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ENVIRONMENTAL MONITORING SUPPORTED BY AERIAL PHOTOGRAPHY – A CASE STUDY OF THE BURNT DOWN BUGAC JUNIPER FOREST, HUNGARY

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Abstract
Wildfire poses a serious risk in several regions of the world threatening urban, agricultural areas and natural ecosystems as well. Nature conservation has important role to be prepared for the management of postfire environmental degradation and restoration for protected areas preserving valuable ecosystems. The improving temporal and spatial resolution of remote sensing and GIS methods significantly contributes to map the changes for accelerating management steps of restoration. In this study a severe wildfire and its impacts were assessed in case of a protected area of the Kiskunság National Park in Hungary, which was partly burnt down in 2012. The aim of this research was to efficiently and accurately assess the damages and to plan and execute the restoration works using remote sensing tools. Aerial data collection was performed one month, and one year after the fire. In 2014 the regenerated vegetation was surveyed and mapped in the field. Using the aerial photographs and the field data, the degree and extent of the fire damages, the types and the state of the vegetation and the presence and proportion of the invasive species were determined. Semi-automatic methods were used for the classification of completely, partially damaged and undamaged areas. Based on the results, the reforestation of the burnt area is suggested to prevent the overspreading of white poplar against common junipers and to clean the area from the most frequent invasive species. To monitor the regeneration of the vegetation and the spreading of the invasive species, further aerial photography and field campaigns are planned.

Keywords: wildfire, aerial photography, invasive species, supervised classification

INTRODUCTION

Wildfire poses a serious risk in several regions of the world these days. This growing risk proves that climate change has an omnipresent influence on the fundamental environmental and ecological resources. Paton and Shroder (2015) point out, that wildfire has had a significant effect on ecosystems for millennia and ecosystems have been formed through people working with the fire rather against it. A social-ecological perspective should always be considered if we want to understand and manage wildfire risk (Buergelt and Paton, 2014). Wildfires mean a hazard and a huge threat in recurring drought periods which are caused by climate change. Societies and communities exposed to facing wildfire hazards may experience more and more frequent, large-scale, devastating wildfire events (Adams, 2013). It is evident that the majority of fires are human induced; the Mediterranean region accounts for the larger proportion of human-caused fires in the world (95%) (Leone et al., 2009). In most of European countries, forest fire outbreaks result from human activities without intention to provoke damage (i.e., they start by accident, negligent actions, or risk behavior) (Tedim et al., 2015). The increase in the number of wildfire hazards in recent years has brought a combined results of the ever-larger droughts and all-pervading reporting (Mockenhaupt, 2014), which has called forth the increased number of remedial methods in dealing with fires.

Wildfires have the unique characteristic due to the complex interdependencies that exist between humans and the forest sources of wildfire hazards. Forests have always presented the crucial territory for agriculture, livelihood, hunting and forests and other natural environments have also played important roles in sustaining human well-being (Clayton and Opotow, 2003). Climate change will have an effect on the patterns of wildfire risk and their distribution (Nicholls and Lucas, 2007). Locally, wildfire consequences affect directly air quality, ecosystems and landscapes. Secondary consequences can be traced when we examine the impact of fire hazards on water and soil quality. These can cause instant damage to vegetation and fauna and have direct and indirect impacts on soils through heat release and ash deposition, and contribute to postfire environmental degradation (Vallejo and Alloza, 2015). At the beginning of this century a large-scale flooding period and forest fires started this is why the European Parliament had to adopt the "European Parliament resolution on Natural Disasters (fires, droughts, and floods) environmental aspects (2005/2192(INI))". To protect the forests throughout the EU is one of the most crucial actions of the EU Forest Action Plan, in which the member states are invited to support forest fire prevention measures, restoration of forests after being damaged by natural disasters (Tedim et al., 2015).

There are two main periods in the year when forest fires pose a great risk in Hungary. The first group of fire incidents is connected with the beginning of agricultural work (burning of fields and stubbles) which starts after the snow has thawed and the weather is characterised by the lack of precipitation between February and April. New plantations are usually prone to more extensive damage in these wildfires, while vegetation consisting of older trees is less endangered. The second group of forest fires occurs from June to September when the dry litterfloor of deciduous and coniferous forests fuels these fires in the hot, drought-stricken summer months. These incidents are mainly characteristic of the drier areas of Bács-Kiskun and Csongrád counties on the Great Hungarian Plane [1].

