Bartın Orman Fakültesi Dergisi | Journal of Bartin Faculty of Forestry
2022, 24(2): 247 – 257 | DOI: 10.24011/barofd.1066636

Assessment of Unmanned Aerial Vehicle Use Opportunities in Forest Road Project (Düzce Sample)

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Article History
Received: 01.02.2022
Accepted: 13.05.2022
Published: 15.08.2022

Research Article

Abstract − Forest roads are important infrastructure facilities that enable forestry activities to continue without interruption. These infrastructure facilities are very important in terms of protection and maintenance of forests, safe transportation of the produced property, afforestation, recreation, and transportation to forest fires as soon as possible. Today, an advantageous environment has been created by the widespread use of Geographic Information Systems (GIS) software, the increase in its use, as well as the integration of clearer and reliable information within the framework of sensitive forestry understanding, with the acquisition of high-resolution images with Unmanned Aerial Vehicles (UAV). This study, with the help of UAV data and GIS on forest roads, which serve as the basic infrastructure in the fulfilment of forestry activities, for forest road design and excavation-filling calculations, drones etc. made to demonstrate the applicability of the technologies. The study was carried out on the 164 coded B Type Forest Road belonging to the Cumaova Forestry Directorate affiliated with the Düzce Forestry Operations Directorate. In line with the study, first of all, data were obtained with a multi-copter drone. A Digital Terrain Model (DTM) of the study area was produced with the raw data obtained. The produced DTM data was compared with the 12.5 m Digital Elevation Model (DEM) data showing the land structure before the road was built. At the last stage of the study, the height and position data obtained from the road line with ground measurements and the excavation-fill amounts were compared using the RoadEng software. In the light of the results obtained in this study, it is thought that safer and more precise data can be obtained in forest road design studies, and it can provide a practical approach to road planning studies for planners, decision-makers and practitioners.

Keywords − *Unmanned aerial vehicle, forest road, road planning, cut and fill*

Orman Yolu Projelendirilmesinde İnsansız Hava Aracı Kullanım Olanaklarının Değerlendirilmesi (Düzce Örneği)

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Makale Tarihçesi
Gönderim: 01.02.2022
Kabul: 13.05.2022
Yayım: 15.08.2022

Araştırma Makalesi

Öz − Orman yolları, ormancılık faaliyetlerinin aksamadan sürdürülmesini sağlayan önemli alt yapı tesislerindendir. Bu alt yapı tesisleri, ormanların korunması ve bakımı, üretilen emvalin güvenli bir şekilde taşınarak değerlendirilmesi, ağaçlandırma, rekreasyon, orman yangınlarına en kısa sürede ulaşım gibi açılardan oldukça önemlidir. Günümüzde Coğrafi Bilgi Sistemleri (CBS) yazılımlarının yaygınlaşması, kullanımının artması ve bunun yanı sıra İnsansız Hava Aracı (İHA) ile yüksek çözünürlüklü görüntülerin elde edilmesi ile hassas ormancılık anlayışı çerçevesinde daha net ve güvenilir bilgilerin birbirine entegre edilebilmesiyle avantajlı bir ortam oluşturulmuştur. Bu çalışma, ormancılık faaliyetlerinin yerine getirilmesinde temel alt yapı görevini üstlenen orman yollarında İHA verileri ve CBS yardımıyla, orman yolu projelendirilmesi ve kazı-dolduru hesaplamalarının daha net yapılabilmesi için drone vb. teknolojilerin uygulanabilirliğini ortaya koymak amacıyla yapılmıştır. Çalışma, Düzce Orman İşletme Müdürlüğüne bağlı Cumaova Orman İşletme Şefliği 164 kodlu B-Tipi orman yolunda gerçekleşmiştir. Çalışma doğrultusunda, öncelikle multikopter drone aracı ile veriler elde edilmiştir. Elde edilen ham veriler ile çalışma alanına ait Sayısal Arazi Modeli (SAM) üretilmiştir. Üretilen SAM verisi ile yolun yapılmadan önceki arazi yapısını gösteren 12,5 m Sayısal Yükseklik Modeli (SYM) verileri kıyaslanmıştır. Çalışmanın son aşamasında yersel ölçümlerle yol hattından alınan yükseklik ve konum verileriyle kazı – dolduru miktarları RoadEng yazılımı kullanılarak kazı ve dolduru miktarları karşılaştırılmıştır. Bu çalışmada edilen sonuçlar ışığında, orman yolu projelendirme çalışmalarında daha güvenli ve hassas verilerin elde edilebileceği, plan yapıcı, karar verici ve uygulayıcılar için yol planlama çalışmalarına pratik bir yaklaşım kazandırabileceği düşünülmektedir.

