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Field Measurement Using an Umanned Flying Vehicle for the Creation of a Terrain Model

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***Abstract* – The first step in any and all digital modeling endeavors is obtaining field data. Measurement techniques vary in complexity and accuracy from the most basic tools such as a measured piece of rope, to the electronic total station, to aerial photogrammetry and LIDAR and satelite imagery. One of the most accurate and efficient methods is aerial photogrammetry because it can cover extended areas quicker than land based measurement systems and has much better accuracy than satellite measurements. Also it is becoming more affordable and easy to operate, to the point that it requires very little operating experience. As such, measurement trials using UAV photogrammetry have been carried out in preparation for a study that requires digital modeling of the terrain for rainfall parameter analysis and comparison.**

Keywords – digital surface model, photogrammetry, unmanned aerial vehicle

1. INTRODUCTION

The cycle of runoff at the scale of a watershed is the continuous dynamic distribution of precipitation between the different components of runoff, and with the exception of precipitation directly intercepted by surface waters; runoff has a very important role. In the study of surface drainage, one has to differentiate runoff, which means the movement of water on the surface, immediately after rainfall without it following a well individualized course and drainage in the elementary beds which represents a usually reduced part of the infiltrated waters that circulate quasi-horizontally in the aeration zone. Direct drainage on the slopes, or runoff, represents the guided movement of water on the shortest route towards the ramifications of the hydrographic network [1].

A parametric study of precipitations that cause flash flood effects is being prepared for the Rasova and Cochirleni localities in the Constanta County. The scope of the study is partly that of identifying precise, efficient and financially advantageous methods of determining specific thresholds associated with the manifestation of flash floods and runoff in the selected areas. At the same time, human development within the basins is proving to be an important influence in the behavior of rain water that runs off the terrain adding another level of modification of the previously recorded data and thus making it less accurate. Deforestation is a major factor in runoff, but other modifications of parts of the basin are equally important for the changing of runoff behavior, such as landscape management (changing perennial vegetation to grass lawns) or transport infrastructure (concrete/asphalt roads) [2] which may have a strong influence on runoff (concentration times of the flood wave). The main reason why this needs to be studied is because most of the recent flood damages registered in the Constanta county [3], [4], [5] were caused by runoff as a form of manifestation of flash floods and not by the overflowing of rivers or creeks. Conventional studies and modeling already made in Romania only cover the effects of floods caused by the overflowing of rivers and thus very little information is available about the effects and quantitative thresholds associated with the manifestation of runoff and related effects. Although there are some studies being carried out, such as Flash Flood Guidance (FFG), they are not yet fully functional, and they have limited resolution (they are large-scale models) which might not provide the best results from the point of view of individual small areas.

The analysis of said issues will be done through a simulation of precipitation over a digital surface using various algorithms and software packages, and for that, as a first step, spatial data is required in the form of terrain measurements. In addition to that, various ground parameters will be determined such as land usage (plant coverage), top soil type, porosity of top soil, dry soil weight, total porosity, soil humidity/saturation, etc in order to determine runoff thresholds. Precipitation and humidity parameters will be determined by locally placed sensors. The study proposes to compare the effects generated by data directly measured and applied on the digital model with the effects measured directly on site. In addition, historic data available from official reports from the past combined with historic data from remote sensing (satellite data regarding ground humidity and precipitation) will be compared to newly obtained data in order to assess the accuracy of past official reports. The area was chosen due to the fact that terrain geometry, soil composition and lack of forest vegetation make it prone to runoff effects as shown by recent rainfall history [4], [5] which show that between 2014-2020 there have been no less than 7 runoff events that resulted in significant damages to local infrastructure.

2. EXPERIMENT DESCRIPTION

For the study preliminaries, a combined set of data was used, respectively: for the localities, considered an area of high importance, high resolution measurements were made, while for the surrounding, less important, areas, existing, lower resolution data was used.