The increased frequency of forest fires observed in the past few decades is most likely to be caused by the more and more extreme climate (less precipitation, higher mean temperature, winters without sufficient snow covering), which ultimately leads to the drying out of plant litter. Due to climate and vegetation circumstances, naturally induced forests fires are of no account (about 1%) in Hungary. 99 % of forest fires are human induced (negligence or arson). Most fires are induced by (adults’ and infants’) negligence and only a small proportion of fires are caused by arsonists [2].

In this study a severe wildfire and its impacts were assessed in case of a protected area of the Kiskunság National Park in Hungary, which was partly burnt down in 2012. The aim was to support the professionals of the national park in their work to estimate damage effectively and properly as well as to plan, organize and implement restoration measures by providing remote sensing strategies and tools, i.e. methods of collecting, processing and analysing data (Szatmári et al., 2014).

STUDY AREA

The study area, the Bugac Juniper Forest is located in the Kiskunság Sandland, in the Danube-Tisza Interfluve (Fig. 1). The No. VI protected area of the Kiskunság National Park (KNP) is situated about 7 km north to the settlement of Bugac. Crescent-shaped sand dunes are the most characteristic features of the surface, they stretch out about 4 km long, and they may even reach 12-18 m height in this region. The majority of sand and loess found here are alluvial deposits of the paleo-Danube. These deposits were shaped into sand dune lines by north-west winds in the Pleistocene and Holocene. The beginning of the Holocene marked the anchor of these aeolian forms, but later in the Boreal period the wind started to move them again (Borsy, 1989). Saline lakes were formed in the interdunal depressions (Temesi, 1986).

The predominant plant association of the area is the open perennial sand grassland. The extent of land cover is about 50%, it reaches its biggest diversity in spring and autumn, while the association usually dries out in summer. Its environmental protection value makes the open perennial sand grassland a very important one (Facsar, 1996); most of the endemic herbaceous plants of Hungary can be found in this association (e.g. Hungarian or sand fescue (*Festuca vaginata*), different feather grass species (*Stipa sp.*)). The natural multi-layer flora on the top and the southern slope of the sand dunes as well as steeper parts of the area is made up of juniper-poplars