Anahtar Kelimeler − *İnsansız hava aracı, orman yolu, yol planlama, kazı ve dolduru*

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1. Introduction

Forest roads are systems that directly affect the ecological balance. It is very important to plan forest roads correctly, adhere to engineering measures in their construction and perform regular maintenance after construction. If it is planned incorrectly and the necessary protective measures are not taken during its construction, negative effects such as flood-flood, erosion, landslide, sedimentation and a decrease in the quality of life of wild animals occur (Erdaş, 1997; Görcelioğlu, 2004). For these reasons, it is extremely important to plan forest roads under the name of sensitive forestry studies, taking into account the social, ecological and economic effects of forest roads.

Forest road planning studies in the world show a great improvement until today with the rapidly developing and widespread technology (Akay and Sessions, 2005). In the period until today, there have been transformations in terms of forest road projecting methods with the effect of science and technology (Acar, 2005; Hasdemir and Demir, 2005). The development of technology has accelerated the development of Remote Sensing (UA) and Geographic Information Systems (GIS) (Buğday, 2019). In the past, studies carried out with classical planning brought about various errors and deficiencies as the measurements were not detailed. This disadvantageous situation has been turned into an advantageous situation by making significant progress in terms of both time and costs in project design works that require a lot of time and expense, thanks to the widespread use of UA techniques and GIS approaches with various software, the increase in the number of experts in this field, and the ease of access to information.

Since forest roads are mostly located in mountainous areas, there are various difficulties in their application (Öztürk et al., 2008). Factors such as unfavourable weather conditions in the area where the measurement is made, and high slope and height affect the measurement negatively. At this stage, Continuously Operating Reference Stations (CORS) device and various devices that work with various principles and measure position and distance can be used for both easy and precise measurements. However, the calculation of all excavation and fill amounts can take a lot of time because it is more complex. A high-resolution Digital Elevation Model (DEM) can be used for both efficient use of time and clearer volume estimation. These DEM data can be produced completely specific to the study area (Akgul et al., 2018). The most important advantage of DTM data obtained by Unmanned Aerial Vehicle (UAV) is that it is easier to access high-resolution data.

Considering the national and international literature, UAVs are widely used (Çömert et al., 2012), excavation-filling costs can be minimized by using software in the design of forest roads (Akay and Sessions, 2005; Julge et al., 2019), UAVs can be suitable for engineering measurements (Manyoky, 2011; Zulkipli and Tahar, 2018), It can be used in volume calculations (Contreras et al., 2012; Siebert and Teizer, 2014; Bugday, 2018; Şentürk et al., 2018), it can be an important alternative in forestry applications (Akgül et al., 2016; Menteşeoğlu and İnan, 2016; Varol et al., 2017), it can create a low-cost and reliable platform. (Erdoğan, 2016; Gülci and Kılınç, 2018), it has been reported that it provides advantages in terms of productivity (Tercan, 2017; Akay et al., 2018; Fidancı and Karabörk, 2019). It has also been stated that it can be used in decision support systems (Kangas et al., 2018; Akay and Sessions, 2005) and precision forestry studies (Kellndorfer et al., 2003; Rango et al., 2006).