The low-resolution data was imported from NASA websites either directly or by using the SRTM downloader plugin for QGis. 2 distinct data sets were found and imported. The first one was obtained from the “Earth Observing System Data and Information System (EOSDIS)” in the form of a digital elevation model (DEM) obtained by the Shuttle Radar Topography Mission (SRTM) which has a resolution of 30x30 meters per square (pixel). A second, better resolution DEM was obtained from the ALOS PALSAR (Phased Array type L-band Synthetic Aperture Radar - mission). This second DEM has a resolution of 12x12 meters per square (pixel). The two digital elevation models were used for various watershed analyses that were carried out using GIS. For tasks such as the determining of the watershed boundaries or contour and SRTM or PALSAR data is sufficient for those tasks. Other determinations were also carried out such as the Topographic Wetness Index (TWI).

For the runoff studies it was deemed necessary to obtain high-resolution data which was obtained by aerial photogrammetry using an unmanned aerial vehicle (UAV), or drone. This was a radio-controlled, quad rotor drone, namely DJI Phantom 4 RTK. This type of drone represents the most commonly used type in the civilian sector [6], [7]. The quad rotor drone has 4 support arms with 2 propellers that rotate clock-wise and 2 that rotate counter-clockwise so that the angular momentum of one propeller is canceled by another propeller rotating in the opposite direction.

The drone is equipped with a Real-Time Kinematics (RTK) module, which allows for the fast collection of field imagery with associated, real-time position data, with a high accuracy (precision down to centimeters) generating 3D coordinates (X, Y and Z). With the RTK system we get an absolute and improved precision of image metadata compared to the ones obtained just by using satellite positioning data (GPS) because RTK helps correct inaccuracies and discrepancies generated by the distortion of the satellite coordinates by factors such as weather, tall buildings, mountains and other physical interference. These errors are called "Tropospheric delays" and the RTK system has the task of completing these shortcomings with real time data from the UAV by means of an internet connection through a 4G modem or Wi-Fi, or from the base station. The model used has the RTK receiver located on the top side of the UAV.

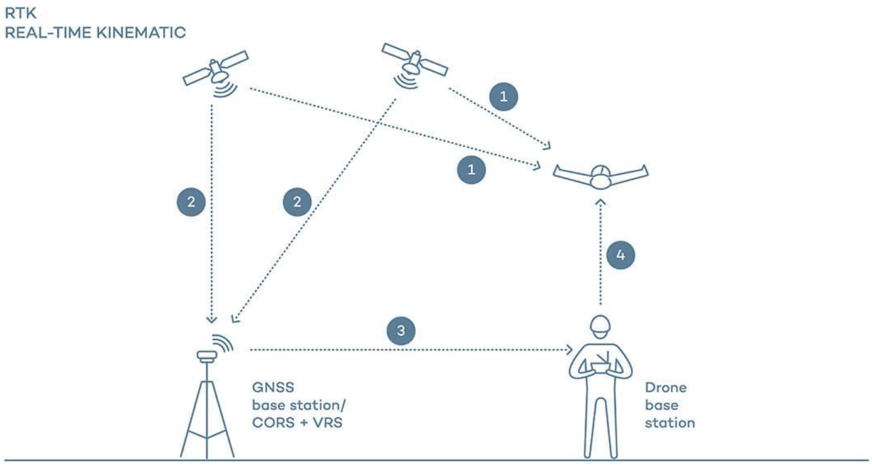

Fig. 1 Real-Time Kinematic - data transmission [8]

During the flight, the UAV executes a succession of aerial photographs by means of a 20-megapixel, 1 inch CMOS (Complementary metal oxide semiconductor) sensor. Due to the high-resolution equipment, the Phantom 4 RTK UAV can achieve a ground sample distance (GSD – the distance between the centers of two adjacent pixels) of as little as 2.74 centimeters from a flight altitude of 100m.