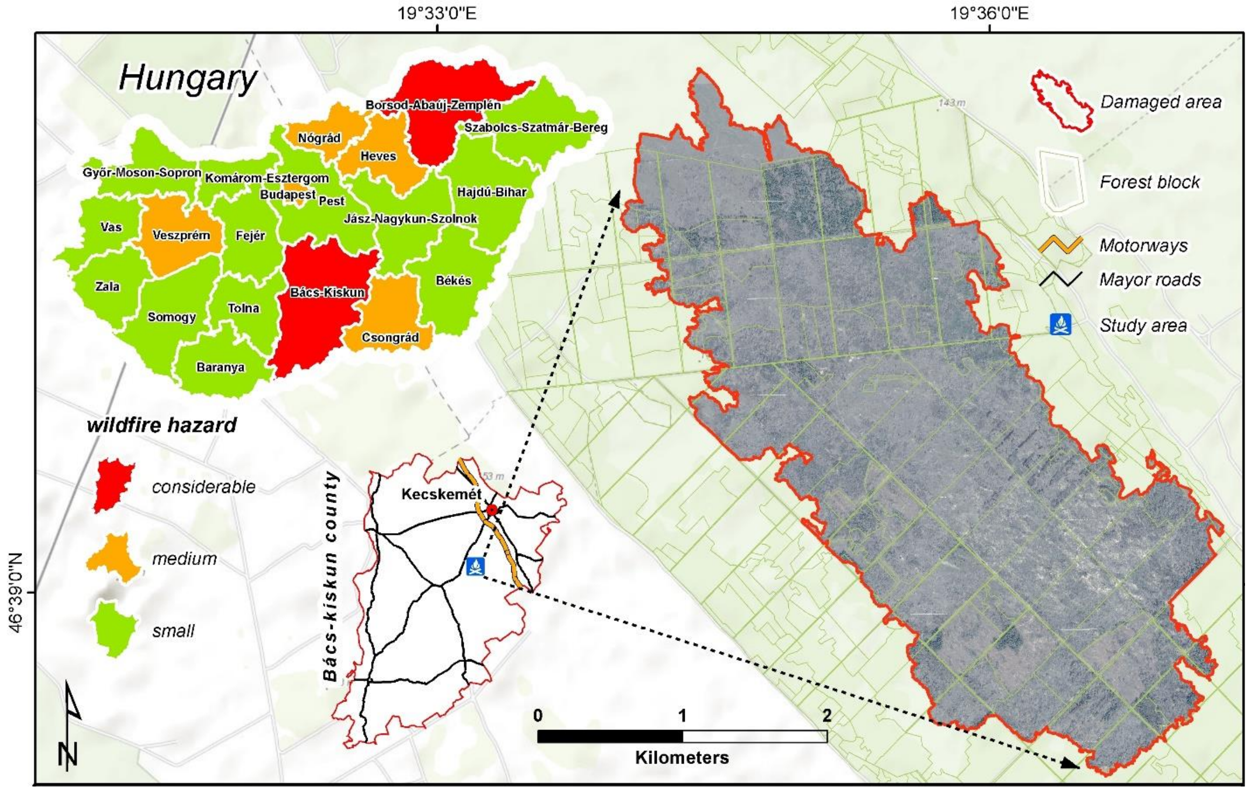

Fig. 1 Wildfire hazard of the Hungarian counties and the location of the study area in Bács-Kiskun county, characterized by a considerable wildfire hazard

(*Festucetum vaginatae juniperetosum*). The canopy layer consists of white poplars (*Populus alba*) mainly, and sometimes grey poplars (*Populus canescens*), the understorey layer consists of common junipers (*Juniperus communis*) as well as small groups of common hawthorns (*Crataegus monogyna*) and blackthorns (*Prunus spinosa*). There are several rare orchid species to be found in the forest floor such as the Red Helleborine (*Cephalonthera rubra*), the Royal (*Epipactis etrorubens)* and the Bugac Helleborine (*Epipactis bugacensis*) (Borhidi, 2003). English oaks (*Quercus robur*) also mix into the closed canopy layer of the associations in the valleys and on the sand dune slopes. Surface fires, when surface litter and other dead vegetal parts and smaller shrub burn have been common in this type of forest vegetation. They can develop in whole fire season. Forest litter, needles, dead twigs and branches get totally dry in arid periods without rainfall and start easily burning as a consequence of negligently lighted fire [2].

On 29 April 2012, a fire broke out in the study area, and it was finally extinguished on 5 May 2012. The south-southeast winds took its smoke as far as the outskirts of the capital as is shown on satellite images (Fig. 2). Wildfire suppression was made difficult by embers in tree hollows that kept on smouldering for days, unfortunate soil conditions, and sudden gusts of the wind. It was a high-alert wildfire that flamed up numerous times until the afternoon of 1 May 2012, and more than a fifth of the protected area had burnt to the ground. Both flora and fauna suffered considerable loss, for example, many protected reptiles and bird hatchlings fell victim to the fire.

The Hungarian state contributed to the restoration of the damaged vegetation by mobilising new work force who helped the employees of the national park clean up debris, plant saplings, and eradicate invasive plant species that started to spread aggressively in the burnt area.

METHODS

Aerial photography

Remote sensing data were collected by equipping a Cessna 172 with a high resolution aerial photography system (Tobak et al., 2008a). Out of the numerous advantages of the system, its cost efficiency (Novák, 2015), and its operativity can be highlighted (Tobak et al., 2008b). The fact that the system is easy to operate becomes particularly important in projects that investigate quickly changing phenomena (Bakó, 2010). The central unit of the aerial photography system is a Trimble Aerial Camera which is a 39-megapixel model with a PhaseOne P45+ back wall, interchangeable 47 mm RGB and CIR (color-infrared) imagery lenses, and various controllers. The camera system is supported by adequate power supply, GPS tools to provide correct navigation, and a portable computer. The Aero TopoL software of the system supports both the planning and navigational phases (Tobak, 2013).

In order to estimate damage as soon as possible, the study area was surveyed one month after the forest fire (7 June 2012), while monitoring its regeneration and the spread of invasive species happened one year later (1 July 2013). The same monitoring system and procedure were applied on both occasions. A precise flight route was planned before the aerial survey itself, which enabled us