This study aims to use drones, etc., for forest road projecting by using UAV technology of forest roads, which perform the basic infrastructure task in fulfilling forestry activities. It brings a practical approach to forest road project studies by demonstrating the applicability of featured technologies. Within the scope of the study, firstly, the Digital Elevation Model of the time before the road was built was downloaded from www.usgs.gov internet address and saved in raster format with 0.5 m resolution with the help of reference control points using ArcGIS 10.3 TM software. On the other hand, the Digital Terrain Model (DTM) belonging to the post-road construction, images were obtained by flying with a UAV vehicle with 80% pre-overlap and 70% side-overlap. Then, a 3-dimensional point cloud was produced from these images and a 0.05 m resolution DTM was created. The DEM data of the land before the road construction and the DTM data after the road construction were adjusted to the same spatial resolution (0.5 m) in the GIS environment, and the difference between the surfaces was determined in the 20-meter area where the road line is located. In addition, the road line was designed by the geometric dimensions of the Communiqué No. 292, B-Type Secondary Forest Road, using the RoadEng software in the computer environment for excavation and fill calculation on the surfaces. The comparative volume amount made from the DEM and DTM data and the volume amounts obtained using the projecting software were compared and the amounts were determined.

2. Material and Method

2.1. Material

The main material of the study; Western Black Sea Region, Bolu Regional Directorate of Forestry, Düzce Forestry Management Directorate, Cumaova Forestry Operations Directorate Between Muratoğlu and Paralı Tepe 40° 49' 59" - 40° 57' 28" north latitudes and 30° 46' 35"- 30 It is located between ° 58' 15" east longitude. The study was carried out on the newly constructed 164 coded B type secondary forest road route in Düzce Province Duzce Forestry Operations Directorate Cumaova Forest Operation Chief, covering an area of approximately 12378 ha. The study area is 48 km away from Düzce and within the borders of Sakarya province (Anonymous 2019). The length of the route section chosen as an example in the study is 395 m. The location of the study area is shown in Figure 1.

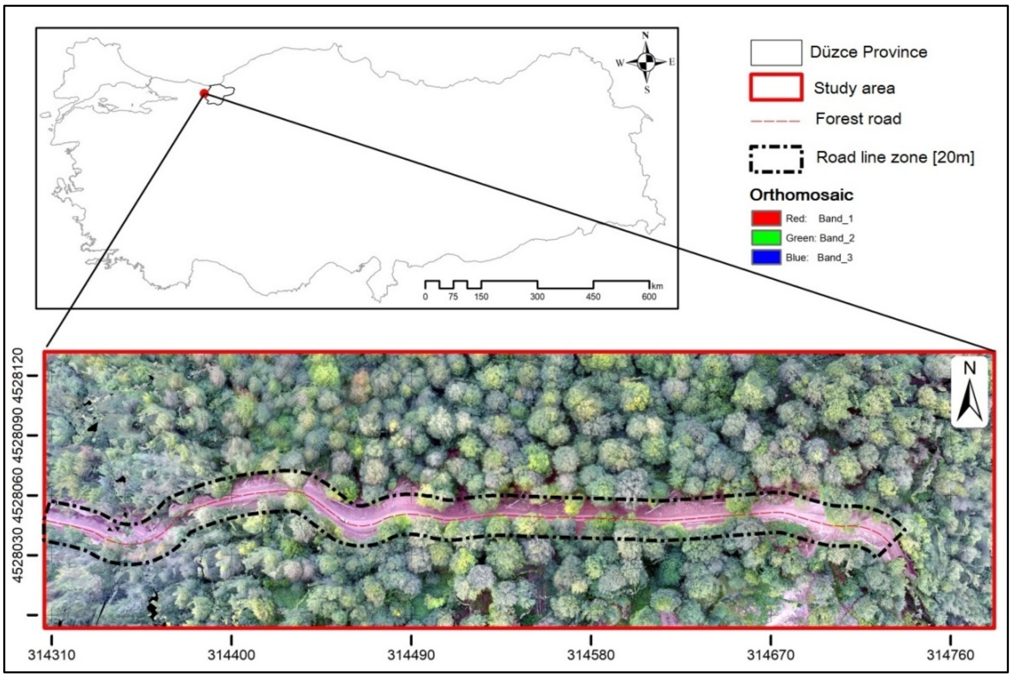

Figure 1. Location of the study area

2.2. Method

This study, with the help of UAV data and GIS on forest roads, will use drones, etc., in order to make forest road projects and excavation-fill calculations clearly carried out to demonstrate the applicability of the technologies. The flowchart prepared for this study is given in Figure 2.

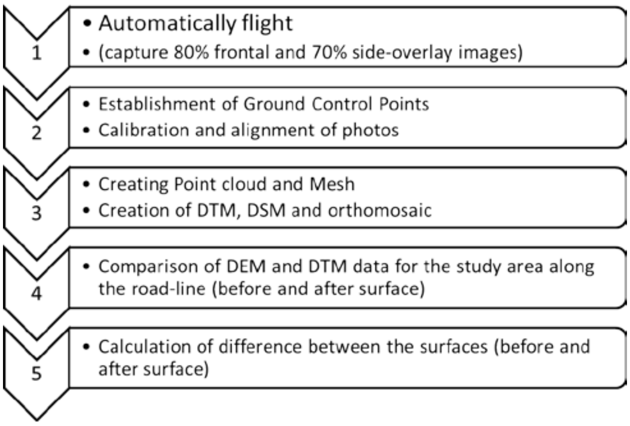

Figure 2. Flowchart of the study

The study area, Cumaova Forestry Directorate, coded 164, B-Type forest road, was used after the road construction work was completed. In order to reveal the land surface, the flight was carried out with the DJI Phantom 4 vehicle. The DJI Phantom 4 device weighs approximately 1350-1400g with its battery. It has a maximum altitude of 7000 m and a flight capacity of up to 30 minutes. Some other features of the drone are given in Table 1.

Table 1
Technical specifications of the drone device used in the study

• Weight: 1350gr-1400gr
• Battery: 5870 mAH LiPo
• Size: 36cm-40cm
• GPS Mode: GPS Yes
• Camera: 4K
• Maximum Speed: 40kmp-50kmp
• Flight Distance: 5000m-6000m
• Flight Time: 26-30 Minutes
• Angle of View: 94°
• Aperture: 2.8 /f
• Sensor Type: CMOS
• Sensor Size: 1/2.3 inch
• Effective Pixels: 12 MP

The flight was planned and implemented with the mobile software called Pix4D to automatically capture 80% frontal and 70% side-overlay images. Data obtained from drone tools must be processed in a computer environment. In this study, the software named Pix4D Mapper, which is the trial version of the mobile software used in automatic flight, offered for desktop computers was used (Figure 3).

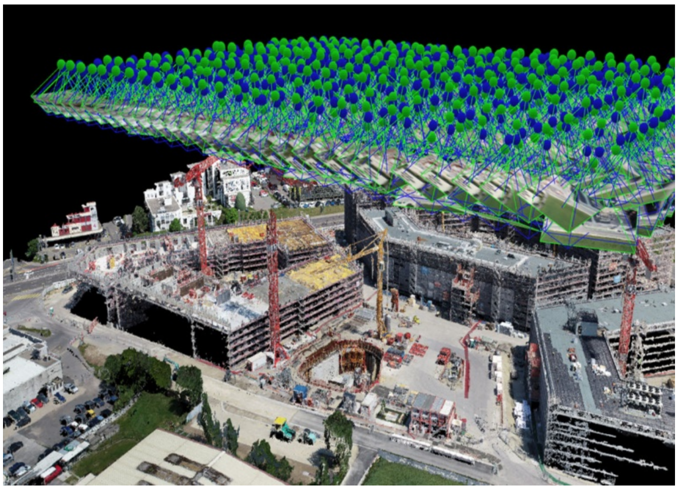

Figure 3. The interface of Pix4D software (URL 2021)

Ground control points (GCP) are required to process the data obtained from the flight in real coordinates. Here, the starting and ending points of the measured road are taken as GCP (Figure 4). In this study, Gintec G9-Model receiver was used as GNSS device. The XY and Z values obtained with this receiver were entered in the Pix4D software at the beginning of the whole process for verification, and the processes were started.

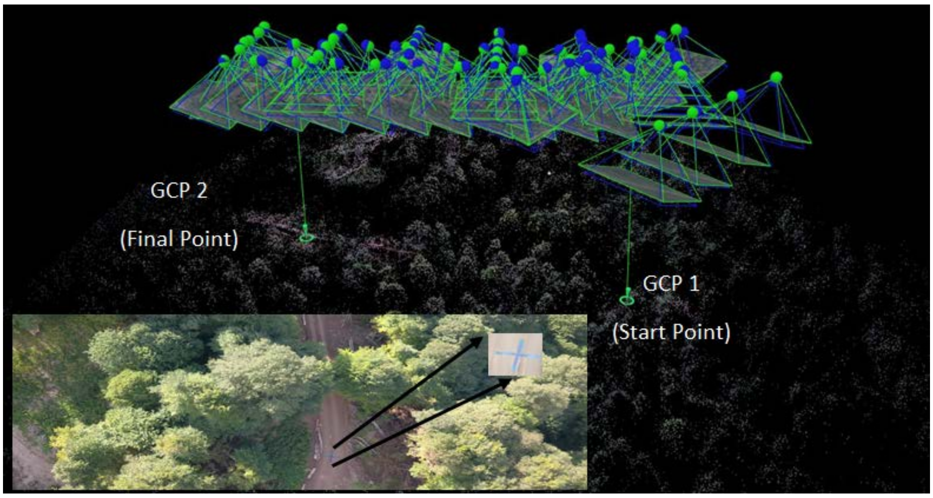

Figure 4. Field data and GCP positions processed in Pix4D software

The computer features used in the study and the preferred projection for processing the data produced in the study are presented (Figure 5). The processing of the total land was completed in approximately 17 minutes.

System Information

Hardware	CPU: Intel(R) Core(TM) i7-6700HQ CPU @ 2.60GHz RAM: 16GB GPU: Intel(R) HD Graphics 530 (Driver: 27.20.100.8681)
Operating System	Windows 10 Pro, 64-bit

Coordinate Systems

Image Coordinate System	WGS 84
Output Coordinate System	WGS 84 / UTM zone 36N (EGM96 Geoid)

Processing Options

Image Scale	multiscale, 1/2 (Half image size, Default)
Point Density	Optimal
Minimum Number of Matches	3
3D Textured Mesh Generation	yes
3D Textured Mesh Settings:	Resolution: Medium Resolution (default) Color Balancing: no
LOD	Generated: no
Advanced: 3D Textured Mesh Settings	Sample Density Divider: 1
Advanced: Image Groups	group1
Advanced: Use Processing Area	yes
Advanced: Use Annotations	yes
Time for Point Cloud Densification	11m:41s
Time for Point Cloud Classification	01m:51s
Time for 3D Textured Mesh Generation	04m:02s

Figure 5. Computer system information and data processing information used in the study

The road that is the subject of the study was built in 2020. Using the raw data obtained after the drone flight over the road line, the Digital Terrain Model (DTM) of the study area was produced with a resolution of 0.04 m (Figure 6). DEM data with a resolution of 12.5 m was used as it is the closest comparable surface data. The land surface of the study area before being subject to road construction; The 12.5 m Digital Elevation Model (DEM) data for 2007 was downloaded free of charge from the internet address www.usgs.gov (URL12 2021) and converted to 0.5 m resolution using terrestrial references and saved in raster format (Figure 6). For comparison, new rasters were created by equating both height data (DEM and DTM) to 0.5 m resolution. The area difference before and after the road construction was calculated on the 20-meter road route section using the Cut-Fill module in the ArcGIS 10.3 TM software (ESRI 2018).

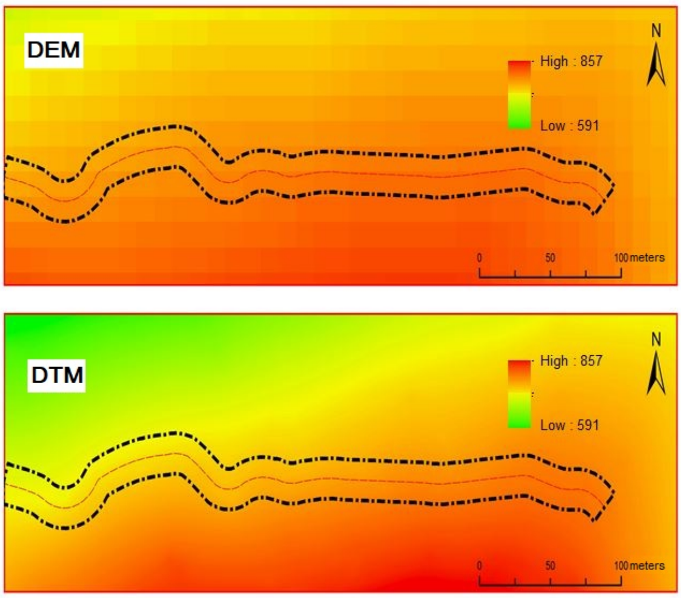

Figure 6. Study area DEM and DTM data

At the last stage of the study; by using both DEM and DTM data, height and location data obtained from the road line with ground measurements, excavation – fill amounts were designed using RoadEng software by the principles of Communiqué No. 292 (GDF, 2008). Excavation and fill calculations were made on both land elevation data (DEM and DTM) and the results were compared.

3. Results

The work area road line and its surroundings were imaged with a drone and processed using Pix4D software and ArcGIS 10.3 TM GIS software. According to the grid method, an automatic flight was made from a height of 120 meters from the road surface and the image acquisition process was completed in 7 minutes. A "road line zone" has been formed according to the total 20m road width mentioned in the Communiqué No. 292. The area of this zone is 8850 m^2 in total and the length of the forest road section measured on the route is 395 m.

The coordinates of the start and endpoints (total of two points) of the road in the study area were taken with the help of the GNSS-CORS device. The DTM and orthomosaic image of the study area was obtained using the temporary version of the Pix4D Capture software (Figure 7).

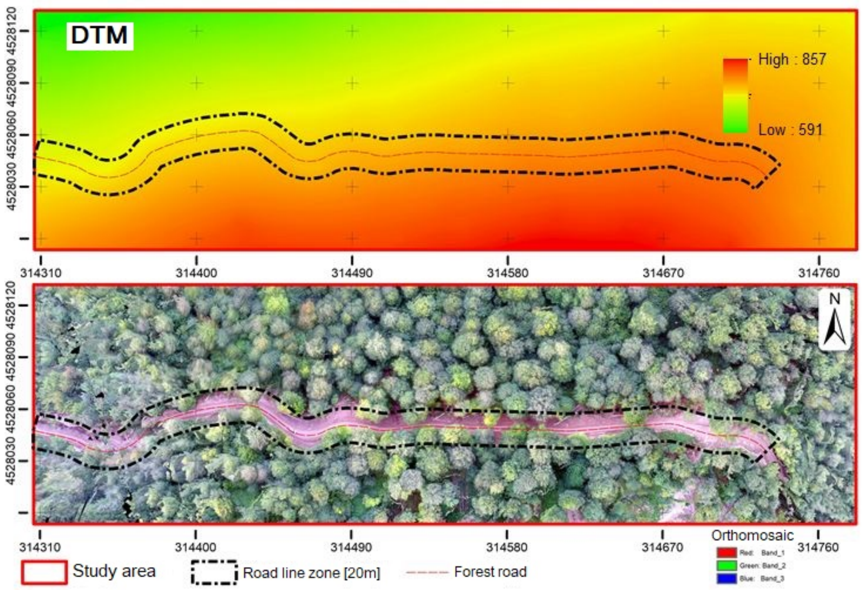

Figure 7. DTM data of the study area

In the measured route section of the forest road in the study area, DEM data of 2007 (12.5 m×12.5 m resolution) and DTM (0.05 m×0.05 m resolution) data obtained after the flight in 2020 were used with terrestrial references. It was compared with the same resolution (0.5 m×0.5 m) in ArcGIS 10.3 software. As a result of the comparison, it was calculated that the road line consisted entirely of the excavation area and the total excavation amount was 7804 m^3 (Figure 8).

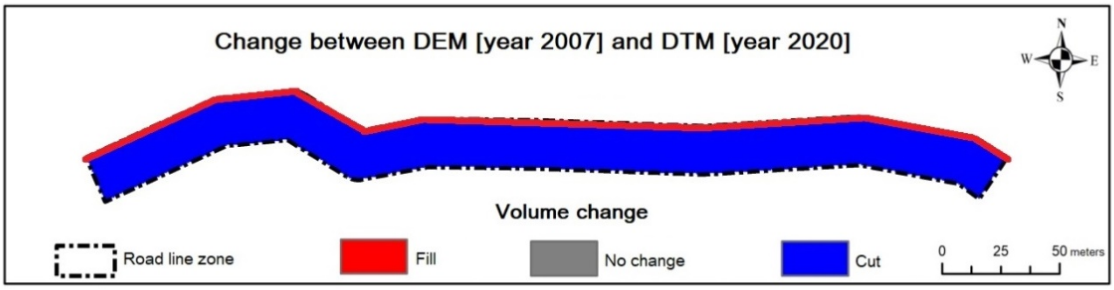

Figure 8. Road line cut and fills locations

In the study area, by the Communiqué No. 292, the geometric features of the B-Type Secondary Forest Road were entered and the road sizing and projecting processes on the DEM and DTM data were made using RoadEng (with trial license) software. After the horizontal and vertical curve arrangement of the forest road was made in the computer environment, the accuracy was checked by overlapping the existing road one-to-one. After the calculations made with the RoadEng software, 6238.6 m^3 of excavation and 936.6 m^3 of fill (net excavation amount = 5302 m^3) were calculated based on the DEM data (Figure 9).

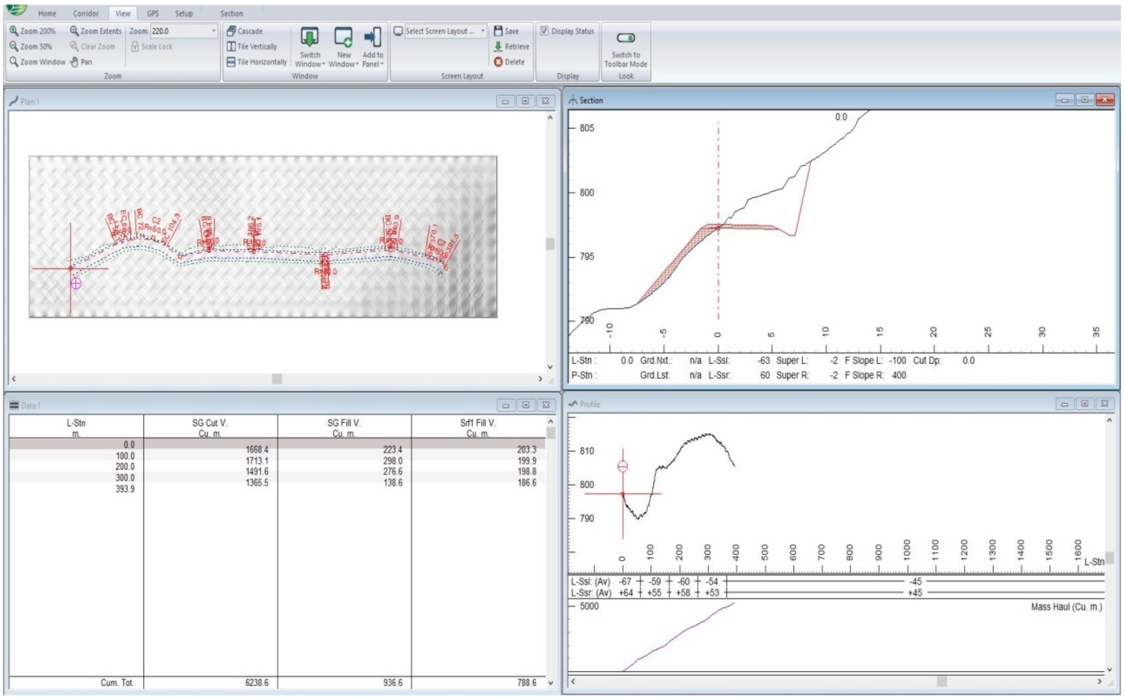

Figure 9. Cut–fill calculation using DEM data

Similarly, 6091.5 m^3 of excavation and 580.6 m^3 of fill = net excavation amount = 5510 m^3) were calculated based on DEM data (Figure 10).

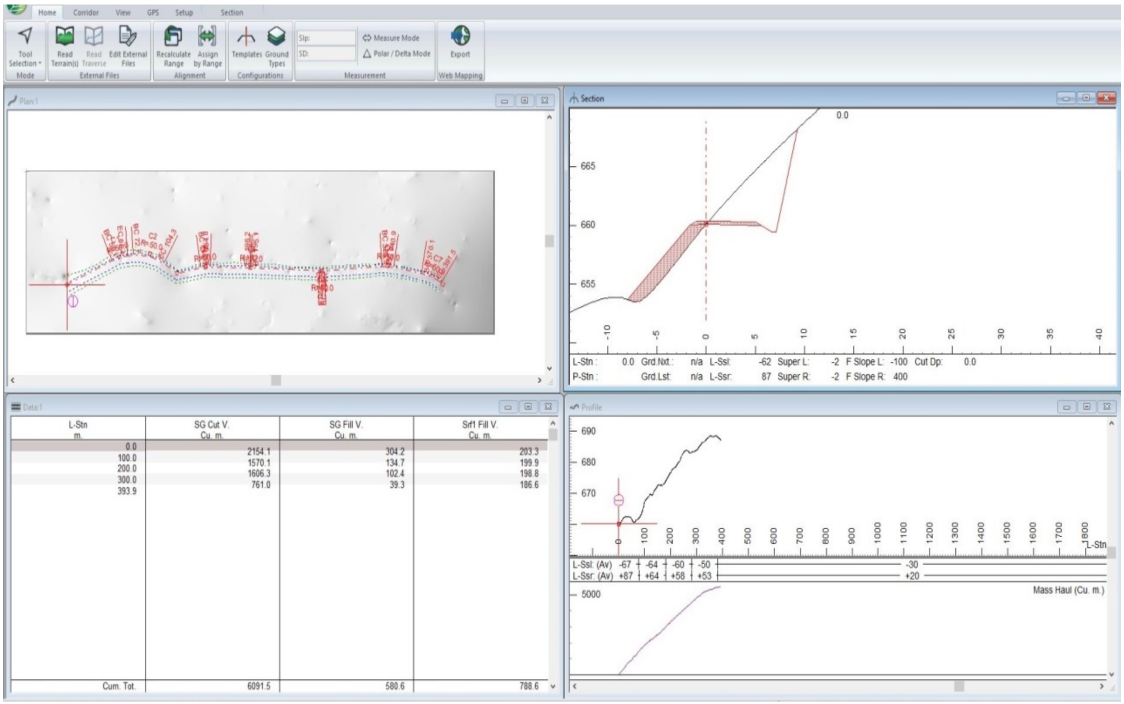

Figure 10. