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Capabilities of using UAVs in Forest Road Construction Activities

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Abstract

The forests in Turkey is classified and managed according to their functions within the framework of Ecosystem Based Multi-Purpose Planning policy. It is very important to ensure that planning activities are handled appropriately in order to carry out forestry activities which are labor intensive, difficult and dangerous. Forest roads have served as the main infrastructure facility for forestry activities in accordance with multiple purposes. In order to increase efficiency within the concept of precision forestry and to transfer the plans to the application more clearly, it is essential to use technology and technological machinery. In this context, this study aimed to reveal the capabilities of using Unmanned Aerial Vehicles (UAVs) and Geographical Information Systems (GIS) tools in planning the forest road construction. For this purpose, cut and fill volume of a 300 m long sample road was computed by using USGS based Digital Elevation Model (DEM) with 1 m x 1 m resolution and UAV based DEM with 0.05 m x 0.05 m resolution which were generated prior to road construction and after the road construction, respectively. The results indicated that the cut volume and fill volume were 81804.4 m^3 and 74.2 m^3, respectively. It was found that the use of UAV will be quite advantageous in terms of capturing high quality and high-resolution data for planning the forest road construction and evaluating alternative routes.

Keywords: Forest road, road construction, cut and fill, unmanned aerial vehicles

1. Introduction

The execution of forestry activities in Turkey and various forestry basic infrastructure facilities with forest

In Turkey, forest roads and forestry activities for the execution of basic infrastructure facilities are used for delivering the objectives of the various forestry planning. According to the information provided by the Oregon State Highway Comission (1924), the planning of forest roads in the world is estimated to have begun in the early years of the 1900s. In Turkey, forest road planning and construction work began in 1937 (Erdaş, 1997) but substantially accelerated to the beginning of the 1960s (Seçkin, 1978). Forest road planning studies in the world are constantly changing with the ever-increasing and rapidly developing technology (Akay and Sessions, 2005). Within this period, developments have been experienced with the effect of science and technology in terms of forest road design methods. In the past, the studies carried out within the framework of the classical planning approach were subject to various errors and shortcomings because data measurements were not very sensitive. Rapid expansion of Remote Sensing (RS) techniques (Benz et al., 2004; Kleinschroth et al. ,2018) and GIS tools (Abdi et al., 2009; Akgül et al., 2017; Picchio et al., 2018), training of experts in the field, and easy access to information has provided serious advantages in terms of both time and costs in forest road planning. At the same time, a sustainable platform which is convenient for innovation and development has been generated for more successful and feasible planning using these techniques and tools.

The successful implementation of the road plans is possible with the presence of accurate and higher quality data. The data obtained by technological means can be effectively used to achieve the determined goals within the concept of precision forestry (Kellndorfer et al., 2003; Gülci et al., 2015; Becker et al., 2018). The usage of GIS tools enables more accurate decision making and more feasible plans at every stage of the planning process. Obtaining high quality and detailed data using modern and technological methods and making decisions by processing these data using various tools is important for the success of road planning (Holopainen et al., 2014; Kangas et al., 2018).

According to the General Directorate of Forestry (GDF) in Turkey, approximately 258000 km of forest roads has been constructed until today (Anonymous, 2007). According to Forestry Specialization Commission Reports

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about the development of forest roads, it was emphasized to reach 350000 km within the scope of the development plans (Anonymous, 2007). From this point of view, it is seen that there is still long way to go in order to reach the targeted road length. While building new roads to achieve managemental objectives, it is anticipated that another challenge is to improve the standards of the existing forest roads in regions where large size trucks are favorable for forest transportation.

In Turkey, forest road planning, construction and maintenance are carried out according to the principles of No. 292 notification issued by the GDF (Anonymous, 2008). According to this notification, forest roads are divided into primary and secondary forest roads. Secondary forest roads are classified as Type A and Type B secondary forest roads. Type B secondary forest roads are the most commonly used forest roads among all forest roads in Turkey. The most distinguishing features of this type of forest roads are that their geometric features are low and they can be constructed at very low cost compared to other types of forest roads (Erdaş, 1997).

Since forest roads are mostly located in mountainous areas, there are number of problems in implementation of the road projects (Öztürk et al., 2010). Among all the feasible route alternatives, it is important to determine the route where the land characteristics and plan mismatches are at the lowest level (Demir and Hasdemir, 2005). Factors such as harsh weather conditions, steep slope, and high elevation negatively affect field measurement works. At this stage, the CORS device can be used for accurate measurements, along with various other devices for measuring positions and distances. However, the calculation of cut and fill volumes at office still can take some time as it requires complex computations. On the other hand, high-resolution DEMs can be used for both accurate volume estimations and efficient use of time. By using modern UAV technology and GIS techniques, DEM data can be produced exclusively for any study area designated for forest road construction (Akgül et al., 2018, Gülci et al., 2017). The most important advantage of DEM data provided by UAV is that high-resolution data can be easily produced at conveniently short time.

In this study, capabilities of using a UAV (DJI Phantom 4) was evaluated in estimation of cut and fill volumes on a 300 m sample forest road section located in the border of Ankara, Turkey. In the solution process, a high-resolution DEM generated based on USGS data before the road construction and a high-resolution DEM generated by a UAV flight after the road construction were evaluated to calculate cut and fill volume with the help of ArcGIS 10.3 program.

2. Material and Methods

2.1. Study Area

In this study, sample road section was selected in Hızardere Forest Enterprise Chief which is located in the border of Ilgaz Forest Enterprise Directorate in Ankara Forestry Regional Directorate. A 300 m sample road section was a part of 223 Code forest road with total length of 4300 m. The study area is located between 40° 50' 59", 40° 50' 55" north latitude and 33° 45' 27", 33° 45' 34" east longitude (Figure 1). The average ground slope and elevation are 28% and 1650 m, respectively. The dominant tree species in the study area are Black pine (*Pinus nigra* Arnold var. *pallasiana*) and Scots pine (*Pinus sylvestris* L.).

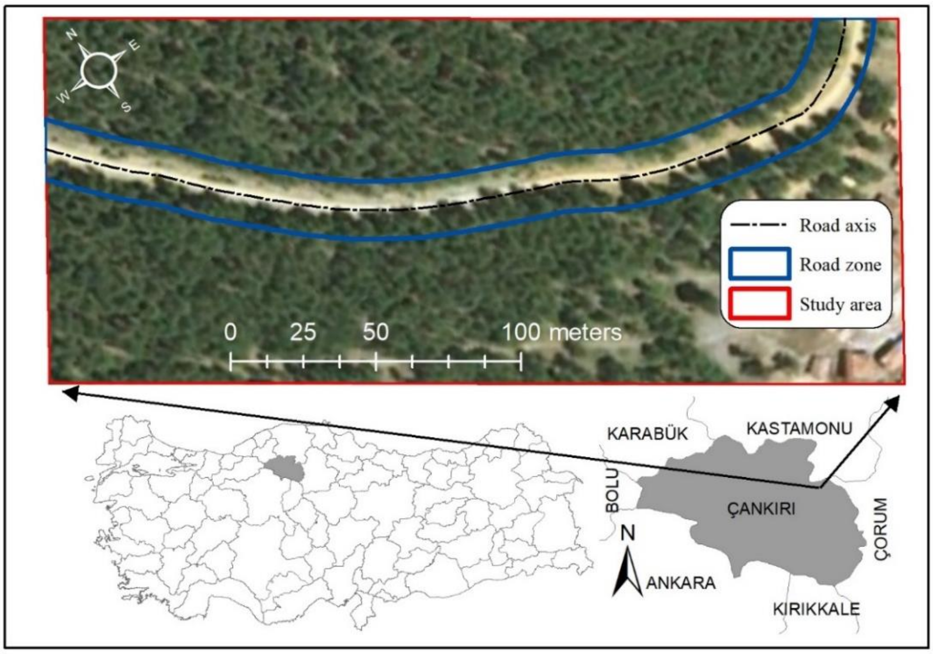

Figure 1. Location of study area and sample road section

2.2. Data Capture

In the study, flights were carried out above the road section by using DJI Phantom 4 aircraft at daytime on August 1, 2018. The flight line with 60 m altitude was generated by using Android OS installed tablet and Pix4D Capture which is widely used software in the field of professional photogrammetry and drone-mapping. Autopilot mode with the Double Grid Mission option was used during the data capturing by Pix4D (Figure 2). The raw data obtained from the flight were processed using the Agisoft software to produce DEM data of the forest rod section with 0.05 m x 0.05 m resolution. To generate high-resolution DEM of the same area prior to road construction, high-resolution DEM data with a 1 m x 1 m resolution was obtained from the data produced by The United States Geological Survey (USGS) in August 2009.