The drone is capable of executing an autonomous flight in accordance with a flight plan established in advance. While executing this task it is being monitored and, if necessary, controlled from the ground through a radio controller. The controller has an integrated display and shows the operator a simplified sketch of the flight plan for data acquisition missions including photogrammetry 2D and 3D, flight through pre-set checkpoints and others. For the optimization of the work time KML/KMZ files may be imported and the operator can visualize and also plan the desired mission directly on the integrated display.

The collected photographic data is then processed through specialized software, in this case the "Pix4D Mapper". The software uses photogrammetry algorithms to transform aerial imagery into digital maps and 3D elevation or surface models. During processing, one can access and improve project quality with the aid of quality reports regarding the generated results, calibration details, etc. Once the data is processed, from the digital model it becomes possible to extract distances, areas, volumes, elevation profiles, contours, etc.

Fig. 2 DJI Phantom 4 UAV with RTK module (top side) and Controller [9]

The main advantages of the software used are as follows:

- Automatic point classification with a revolutionary algorithm that uses machine learning;
- Surface finishing and automatic filling of voids;
- Easy measurement of distance, areas, elevation and volumes, directly on the digital model;
- Inspection and marking of project elements both local and remote;
- Fast and secure sharing of project data as well as a possibility of collaboration in the editing of data;
- Pix4D Mapper can process data from images taken from any camera, any drone and any kind of image: RGB images, drone images, multi-spectral images, thermal images, “fisheye” (ultra-wide angle) images, 360o images and videos.

The effective measurements were carried out in two separate days, one day for each locality from the study area. One disadvantage of the system is that the measurements are influenced by wind speed at the chosen operation height. This is quite an important aspect if you consider that fact that the Dobrogea region (Constanta and Tulcea counties) is windy most of the time, hence why it is the perfect place for wind turbine fields. The UAV has a smart flight stabilization system which compensates for wind speed in order to achieve the most stable possible position and obtaining clear pictures as well as keeping a steady level which is crucial from the measurement point of view. This however, in windy weather, requires extra load on the motors and thus leads to faster battery discharge and less overall flight time. The top wind speed at which the UAV can work is 10 m/s. Taking into consideration the limited flight time, the team had to plan the flights in such a manner that the path was most efficient and the covered surface was strictly the minimum required. Also, time of day when the measurements are carried out is important as wind speeds and directions vary throughout the day. Each battery assembly provided around 20 minutes flight time, from full capacity (100% charge) to about 15% charge when the UAV automatically returns to the selected landing site or the launch site. For uninterrupted operation 5 batteries were prepared for the operation and they were recharged on-site using a 60,000 mAh power bank. This would provide about 7 continuous flight cycles (5 initial batteries + 2 recharged on-site) for a total operating time of about 140 minutes. The flight planning provides some information about required flight time for the planned surface so the operator can prepare enough batteries or take into account time gaps due to the necessity to recharge batteries.

3. 3. RESULTS AND SIGNIFICANCE

The total measured surface is 4.186 km^2 for the Cochirleni locality and 4.111 km^2 for the Rasova locality. It is to be expected that a similar flight time would correspond to a similar measured surface. In our case, the similarity of the areas was a coincidence, but it enabled us to verify the correspondence between flight time and covered surface.

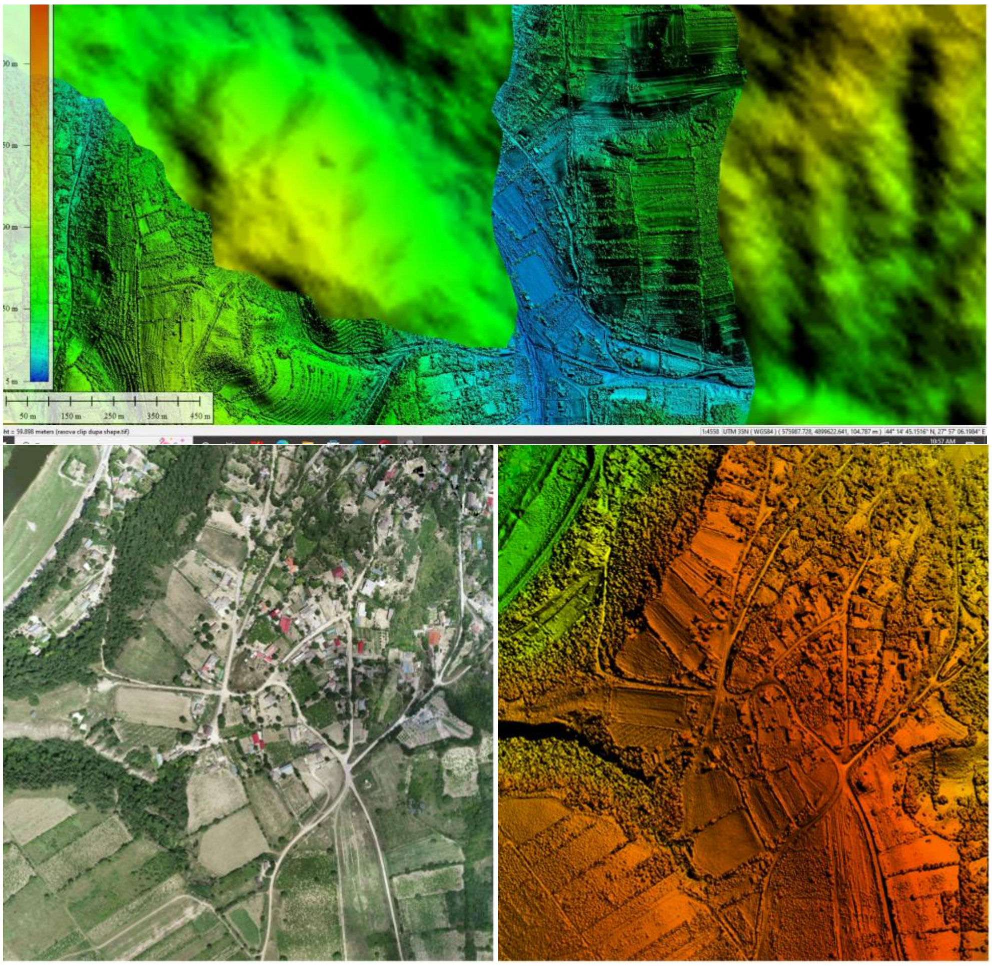

Fig. 3 Difference between PALSAR satellite DEM and DSM generated with UAV

Some issues were encountered when measuring related to the poor connection for the RTK generated either by weak GSM coverage in certain areas of the measured perimeters or weak coverage from the national Romanian Position Determination System (ROMPOS). This was linked to the terrain topography relative to communication relay placement.

4. CONCLUSIONS

Identification, localization and determination of boundaries of areas exposed to natural risk, in our case floods and more specifically flash floods in the form of runoff, are important for the generation of risk maps for localities, especially rural localities. The efficiency and ease of access to data is a must in order to assure that rural localities get a clear view of risk. The definition of conditions for the manifestation of such phenomena in accordance with local conditions is most important for the establishment of measures for the prevention and reduction of flood effects. The results of the proposed research can become the basis for future local regulations such as the General Urbanistic Plan for the localities with the aim of implementation of specific measures for either avoidance of risk areas or construction of buildings and infrastructure that are resilient to known flash flood and runoff effects. In addition, pinpointing areas of potential risk and understanding the expected effects according to pre-determined thresholds can help in planning of adequate structural and non-structural measures as well as highlighting the necessity and opportunity of specific works in sectors that may lead to flood damage control and protection of human lives and livelihoods, while still developing the area within reasonable parameters of commodity.

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Note:

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