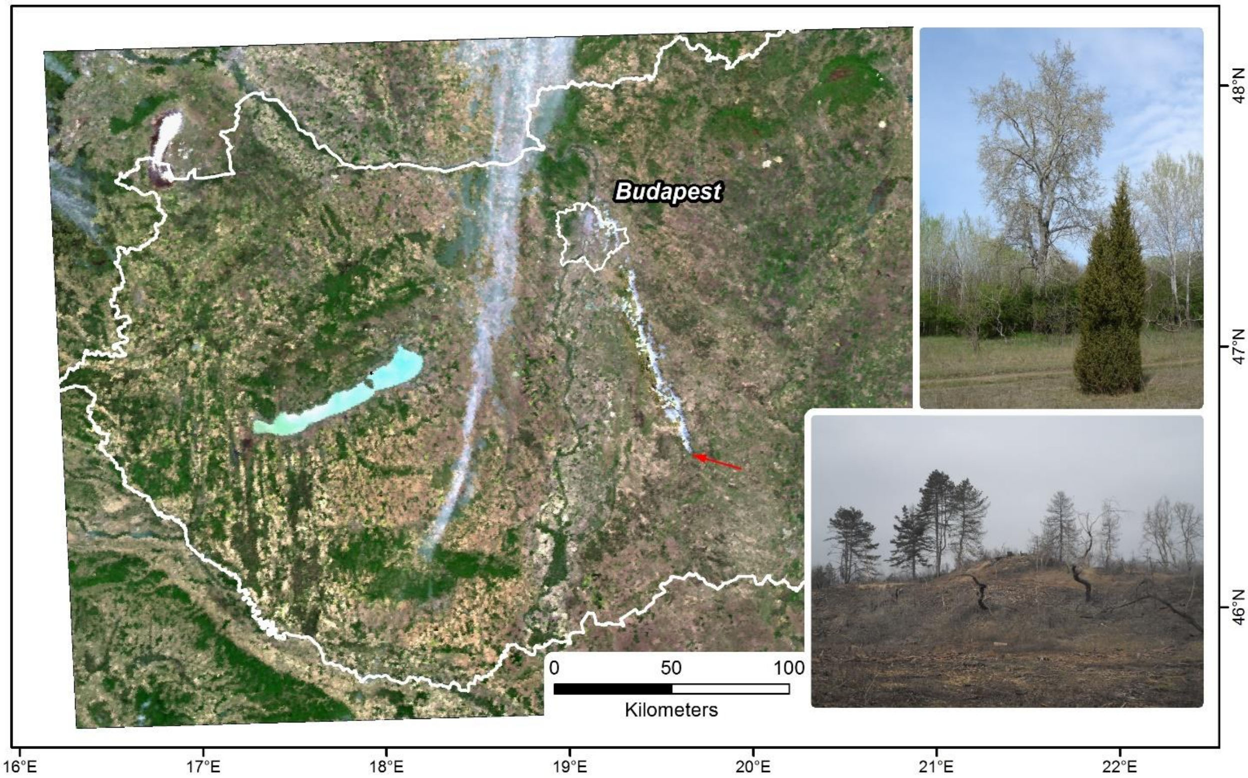

Fig. 2 Spread of the smoke of the 2012 Bugac forest fire as depicted on a satellite image [3], *Common juniper* with an old white poplar (*Populus alba*) in the background and a part of the burnt area

to prepare the geometric file of the flight rows and image centres based on the data of the study area borders given by the KNP. It is the basic requirement of navigation- and position-based aerial photography. The images were collected with a 60-70% overlap in the along track direction, and 20-30% in the cross track direction. These overlaps allowed the continuous cover of the study area as well as its spatial analysis (e,g. altimetry). A further important parameter of aerial photography is GSD (ground sample distance) which, in our case, was 20 cm (2012 survey) and 10 cm (2013 survey) respectively. 58 images were taken in 4 flight rows from altitudes of 1,400 m and 700 m in 2012, and 179 images were taken in 7 flight rows from the same altitudes in 2013 (Fig. 3).

Data acquisition was followed by raw data – navigational and image – processing. The co-ordinates of the actual flight route and the aerial photo processing centre can be obtained in ASCII format, which can be integrated into a geographical information system directly after being converted to the proper format. It means that we had 3 co-ordinates and one camera rotation angle (kappa) value, out of the 3 possible ones (omega-phi-kappa), per image at our disposal as initial exterior orientation parameters. This information is the input data for the aerial triangulation of the aerial photographs. The unit of the camera rotation angle was degree and the centre co-ordinates were recorded in the EOV (Unified National Map Projection) system in metres.

Creation of orthophotos

By using small format aerial photography system, photographs can be taken at any time at any frequency, which provides precise orthophotos for further image classifications and analyses. The so-called block of aligned photos was prepared from individual photographic images. The auto detection of common points in the overlapping image parts and the initial parameters of the exterior orientation are used in this process. After aligning the images the software automatically starts detecting common points in the overlapping parts of the block, and creates a sparse 3D point cloud. In order to filter our gross geometric errors, a mesh is generated based on the sparse cloud.

In order to match the model and the actual geographic space accurately, on site ground reference points are also needed. Professionals of the KNP placed 162 foil stripes in the study area so that they could be identified in the images too. The co-ordinates of these stripes were fixed with RTK GNSS, and during data procession they served as GCPs (Ground Control Points) in the exterior orientation of the model. A homogeneous distribution of 8-9 GCPs in the multi-overlapping image parts were enough in the total block of aligned photos. As a result, an orthomosaic (an orthophoto from rectified photos, with the same geometric resolution as the original aerial photos) is produced on the basis of the oriented aerial photo block of the whole study area.