By using the Agisoft software, the special TIN (Triangular Irregular Network) model was developed based on raw data and then DEM of the study area was produced (Figure 3). In order to ensure the efficiency of these tasks, the flight route should be well planned, the 3D data obtained should be of acceptable scale, and the computer used during the data process has sufficient processor speed and ram capacity for processing raw flight data. A PC with an Intel i7700 processor, 16 GB RAM, a 2 GB GPU graphics card, and 1 TB hard disk was used in this study. The DEM data can be generated by using digital images captured by the UAV and their associated 3D data (X, Y, Z coordinates) transferred into the Agisoft software.

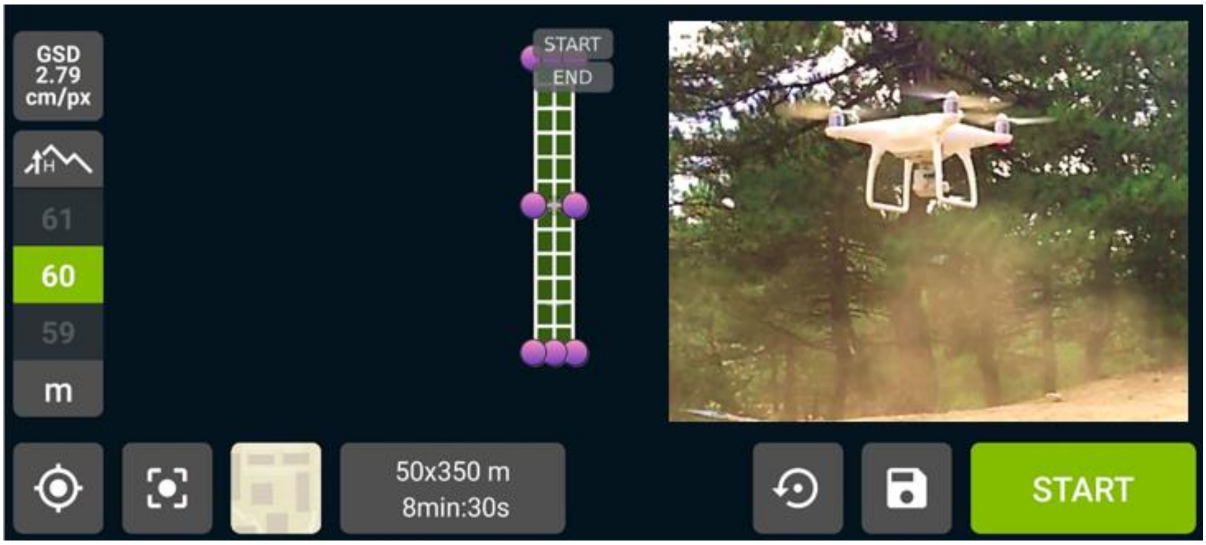

Figure 2. The view of DJI Phantom 4 and Pix4D interface used in the study

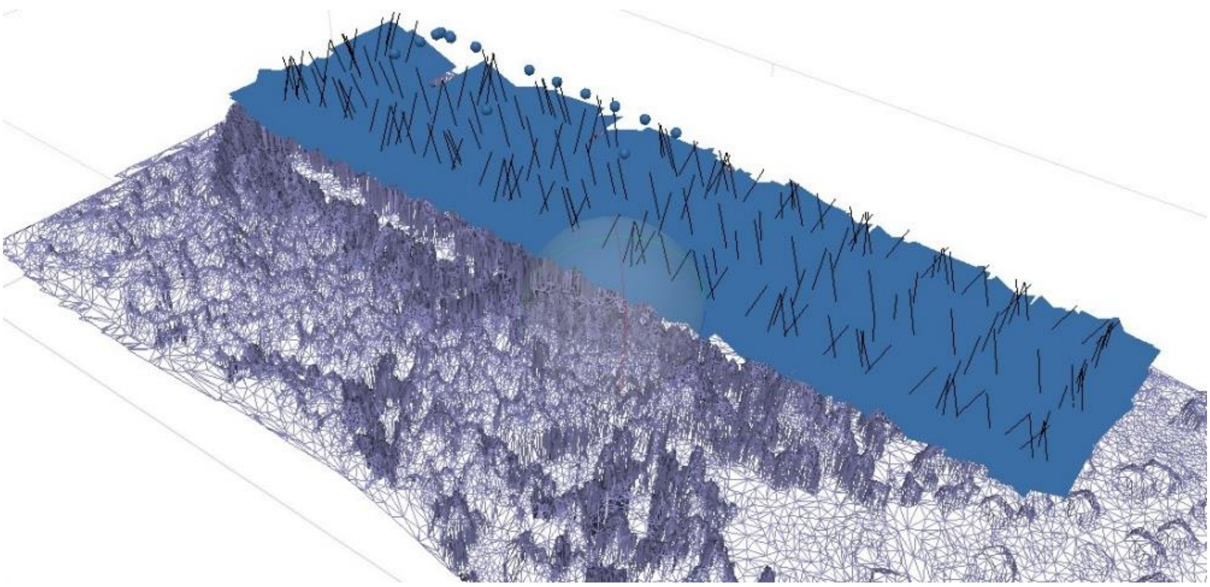

Figure 3. Flight alignment and DEM data

The GPS device located on the drone should be validated due to its weaknesses in studies requiring high-precision. For the coordinate validation of the measurements along the flight line, a GNSS-RTK measuring device with advanced and precise system was used. For the validation of the UAV measurement, control points were marked on the ground by using spray paint and then marking and ground measurements were made by giving sequential numbers (Figure 4).

At the final stage, the estimated cut and fill volumes during the road construction was calculated using the "CutFill" tool under the "Spatial Analyst" extension of ArcGIS 10.3 software. Cut and fill computation is a process involving a procedure in which difference between two surfaces with two different time periods is computed by subtracting or adding the elevation of a surface from the other surface (ESRI, 2018). In this study, road alignment zones were extracted from both DEMs, one captured before road construction (Before_Ras) and one after road construction (After_Ras), and then cut and fill volume of the road zone was computed by using "CutFill" tool (Figure 5).

3. Results and Discussion

Grid method in automatic flight mode was used in Pix4D Capture software to produce 60% superimposed photos of the study area. The UAV flight took about 10 minutes to cover the forest road zone of 6106 m^2. For the control points on the ground, a total of 32 coordinate measurements were performed using GNSS-CORS device. The raw data transferred from UAV to the PC after the automatic flight were used to generate DEM (Figure 6) and Ortophoto (Figure 7) with the help of the Pix4D Capture software.

Figure 4. Ground control points used for coordinate validation

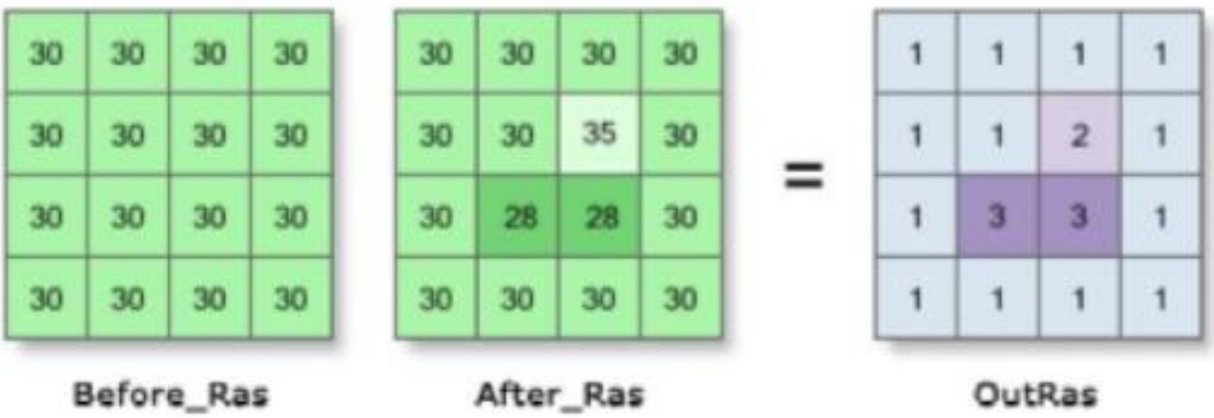

Figure 5. Illustration of how CutFill tool Works under Spatial Analyst extension (ESRI, 2018)

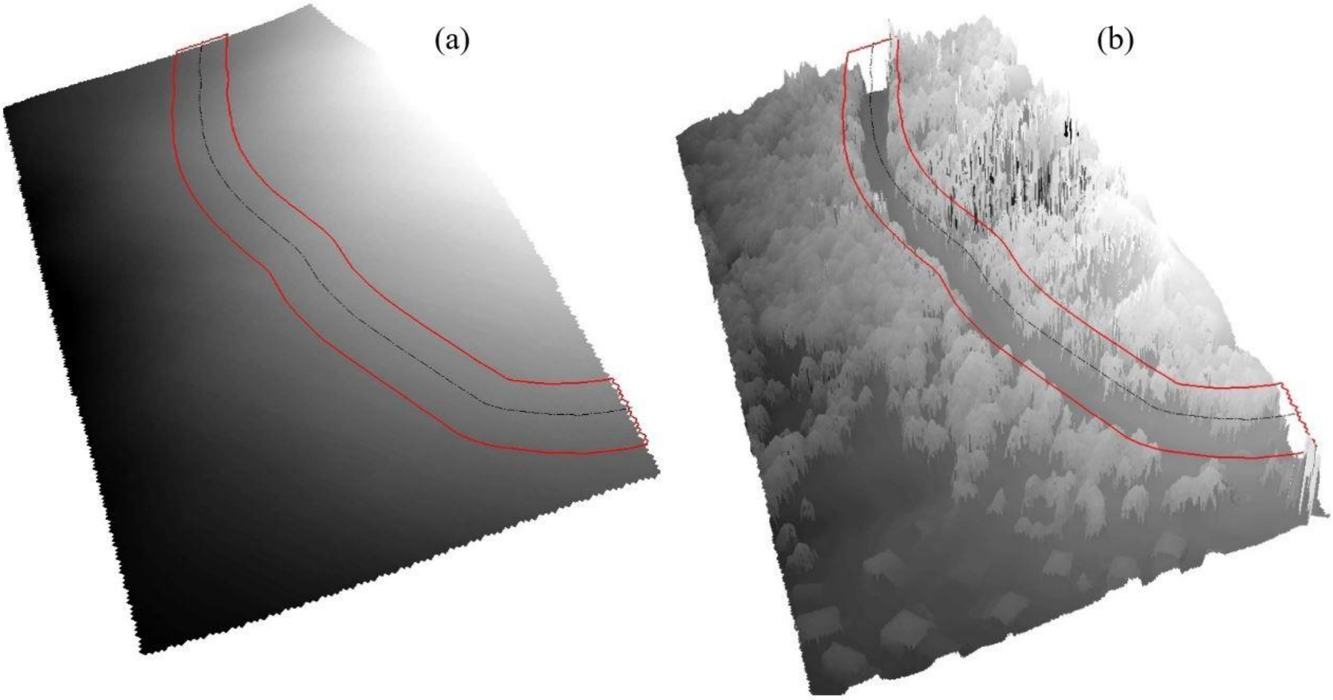

Figure 6. USGS based DEM 1m x 1m resolution prior to road construction (a) and UAV data based DEM with 0.05 m x 0.05 m resolution after the road construction (b)

Figure 7. Orthophoto obtained from UAV

As a result of the data analysis in ArcGIS 10.3 environment, cut and fill areas were determined and then their volumes were calculated. The results indicated that there was a total of 81804.4 m^3 cut and 74.2 m^3 fill along the sample road alignment (Figure 8). The most recent studies conducted in the subject of cut and fill volume computations using UAVs had some similarities with the present study (Akgül et al., 2017; Anurogo et al., 2017). The UAVs used in these studies differ in terms of their hardware and technical features and costs. These studies showed that UAVs can play an important role in precision forestry studies. However, there is still opportunity to improve the workflow specified in this study by validating cut and fill volumes by using alternative measurements methods.

