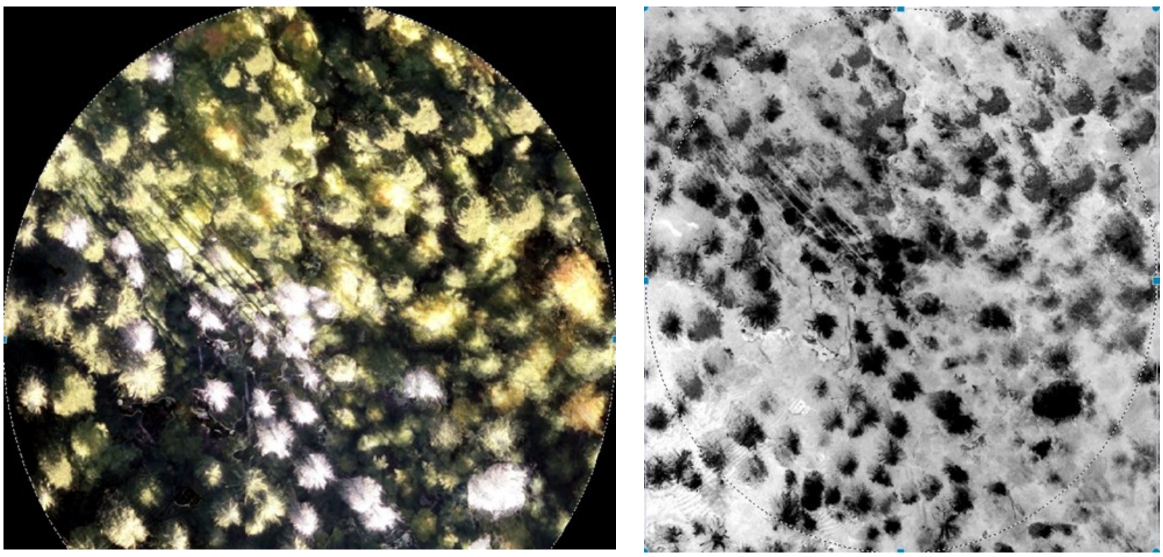

Fig. 2. Part of the Orthophoto mosaic with a spatial resolution of 11cm in RGB - on the left and NDVI - on the right.

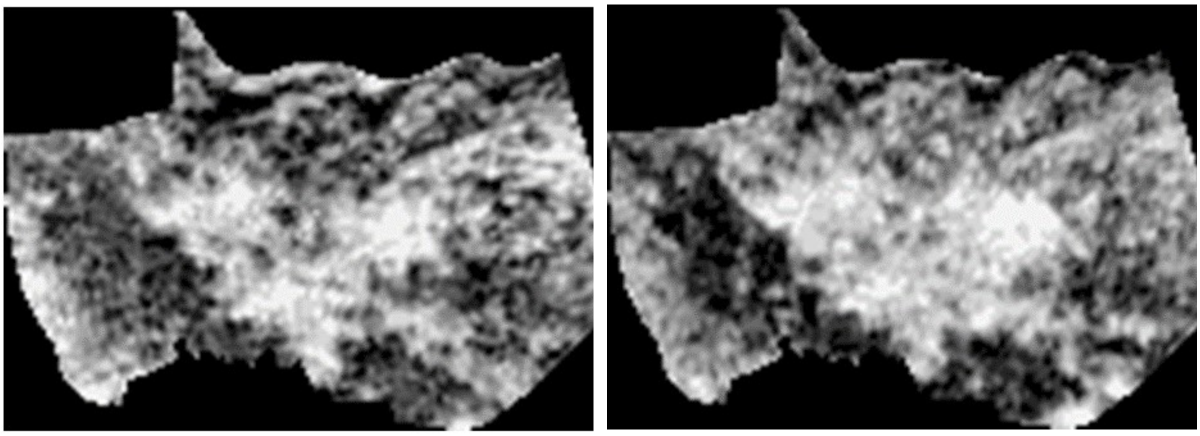

Fig. 3. 36 classes of the NDVI values (13.07.2009 on the left and 20.07.2017 on the right) along the small Area of interest – northwestern corner of the Parangalitsa reserve. White colors represent a vegetation in good health, the dark colors represent dry or vegetation in bad health. The table with the NDVI values can be found in appendix 1 and 3.