Analysis of aerial photos

The orthorectified RGB and CIR images can be used in a wide range of studies. The common characteristic of these studies is that they require high spatial and temporal resolution and visible as well as near infrared spectral information. The detailed analysis of the processed data was done in the total of the study area. The applied methods can be categorised into manual, semi-automatic, and automatic methods based on the extent of the necessary intervention of the analysing process. In order to optimise

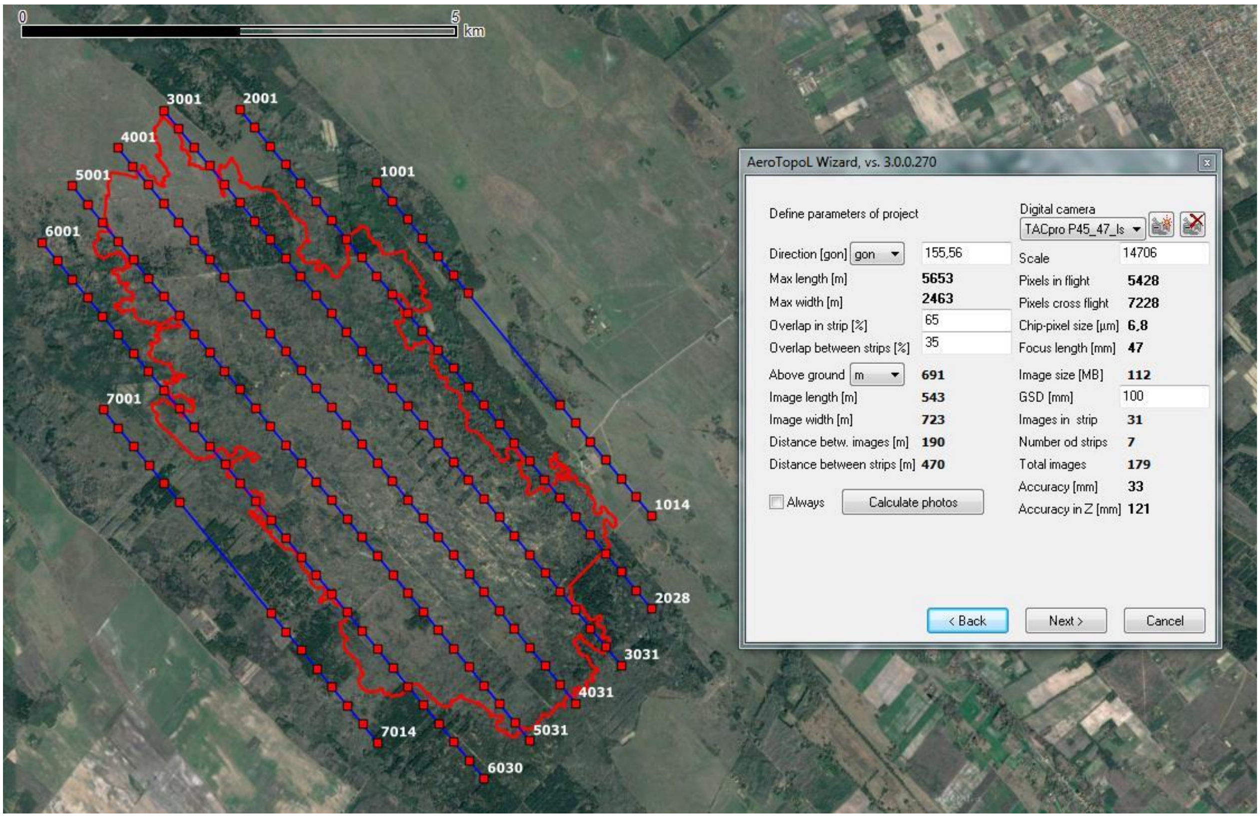

Fig. 3 Flight plan and its parameters of the 2013 aerial survey campaign

the ratio of temporal and personal resources of the analysis to the expected quality and availability of the results, semi-automatic methods were employed primarily.

Manual analysis was employed to the visual separation and bordering of the parcels damaged to a varying extent. At this step it was important for the analyst of the data to be profoundly familiar with the study area, which was established by the on site fieldwork with the professionals of the KNP and a thorough GPS survey.

Remote sensing data were stored in raster format, and different image classification algorithms were run on them. We also tested the *ISODATA* technique, which automatically allocates the image elements to classes. In this case, identifying (labelling) classes happens afterwards. From the supervised classification methods, which demand bigger user intervention, the Maximum Likelihood algorithm was applied. In this classification method, classes were created on the basis of previously identified training sites with already known vegetable type and damage extent.

On site field survey

On site data collection took place on 9 April 2014, the state of the study area and the vegetation was surveyed. Each parcel was categorised during the on site field survey, then the descriptive data of the surveyed objects were captured systematically in geographic information system. The type of the vegetation, the name of the most densely occurring invasive species, the extent of the species' spread were all categorised from 1 to 5. Special data belonging to certain polygons were also captured, these data included information such as the newly planted poplars, the aging vegetation

Invasive species and their land cover rate in the study area

Invasive plants (or adversed introduced plants) are usually plant species which are not native to a specific location. Invasive plant species usually do not have any special requirements, tolerate a wide range of environmental conditions, and have no natural controls therefore their pest-resistance is high. By adapting fast, they drive local native or indigenous species to (near) extinction. They have a tendency to spread aggressively and, as a result, they may seriously disrupt the native ecological system (Sipos, 2004).

The invasive species in the study area are as follows: tree of heaven or ailanthus (*Ailanthus altissima*), false acacia or black locust (*Robinia pseudoacacia*), common milkweed or silkweed (*Asclepias syriaca*), wild black cherry (*Prunus serotina*), non-native Canadian (also known as American) poplar (*Populus x canadensis hybrids, Populus x euramericana syn.*), and black pine (*Pinus nigra*). During the on site field survey 5 categories of invasive plant species were created on the basis of their density:

1. no presence in the parcel
2. 0-10% density in the parcel
3. 10-25% density in the parcel
4. 25-50% density in the parcel
5. over 50% density in the parcel

Surveying the vegetation of the study area

The following types of vegetation were identified in the parcels of the study area when surveying vegetation and its general state: white poplars, junipers, white poplar-junipers, Scots and black pines, false acacias, and open grasslands in some places. On the basis of the damage caused by the forest fire, intact and burnt parcels were identified.

RESULTS

Extent of damage based on remote sensing data

Interpreting the pre-processed – orthorectified – aerial photographs meant manual delineating of parcels in the simplest case. In accordance with the expectations of the KNP, this method was employed when surveying the damage to the non-native (introduced and purposefully planted) pine trees. On the basis of the forest maps 24% (202 ha) of the study area (a total of 835 ha) was classified as intact, 38 % (318 ha) as partly, and 38% (318 ha) as totally damaged (burnt) (Fig. 5A, [4]).

The results of the supervised (Maximum Likelihood) and the automatic (ISODATA) methods of the (semi-)automatic workflow are shown in a sample area of 11 ha, which represents the analysed categories of the whole study area. The supervised classification of the previously fixed training sites allocated 50% of the sample area as damaged (burnt), 30% as partly damaged, and 12% as intact. The rest of the study area, ca. 8%, was allocated as shadowed or open sandland (Fig. 5B).

The results of the ISODATA clustering run with 9 initial classes showed a more heterogeneous picture, at the same time, the border lines of the most damaged area was clearly seen here too. This method allocated 30% of the pixels to the damaged (burnt) class, 28% to the partly damaged, and 14% to the intact classes. The proportion of the shadow areas was bigger (21%) (Fig. 5C).

Types of vegetation

The study area (1748 ha) was covered by white poplars (622 ha, 34.8%), white poplar-junipers (488 ha, 27.3%), Scots pines (307 ha, 17.1%), open grasslands (185 ha, 10.3%), junipers (115 ha, 6.4%), and false acacias (68 ha, 3.8%) two years after the wildfire (Fig. 6). Scots pines are found in the periphery, which may indicate that this type of vegetation may have a certain protecting role.

On the basis of on site field data, more than half of the study area was damaged in the wildfire. Juniper and Scots pine associations were damaged the most extensively (Fig. 7). There were no visible traces of wildfire damage in the open grassland associations, they had regenerated from seeds found in the soil.

The burnt white poplar associations were sprouting which indicated their strong regeneration ability. The size of the sprouts were between 1-1.5 m. There were many aging stands in the forest which indicated the bad health state of the vegetation. The dead, burnt tree trunks left in the study area after the suppression of the wildfire were all decaying.

