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DRONE APPLICATION FOR SUPPORTING PREVENTIVE FLOOD MANAGEMENT – CASE STUDY OF THE BÓDVA RIVER BASIN, HUNGARY

Abstract

Hungary is one of the most flood threatened country, therefore to make the preventive flood management more effective is a very important task. Authors show the drone technology, as a most developing part of the aviation, how it could help water manager specialist to make their work easier or higher effective. Study area was two dedicated places in the basin of river Bódva, where a valley dam made of concrete and a new embankment made of soil were analysed. In the first case some cracks were found on the surface of the concrete and in the second case a missing section and its effect in case of flood was demonstrated. Results show that drone technology can be a very effective tool in the hand of experts.

Key words: drone, drone application, flood, prevention, flood management, Rakaca reservoir

DRÓNOK ALKALMAZÁSA AZ ÁRVÍZVÉDELEMBEN – ESETTANULMÁNY A BÓDVA FOLYÓ VÍZGYŰJTŐTERÜLETÉRŐL

Absztrakt

Magyarország az árvíz által az egyik legnagyobb mértékben veszélyeztetett ország, ezért az árvízi védekezés hatékonyabbá tétele rendkívül fontos feladat. A cikkben a szerzők bemutatják a drón technológiát, mint a repülés legfejlettebb egységét, illetve azt, hogy ezek alkalmazása hogyan segíthet a vízgazdálkodásban. A vizsgáltra két különböző helyszín állt rendelkezésre a Bódva folyó medencéjében, ahol a szerzők elemezték a betonból készült völgygátat és a talajból készült új töltést is. Az első esetben néhány repedést találtak a beton felületén, a második esetben egy hiányzó szakaszt és annak hatását mutatták be áradás esetén. A cikk eredményeként bemutatják, hogy a drón-technológia milyen módon lehet hatékony eszköz a szakértők kezében.

Kulcsszavak: drón, drón használat, árvíz, megelőzés, árvízvédekezés, Rakaca víztározó

1. INTRODUCTION

Hungary's hydrological hazard - due to its geographical location – is the highest on a European scale. Because of its geographical location during the last few years quite a few hydrological cases endangered human lives and material goods. Hungary is catchment area, namely, more than 90 per cent of its rivers originate, come from abroad and it means: if floods occur in rivers' basins abroad, it may result in severe flooding in Hungary. The inadequate amount of water can cause damage be it floods, droughts or inland waters. 52% of the country is at risk from floods and inland waters. Most of the rivers in Hungary have violent flow regime, the Danube's biggest base flow several times exceeds its low water flow. In case of our smaller rivers this rate is even higher. The fact, that more than 20.000 square kilometres floodplain is located below the flood level of the rivers underlines the importance of flood protection. The arable land found here reaches almost 2 million hectares. A quarter of the total population of Hungary lives in floodplains, in 700 hectares. Floods over the years drew attention to the role and importance of flood protection systems. Increase in flood levels emphasized the importance of flood protection. [1] [2]

Intercatchment floodways play a prominent role in flood peak reduction. Security increases with the deployment of the system; in addition, flood protection costs are reduced. In the last years due to weather conditions a number of inland and local water damage have developed. Due to increasing water damage the protection of environmental safety has become a priority. Protection against floods and inland waterways has a multi-band annual tradition in Hungary. More than 4000 km long water meadows were built along our rivers [3]. Flood levels have risen significantly which is due, on the one hand, to extreme weather, on the other hand, deterioration of water transport capacity as a result of human interventions.

Flooding is nothing but unfavourable, extreme rainfall activity, or due to sudden snowmelt, a process that results in the flow of water leaving its riverbed. Consequently, areas not covered by water are temporarily submerged.

In Hungary there are some study focusing riverbed analysis or summarizing the options in case of flood management based on drone technology. In Hungary, the first drone application supporting flood management happened in 2010 at the north – east part of the country at a very serious flood [4]. In Hungary the most remarkable studies came from Bertalan at al. who made many experimental work with drones, some of them focused on the river Sajó [5] [6] [7] [8] [9]. Authors have also some works focusing on drone application in case of flood management [10] [4] [7] [11] [12]. Because of the wide range of drone application all of the country, we can assume that many pilot used his drone above river beds perhaps in case of floods however these applications were not worked up to publish, however the General Directorate of Water Management of Hungary also uses drones regularly supporting own work [13] [14]. Hungarian Army also uses drone for aerial monitoring in case of floods, the first one happened in 2013 at the flood of river Danube [15]

Characterization of the study area

The total length of the river Bódva is 113 km, of which the Hungarian section is 64.6 km. The average fall of the riverbed is 83.8 cm / km, so it is the steepest of the rivers in Hungary. Width of the river is vary, usually 8-14 meters, the average water speed is 2–4 km / h, depth is 0.5–1 m. Water flow is in dry season can drop below 0.5 m^3 / s, however in case of flood the flow can rise up to 80.0 m^3 / s, that means more than 160 times higher volume! The average water flow at the estuary is 6.92-9 m^3 / s. [16]

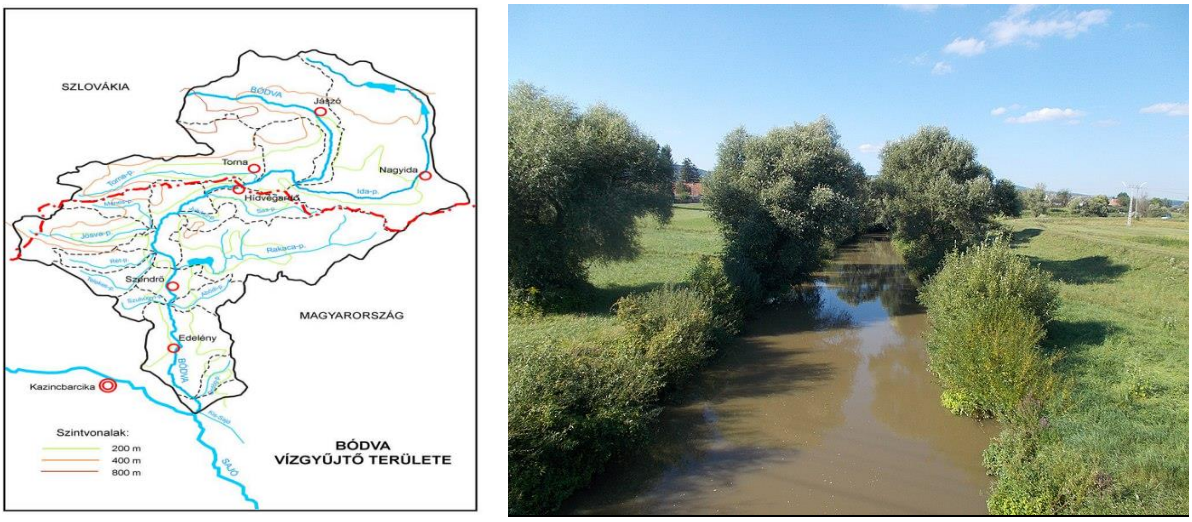

Figure 1 - The total catchment area of the river Bódva (left) [16] and a typically characteristic section at city Szendrő, Hungary (right) [17].

Rakaca-reservoir is a special place of the Bódva river basin that was created in 1963. It can be found in a valley between two villages: Szalonna and Meszes. The reservoir can store 5.5 million m^3 water; the catchment area of the dam is 233 km^3. To prevent flooding of downstream settlements Rakaca Reservoir plays an important role, as if it is well designed, built and executed, then in the event of a sudden heavy rainfall it can conduct the water mass continuously and the peak flood yield intermittently [18].

Figure 2 - Aerial view of the Rakaca reservoir (north view – left;
east view from village Meszes – right)

2. DRONE APPLICATION AT THE RAKACA RESERVOIR

Having damage free dams and the accessibility of the beds are essential factors in successful flood control, which contributes to the drainage of excess water. A couple of flying can help with measuring the condition of flood defence structures in a larger reservoir within short time. Structurally it can be planned in advance, since later, with the application, which was also used, the flight could be planned in advance in the area we want to fly. Illegal activities, like fishing on flood control structures can be discovered in time and the necessary measures can be taken in a timely manner.

Flight planning is very important task to ensure the flight safety and to make the work effective. The aerial mapping of the reservoir dam had been planned on an Internet platform. This application makes available:

- Preparation of flight plans in advance;
- Automat imaging, flight, take-off and landing;
- Automat flight disabling;
- Mapping of large areas within short time.

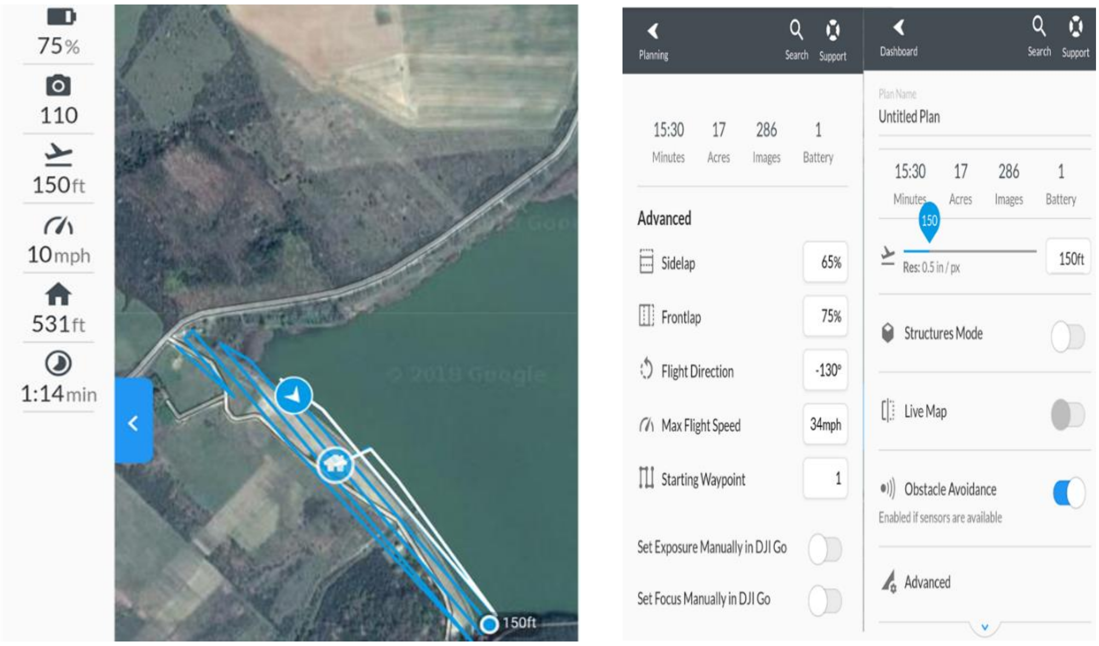

Figure 3- Flight path above the dam (left) and the setting option of the platform (right).

A distant top view have been made about the flight plan for easier geographical identification and a closer top view to make the route of the plan visible. The area surrounded by the blue line is the area authors will get information about with the help of the drone based on what is set in the application. The lines marked in blue show the route of the drone during its flight (Figure 3, left). The flight route is set in a way to have a continuous overlap in both the forward and lateral directions. Author as pilot set the Rakaca-reservoir and the drone fly around it.

Before starting the flight, pilot had several setting options:

- The starting point of the flight
- Overlap in flight line when taking pictures
- Flight side overlap when taking pictures
- Flight speed
- Flight altitude
- Monitoring the flight
- Ability to take 3D images at the end of a flight

After selecting the area, the application shares every important information with us, for example, how much time the flight will take, which depends on the flight speed and the flight altitude (Figure 3, right). In this case, it took 15 minutes. During the flight, the drone took 286 pictures and flew in 18 acres. While planning the flight the application can tell how many batteries are needed.

Results of the flight

The flight was planned to discover adverse phenomena. Cracking on the flight protection dike is the most common fault and no flooding is required for its formation. Cracking can lead to mass movement of the dam filler, due to the alternation of water-permeable and water-tight layers. Water enters the saved side through the cracks, so the embankment has only a slowing effect in flood protection. Here is some important measures in flood protection:

- Reinforcement of flood protection dike
- Dredging of the riverbed, riverbed stabilization
- Increase water space
- Building sump pipe

- Maintenance of the intercatchment floodway

Riverbed stabilization is one of the main purposes of the dredging- mud dredging –is to increase the bed cross section. With riverbed stabilization interventions we can prevent undesirable transformations, it is important to make the bank of the reservoir secure. During the works, the vegetation may be damaged, but flood drainage will be improved.

The purpose of water retention is to drain excess water and this way reduces the water level and the risk of flooding. As it was already mentioned, Rakaca Reservoir plays important role in reducing flooding and in storing excess water in the stream. Authors personally observed that in springs, due to snowmelt, water flow of the stream increased significantly, along with it the water level of the reservoir also increased sharply. The same phenomenon can be observed after heavy rainfall.

A stone dam was established at the junction of the reservoir and the stream to prevent siltation. The section in front of the stone dam became engorged over the years and it posed a threat to the villagers of Meszes. It was possible not only to build a stone dam but to extract the sludge accumulated at the stone dam, which was about 3200 m^3 [19] Here the emphasis is on the elimination of siltation, which is harmful to the drainage of floods. The main purpose of riverbed dredging is to ensure riverbed stabilization and to increase the bed cross section.

Deforestation causes soil degradation. Afforestation is required around the Rakaca reservoir. Drones may allow the extent of deforestation to be assessed and the delimitation of areas affected by soil erosion [20]. Due to the unfavourable land use and the lack of sewerage at the recreation area, the lake started to silt up. The necessary improvements were lagging behind in series, which of course had negative effects. The most serious problem is the leaching of the sludge, which has had restrictive effects.

The construction of intercatchment floodway can have positive effects ecologically. With proper water supply, it increases biodiversity. As for flood protection, the construction of intercatchment floodways and ditches is essential. The main aim is to distribute excess water in case of a flood, thereby reducing damage. Vegetation obstructing the flow of water must be removed from the beds. The water supply of the industrial area mentioned earlier flows into the Bódva stream through the canal shown in the picture.

Figure 4 - Photo of the normal floodway of the dam (left) and one of the crack author noticed during the flight (right).

During the flight, author noticed a crack in the concrete structure of the intercatchment floodways which may make protection more difficult during a flood period or may contribute to an undesirable phenomenon (Figure 4). The more layers or more permeable layers there are on the surface, the sooner the water penetrates the embankment.

The dam of the Rakaca Reservoir has a built-in drain at the front of the dam, which has an important function. During a flood, meteorological or other hydrological event, excess water can escape, so the dam is not exposed to too much pressure, which could lead to a possible dam failure. The purpose of the flight at the drain was to detect cracks or rust and to determine whether it was suitable for the task. In the event of a crack, after heavy rains, there is a risk that it may loosen its structure by entering the embankment through the crack. It is important to assess its condition occasionally.

Figure 5 - Photo of the water-draining canal of the dam in case of normal weather condition (left)[18] and in case of flood (2010) (right)

During the mission, author took pictures even at the mudguard dam to map the riverbed line. Flight was performed in order to explore the undesirable phenomena that appear after the riverbed maintenance works were carried out.

Figure 6 - Photo of the mudguard dam made to reduce the negative effect after heavy rain.

At the mudguard there were no found any anomaly, it seems it is a useful part of the reservoir to keep its condition well.

3. ADVANCED DRONE APPLICATION FOCUSING ON THE RIVER BANK AT SZENDRŐ CITY

Szendrő city is located at a wide basin of the river Bódva at the middle part of the Hungarian river section. Water flow can slow down in case of flood therefore it can cause serious problem many times (Figure 7). Szendrő is a flood threatened city with about a 5 thousand population.

Figure 7 - Aerial photos of the flood at Szendrő in 2010.

The most commonly used protection facility for flood control is the flood defense embankment, which reduces the size of the area flooded. Latest time new embankment has been built in Szendrő, which provides safety for the people living there. Above the construction area, some drone flights were carried out to show the building operation and the result (Figure 8). The procedure of the flight planning and the preparation of beginning of the flight was basically the similar as at the Rakaca reservoir before.

Figure 8 - Selected study area of the construction at the north part of Szendrő (left) and a mosaic photo made by drone during the flight (right) (with the permission of drone pilot, Bence Bodnár)

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During the flight many high resolution ortophoto were taken and then with a software a 3D mosaic photo was created. Naturally, it takes time depending on the resolution of the photos and the capacity of the computer, however later we can analyse the completed photo with as detailed as the resolution of the original photo allows. We focused on the south part of the photo and we found a missing section of the construction that is obviously made for the stream or canal that joins to the Bódva river about 100 metres.

Figure 9 - South part of the study area where a missing section found at the construction (with the permission of drone pilot, Bence Bodnár).

We made a test with a flood model what could happen in that case this missing section would not managed by water management specialist. 3D flooding models for the missing dam section show that in case of a possible flood, the incoming water floods the buildings behind the embankment, which can cause extensive damage. Authors assume this section of the embankment is not finished yet; an added technical solution must be carried out soon.

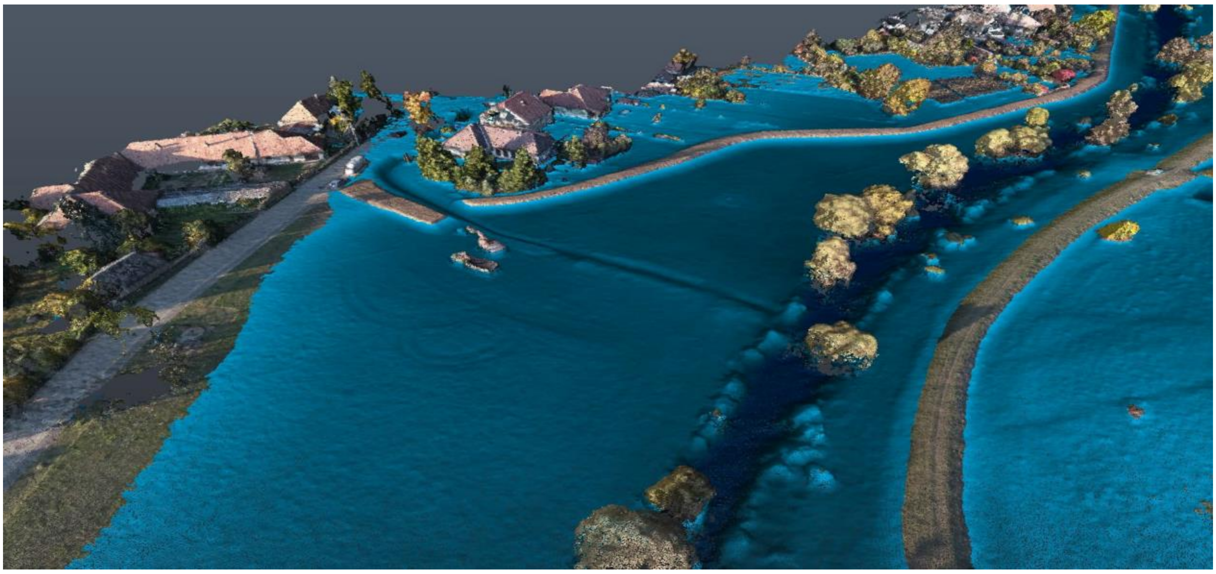

Figure 10 - Using the flood model it can be seen that without added technical solution the settlement area can be flooded by the river Bódva (with the permission of drone pilot, Bence Bodnár)

An orthophoto is a type of scaled photographic map on which measurements can be made perfectly as if it were a standard map. Orthophotos can be taken much more easily than traditional maps and can be reproduced regularly thanks to the cost-effectiveness and fast operation of drones. The accuracy of the orthophoto is directly proportional to the resolution of the image captured by the digital camera. The drone scans the area during image capture, with parallel axes and offsets of a few degrees, to accurately achieve stereoscopic human vision through the camera. [21]

A point cloud is a set of data points in space. Point clouds are usually generated by 3D scanners that measure a large number of points from the outer surface of objects in space. Point clouds are used for a variety of purposes, including creating 3D models, for visualization and animation purposes. In the geographic information system, point clouds are one of the productions of a digital elevation model of the terrain. The point cloud is a digital representation of space in three dimensions. It is created by laser scanning of existing spaces, buildings, dams, floodplains, which connects hundreds of thousands of such spatially coordinated points. [22] [23]

4. SUMMARY

This study focused on a flood threatened area that is the basin of the river Bódva and its vicinity. Two places were dedicated to use drone making aerial photos, the first one is the Rakaca reservoir, the second one is the north part of city Szendrő. In the first case authors focused on the valley dam and its damages and in the second case on the new embankment and its missing section. Dam of the Rakaca reservoir is made of concrete, the embankment is made of soil found at the vicinity of Szendrő.

At the first case authors showed the basic elements of the flight planning and the preparation requirements of the drone flight, then the results were pointed out based on the analysis of the photos made by the simple drone. At the second case, a high-resolution camera was used with an other drone and possibilities of the capability of drone technology were demonstrated. In both cases we can see that drone technology can be a very effective tool in the hand of experts and it is able to support water management specialists to make their preventive flood management more effective [24] [25].

The results of the paper confirm previous research that has also suggested the use of novel technical tools and vehicles in the field of firefighting [26] [27] [28] and protection [29] [30].

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