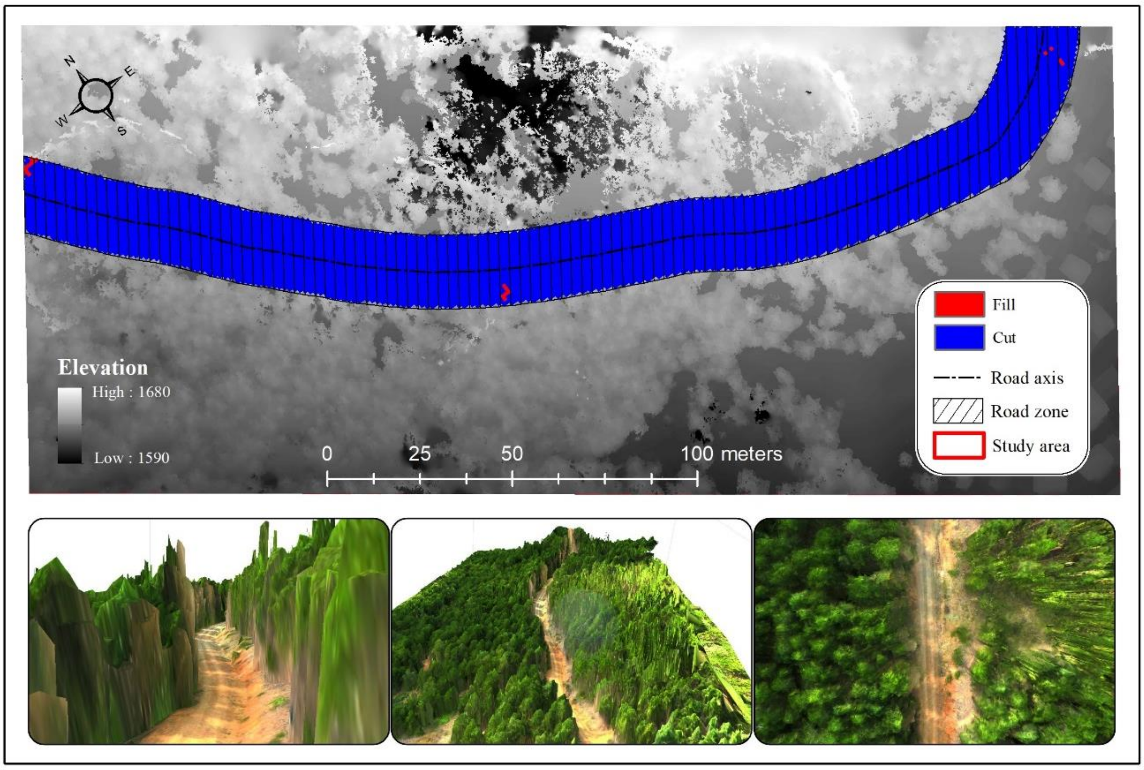

Table 2. Cut and fill areas and orthophoto of the road alignment

4. Conclusions

This study was carried out in order to reveal the capabilities of using UAV in forest road construction activities. A methodology was based on the acquisition of the 3D maps of the sample forest road and the computation of cut and fill volume changes between these two surfaces-before and after road construction.

To calculate cut and fill volume for a 300 m long sample road, a DEM generated based on USGS data prior to the road construction and a DEM generated by a UAV flight after the road construction were evaluated. As a result of this study, it is revealed that the cut and fill volume of the forest road can be effectively estimated by using UAVs. Based on methodological and technological developments, advanced UAV based data capture systems might be developed to automatically perform the workflow specified in this study and calculate the cut and fill volumes in a very short time.

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