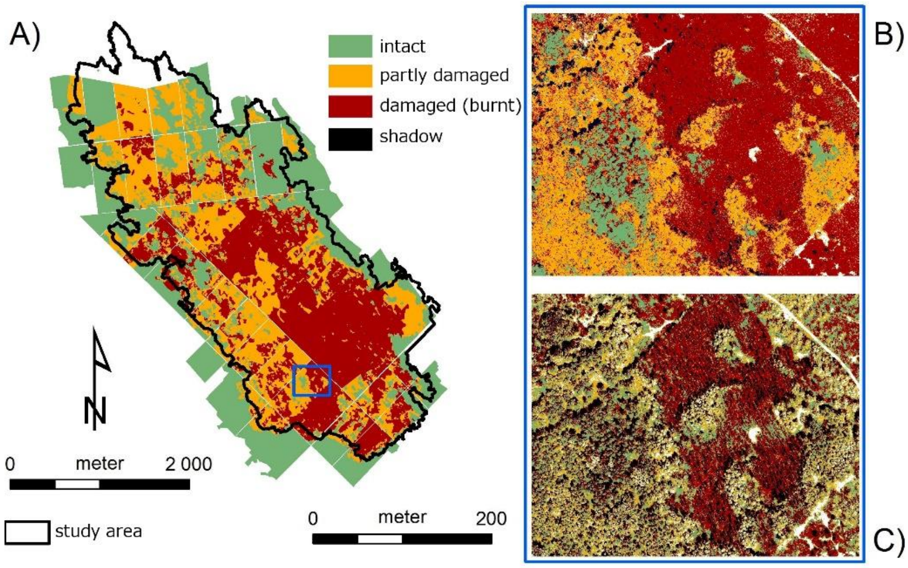

Fig. 5 Manual bordering of the damaged sites of varying damage extent (A) and their classification (B: supervised classification, C: ISODATA clustering) on the basis of aerial photos

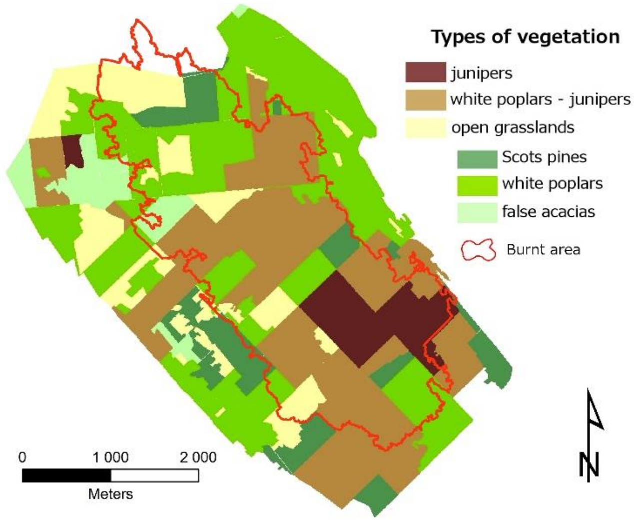

Fig. 6 Location of different types of vegetation in the study area

Invasive species and the extent of their appearance

The rehabilitation of the study area in the Bugac Juniper Forest started in 2012. In the beginning, the dead and burnt wood pieces and logs were not removed from the study area, this process has been in progress since then. However, the transport of these tree remnants is not advantageous as disturbing the area makes it easier for invasive species to appear and spread. At the same time, processing and transporting the remnants is necessary to stop the appearance and rapid swarming of pests that endanger both the remaining and the newly growing vegetation.

The spreading of the invasive plant species in the study area is rapid. The distribution of these species in the forest is as follows: 46% false acacia, 3% Canadian poplar, 8% ailanthus, 2% black pine, 0.04% wild black cherry, and 18% common milkweed (Fig. 8). The most aggressively spreading invasive species is common milkweed. False acacia shows the greatest extent of spreading, this species strongly degrades the conservation value of this more strictly protected area. There were no signs of invasive species in the juniper associations, although it was damaged the most in the wildfire. Figure 9 also shows that the invasive plant species appear in the periphery of the forest and in the open grassland associations.

Fig. 7 An aerial photograph showing the damage to juniper associations

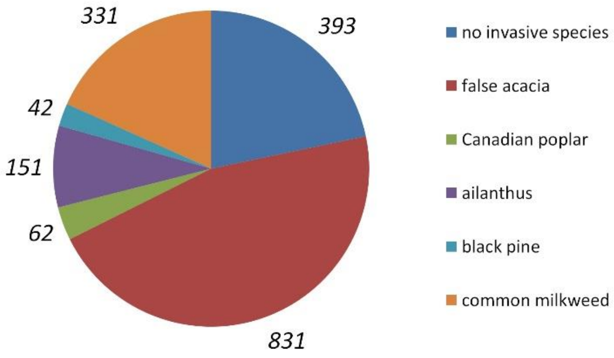

Fig. 8 The appearance of invasive species (ha)

DISCUSSION AND CONCLUSIONS

The extent of damage, the type and state of vegetation, and the extent of the invasive species' appearance were all categorised by processing and analysing aerial photos and on site field survey. Databases were designed for further expansion, too, so that other types of data can be recorded and studied here in the future. The analysis of remote sensing data was aided by semi-automatic classification methods.

Our analyses and geoinformatic database help professionals regenerate the forest and stop the spreading of invasive plant species. In order to successfully regenerate vegetation, it is necessary to plant new stands. New planting of pine forests may be important because they may serve as a protecting belt around the inner area of the forest, and they may as well be buffer zones where the appearance of invasive species is not considerable. Sprouts of white poplar associations in the Bugac Juniper Forest must be controlled so that they will neither spread too much nor suppress junipers' spreading.

It is also important to cut out invasive plant species continuously, and more parcels have to be cleared of the sprouts of false acacia and ailanthus. Stopping common milkweed from spreading in open grasslands is another significant task, which is made more difficult by the fact that common milkweed spreads very aggressively in the area. Their eradication is also made difficult by their mode of spreading: common milkweed reproduces both by seeds and rhizomes, and forms a colony or a long, thick line quickly crowding over other plants.

Further aerial photography and on site field survey are planned to follow the regeneration of the area and monitor the undesirable spread of invasive plant species. With our work we would like to contribute to the regeneration of one of the most visited sites of the Kiskunság National Park introduced in our study.

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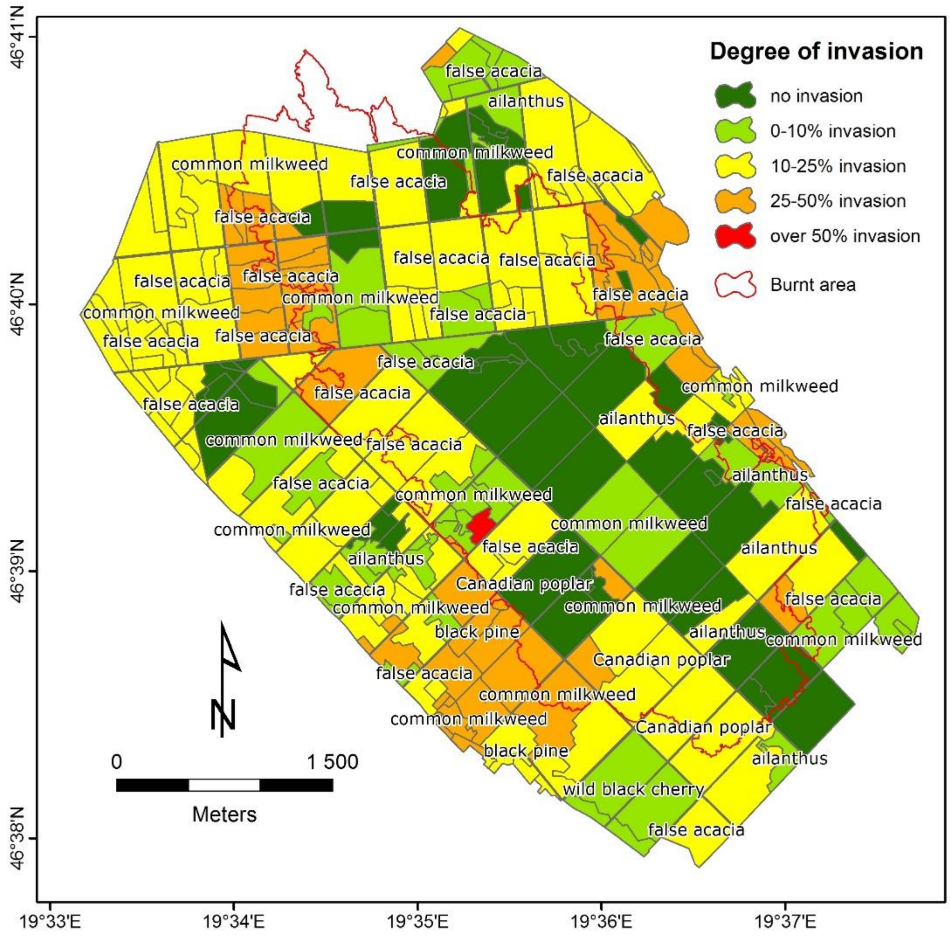

Fig. 9 Invasive species and degree of invasion

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