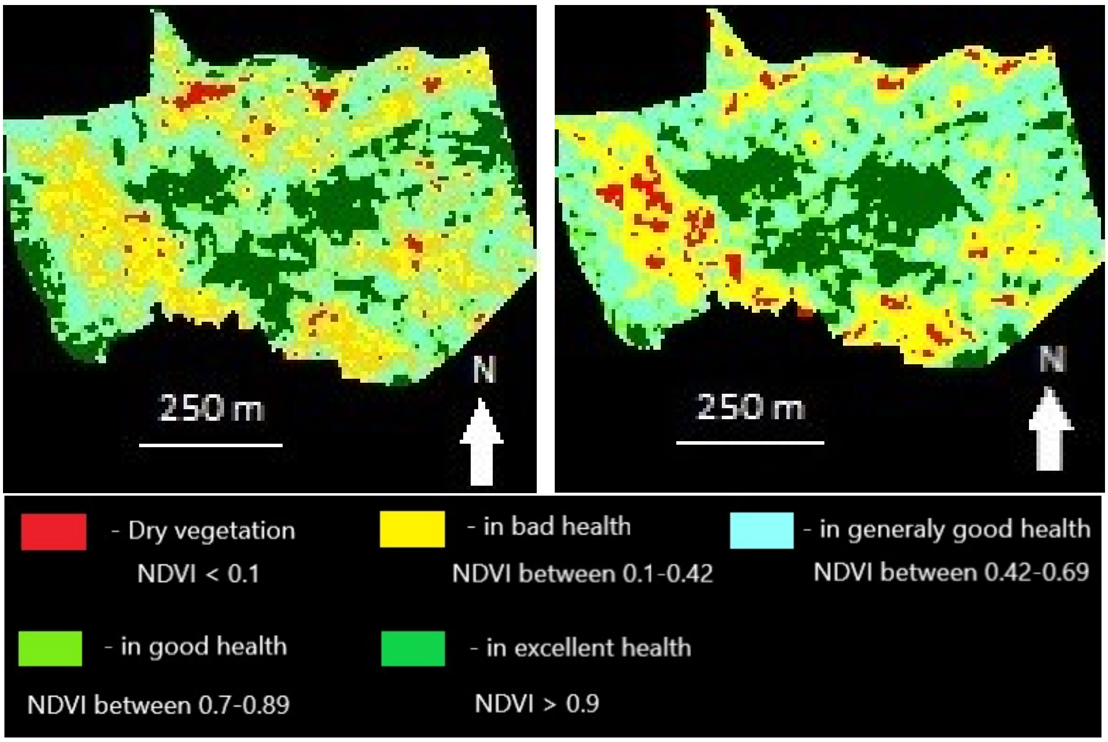

Fig.4. Colored map with the health status of the vegetation in the small area of interest - 2009 on the left and 2017 on the right.

The same methodology was applied to generate the maps (Fig. 5) with the health status of the vegetation, but this time the NDVI values were extracted from satellite images of the whole area (270 ha from which 240 ha are broad leaf and coniferous forest and 30 ha are meadow) occupied by forest inside Parangalitsa reserve area.

Results and Discussion

After thorough investigation of NDVI values generated from the high resolution orthophoto mosaic and the satellite images some general relations were detected. From one side in the NDVI values based on the satellite images in the small area of interest, some single standing dry trees due to the pixel size cannot be detected but their presents generally leads to decrease in the value of the index in this areas. The forests in this area, even though there are some heathy trees, generally are classified as forests in bad condition. Because of this, based on the data from the satellite pictures the dry wood stocks are decreasing between 2009 and 2017 but the area with forest vegetation in bad health is bigger in 2017 than in 2009 (Table 3). This confirms the negative trend in the health status of the forest vegetation and more over it can be used as an evidence that the NDVI build on the satellite images with 5m resolution is not suitable for inventory analyzes of a single dry trees, but is a reliable instrument for evaluation of the general health status of bigger areas.

On the other side on a higher altitudes in the areas occupied with coniferous forest the NDVI values indicate that these forests are in a bad health and more over the areas with a dry trees are also increasing in the research period. This increase in the areas with a dry vegetation is mainly due to the presents of large numbers of dry trees which are evenly distributed along that part of the reserve and more over large number of trees are affected by moss and lichen which decrease the quantities of the leafs (needles) on the coniferous trees. All of the above leads to decrease in the values of the NDVI along the East and South-East Part of Parangalitsa reserve area and confirm the negative trend in the vegetation health (Fig. 5).

After thorough investigation of the NDVI values in the small area of interest (24 ha) have been noticed that between 2009- 2017 the area occupied with dry trees increase with 0.49 ha (Table 3). This area in the past was occupied by the most productive forest with large presents of *Picea abies* L./H, *Abies alba* M., *Fagus sylvatica* L. Based on the data presented in Fig, 4, was concluded that the new dry trees in the small area of interest are distirubuted west of the whirlwinds spots that occurred between 1966 and 2013 (PANAYOTOV *et al.*, 2015). Because Parangalitsa reserve is an area with a maximum protection the fallen trees were left intact inside this whirlwind spots and served as food base for different vermin which consequently affected the living trees around these whirlwind spots.

Furthermore it was noticed that in some of the areas where in 2009 were observed pixels with dry trees in 2017 the same areas are occupied with new broad leaf tree types as *Salix sp.*, *Populus tremula L.*, *Sotbus aucuparia L. Acer sp.*, *Cr* and etc. The reflectance values of NIR light for these broad leaf tree types are bigger than the values of the coniferous trees and this leads to generally higher values of the NDVI in this areas. Because of this in the small area of interest between 2009 and 2017, a decrease in the size of the areas classified as forest in bad health and increase of the size of the area that are in good health with 0.98 ha can be observed.

On the Fig 4. The areas occupied with forests in good health completely much the location of the whirlwinds spots mapped by PANAYOTOV *et al.* (2015). These areas are presented with green and light green colors. Even though the good health areas and the whirlwinds share the same locations there are substantial differences in their size as the area affected by the whirlwinds activity is almost two times smaller than the one that is occupied with vegetation in good health. This can be an evidence that the old coniferous trees around whirlwinds spots have been affected by the vermin activity and because of that, the size of the areas occupied by the new broadleaf tree types are growing constantly.

Because of the bad health status and the loss of old coniferous trees the density of the forest around the whirlwinds spots has been decreased and due to this reason the spatial distribution of new whirlwinds coincide with the borders of the old ones (PANAYOTOV *et al.* 2015).

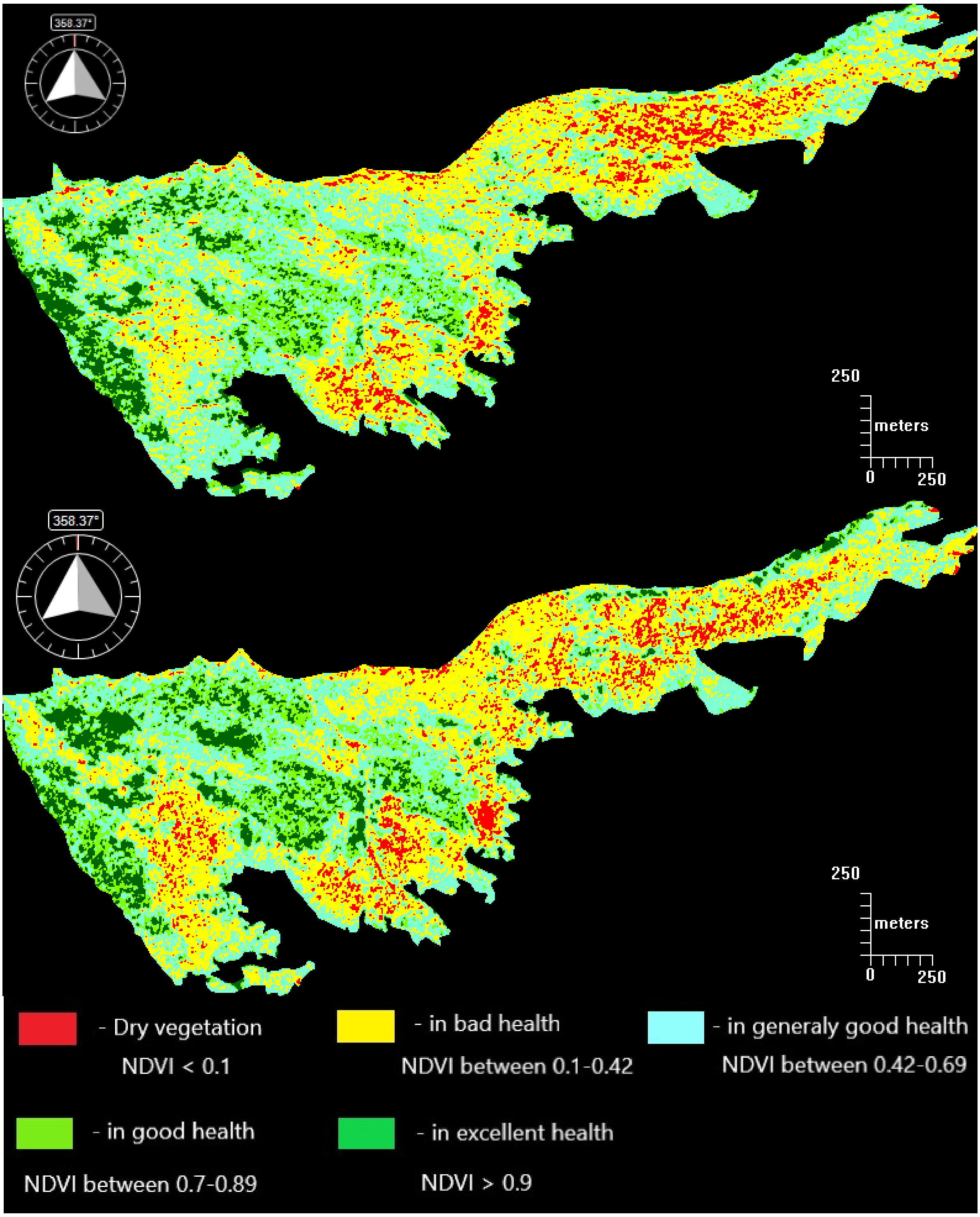

Fig. 5. Colored map with the health status of the forest vegetation inside Parangalitsa reserve based on the NDVI values (above – 13.07.2009, bellow – 20.07.2017).

Table 3. Areas (in ha) in Parangalitsa reserve classified by the NDVI values.

NDVI values combined in five groups	2009 in ha	2017 in ha	Difference in ha	Correction due to the 5 m resolution in ha
Small area of interest				
under 0.1	0.5825	1.0725	+ 0.49	
0.1÷0.4	8.29	7.31	− 0.98	
0.41÷0.69	9.12	9.67	+ 0.55	
0.7÷0.89	1.74	1.93	+ 0.19	
above 0.9	4.67	4.42	− 0.25	
The area occupied by forest in the reserve				
under 0.1	15.7	19.95	+ 4.25	+ 4.2
0.1÷0.4	95.4	101.92	+ 6.52	+ 6.2
0.41÷0.69	104.32	88.13	− 16.19	− 16.4
0.7÷0.89	34.025	34.415	+ 0.39	+ 0.3
above 0.9	20.65	26.4275	+ 5.78	+ 5.7

The forest vegetation in the small area of interest possess a complicated, broad leaf and coniferous, mosaic shaped structure and because of that the vermin activity is not so intensive as it would be if the forests were homogeneously coniferous, but the dynamics of the negative changes in their health status is much faster than the processes of natural drying due to mature age of the trees. The values of the NDVI indicated that in the western part of the small area of interest (Fig. 4) the old forest vegetation that consist of *Picea abies* L./H, *Abies alba* M., *Fagus sylvatica* L. are retreating and they have been substituted by predominantly broad leaf tree types. From one side this new broad leaf vegetation possess grater absorption capacity of CO_2 and it is very useful as a measure to mitigate the climate changes but on the other side this also means a loss of biodiversity and unique forests without equivalent inside the country.

Opposite to the small area of interest the NDVI values of the bigger forest part of the reserve indicated that there is a substantial decrease (16.4 ha which is 6.8% of the total area covered with forest) in the size of the areas that are classified as forest in normal health. Such a high percent for a short period indicate that the changes in the canopy occur with a high intensity.

In the East and the South part of the Parangalitsa reserve, where the dominant species are *Picea abies* L./H, *Abies alba* M., the values of the NDVI indicated that this part of the reserve is occupied by vegetation in a bad shape or already dry trees. Furthermore the analysis of the NDVI shows that between 2009 and 2017 the pixels that indicate dry or vegetation in bad health increase with 10.4 ha and that the most of the pixels that are affected by this change are distributed in these parts of the reserve (Table 3.). The total size of the classes with NDVI values between 0 and 0.40 in 2009 are 111.1 ha which is 46 % of the total forest area, that may be an evidence that negative trends in the vegetation health in Parangalitsa reserve are older than the time span of this research. Higher values of NDVI are also associated with the meadows and sparse, new broad leaf forests which can be observed at the whirlwinds spots. Some of this whirlwinds are older than 100 years and even this long period has not been enough for the restoration of the old coniferous forests.

The increase with 5.7 ha of the area with values of the NDVI higher than 0.9 is very well correlated with the increase in the areas whit NDVI values below 0.4 and this increase is mainly due to new broad leaf tree species inside the whirlwind activity. Evaluation of the changes in the vegetation health inside the big whirlwind spot that occurred between 1962-1965 along Haidushka river which marked the west border of the reserve represent a substantial scientific interest. Between 2009 and 2017 there is no change in the size of this whirlwind spot, but there are some changes in the NDVI values. The number of pixels with NDVI values above 0.9 are smaller in 2017 than in the 2009 but also the number of pixels with NDVI values between 0.5 and 0.89 (good and very good health) are higher. This can be used as an evidence that in this whirlwind spot are running processes of restoration of the normal functionality of the forest vegetation. May be the reason for that is the fact that the fallen wood stock were extracted and the infected standing trees by *Ips typographus* also were fallen down. Probably because of that there are no increase in the numbers of the pixels with NDVI values that indicate dry or vegetation in bad health, inside the neighboring areas. This and the negative changes in the health status of the forest vegetation around the rest of the whirlwind spots that was disclosed in the previous chapter, can be used as an evidence that a new approach for biodiversity preservation inside protected areas is needed. This approach has to be aligned with the modern tendency of non-equilibrium perspective in the management of protected areas and the biodiversity preservation.

Conclusions

Based on the evidences disclosed in the previous chapters the following conclusions can be made:

- Five m. resolution satellite images even though are not good instrument for inventory of single dry trees, can be reliable source for analysis of the health status of forest ecosystems.
- Based on the NDVI values extracted from the satellite image captured in 2009 was concluded that the negative trend in the health status of the forests ecosystems inside Parangalitsa reserve started before the time span of this research.
- Between 2009 and 2017 the negative dynamic in the shape of the forest vegetation inside the boundaries of the reserve is still in tack. In 2017 the area with NDVI values that indicated vegetation in bad health is bigger with 10.4 ha than in the 2009.
- Due to the whirlwind activity the old forest of *Picea abies* L./H, *Abies alba* M., *Fagus sylvatica* L. are substituted with a new broad leaf vegetation.
- The new whirlwind spots are distributed around the old ones and fallen trees inside are very good food based for vermin activity.
- The natural process of restoration of the forest vegetation in the old whirlwind spots which are situated between 1750 and 1900 m.a.b.s.l. is very slow and contemporary meadows and sparse forest are observed inside this spots.
- The forest vegetation inside the big whirlwind spot (occurred in the period 1962-1965) that is situated along the west border of the reserve is in very good health. The good health of the last is due to the fact that all fallen and infected trees were extracted in the past.
- The presented evidences confirmed the need to impose the modern approach of nonequilibrium perspective in the management of protected areas and biodiversity protection.

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Appendix 1. NDVI in 36 classes of the small area of interest based on the satellite image from 13.07.2009.

class36_ndvi_small_2009.img : Layer_1

Row	Histogram	Color	Red	Green	Blue	Opacity	Class_Names	Area
0	4739		0	0	0	0	Unclassified	11.8475
1	233		0	0	0	1	Class 1	0.5825
2	630		0.106	0.106	0.106	1	Class 2	1.575
3	698		0.208	0.208	0.208	1	Class 3	1.745
4	529		0.267	0.267	0.267	1	Class 4	1.3225
5	313		0.298	0.298	0.298	1	Class 5	0.7825
6	238		0.322	0.322	0.322	1	Class 6	0.595
7	180		0.337	0.337	0.337	1	Class 7	0.45
8	179		0.353	0.353	0.353	1	Class 8	0.4475
9	175		0.365	0.365	0.365	1	Class 9	0.4375
10	194		0.38	0.38	0.38	1	Class 10	0.485
11	180		0.392	0.392	0.392	1	Class 11	0.45
12	192		0.408	0.408	0.408	1	Class 12	0.48
13	189		0.424	0.424	0.424	1	Class 13	0.4725
14	179		0.435	0.435	0.435	1	Class 14	0.4475
15	197		0.451	0.451	0.451	1	Class 15	0.4925
16	199		0.467	0.467	0.467	1	Class 16	0.4975
17	197		0.478	0.478	0.478	1	Class 17	0.4925
18	183		0.494	0.494	0.494	1	Class 18	0.4575
19	181		0.506	0.506	0.506	1	Class 19	0.4525
20	180		0.522	0.522	0.522	1	Class 20	0.45
21	193		0.537	0.537	0.537	1	Class 21	0.4825
22	179		0.549	0.549	0.549	1	Class 22	0.4475
23	174		0.565	0.565	0.565	1	Class 23	0.435
24	173		0.58	0.58	0.58	1	Class 24	0.4325
25	197		0.592	0.592	0.592	1	Class 25	0.4925
26	165		0.608	0.608	0.608	1	Class 26	0.4125
27	183		0.62	0.62	0.62	1	Class 27	0.4575
28	177		0.635	0.635	0.635	1	Class 28	0.4425
29	178		0.651	0.651	0.651	1	Class 29	0.445
30	150		0.663	0.663	0.663	1	Class 30	0.375
31	183		0.678	0.678	0.678	1	Class 31	0.4575
32	290		0.698	0.698	0.698	1	Class 32	0.725
33	407		0.729	0.729	0.729	1	Class 33	1.0175
34	602		0.773	0.773	0.773	1	Class 34	1.505
35	765		0.843	0.843	0.843	1	Class 35	1.9125
36	499		0.945	0.945	0.945	1	Class 36	1.2475

Appendix 2. NDVI in 10 classes of the small area of interest based on the satellite image from 13.07.2009.

class10_ndvi_2009_large.img : Layer_1

Row	Histogram	Color	Red	Green	Blue	Opacity	Class_Names	Area
0	209546		0	0	0	0	Unclassified	523.865
1	6280		0.004	0.004	0.004	1	Class 1	15.7
2	12510		0.192	0.192	0.192	1	Class 2	31.275
3	13506		0.314	0.314	0.314	1	Class 3	33.765
4	12139		0.4	0.4	0.4	1	Class 4	30.3475
5	10399		0.467	0.467	0.467	1	Class 5	25.9975
6	9683		0.529	0.529	0.529	1	Class 6	24.2075
7	9986		0.6	0.6	0.6	1	Class 7	24.965
8	11661		0.682	0.682	0.682	1	Class 8	29.1525
9	13610		0.792	0.792	0.792	1	Class 9	34.025
10	8260		0.941	0.941	0.941	1	Class 10	20.65

Appendix 3. NDVI in 36 classes of the small area of interest based on the satellite image from 20.07.2017.

class36_ndvi_small_2017.img : Layer_1

Row	Histogram	Color	Red	Green	Blue	Opacity	Class_Names	Area
0	4739		0	0	0	0	Unclassified	11.8475
1	429		0	0	0	1	Class 1	1.0725
2	730		0.122	0.122	0.122	1	Class 2	1.825
3	592		0.208	0.208	0.208	1	Class 3	1.48
4	383		0.263	0.263	0.263	1	Class 4	0.9575
5	243		0.298	0.298	0.298	1	Class 5	0.6075
6	178		0.318	0.318	0.318	1	Class 6	0.445
7	134		0.333	0.333	0.333	1	Class 7	0.335
8	156		0.349	0.349	0.349	1	Class 8	0.39
9	185		0.365	0.365	0.365	1	Class 9	0.4625
10	164		0.376	0.376	0.376	1	Class 10	0.41
11	157		0.392	0.392	0.392	1	Class 11	0.3925
12	179		0.408	0.408	0.408	1	Class 12	0.4475
13	170		0.42	0.42	0.42	1	Class 13	0.425
14	174		0.435	0.435	0.435	1	Class 14	0.435
15	167		0.451	0.451	0.451	1	Class 15	0.4175
16	209		0.467	0.467	0.467	1	Class 16	0.5225
17	226		0.478	0.478	0.478	1	Class 17	0.565
18	188		0.494	0.494	0.494	1	Class 18	0.47
19	178		0.506	0.506	0.506	1	Class 19	0.445
20	177		0.522	0.522	0.522	1	Class 20	0.4425
21	214		0.537	0.537	0.537	1	Class 21	0.535
22	203		0.553	0.553	0.553	1	Class 22	0.5075
23	183		0.565	0.565	0.565	1	Class 23	0.4575
24	193		0.576	0.576	0.576	1	Class 24	0.4825
25	188		0.592	0.592	0.592	1	Class 25	0.47
26	182		0.608	0.608	0.608	1	Class 26	0.455
27	192		0.62	0.62	0.62	1	Class 27	0.48
28	206		0.635	0.635	0.635	1	Class 28	0.515
29	202		0.647	0.647	0.647	1	Class 29	0.505
30	216		0.663	0.663	0.663	1	Class 30	0.54
31	221		0.678	0.678	0.678	1	Class 31	0.5525
32	330		0.698	0.698	0.698	1	Class 32	0.825
33	443		0.729	0.729	0.729	1	Class 33	1.1075
34	615		0.773	0.773	0.773	1	Class 34	1.5375
35	756		0.839	0.839	0.839	1	Class 35	1.89
36	398		0.949	0.949	0.949	1	Class 36	0.995

Appendix 4. NDVI in 10 classes of the small area of interest based on the satellite image from 20.07.2017.

class10_ndvi_2017_large.img : Layer_1

Row	Histogram	Color	Red	Green	Blue	Opacity	Class_Names	Area
0	209546		0	0	0	0	Unclassified	523.865
1	7678		0.071	0.071	0.071	1	Class 1	19.195
2	15517		0.227	0.227	0.227	1	Class 2	38.7925
3	14377		0.325	0.325	0.325	1	Class 3	35.9425
4	10872		0.4	0.4	0.4	1	Class 4	27.18
5	8593		0.467	0.467	0.467	1	Class 5	21.4825
6	7853		0.529	0.529	0.529	1	Class 6	19.6325
7	8206		0.596	0.596	0.596	1	Class 7	20.515
8	10601		0.682	0.682	0.682	1	Class 8	26.5025
9	13766		0.788	0.788	0.788	1	Class 9	34.415
10	10571		0.925	0.925	0.925	1	Class 10	26.4275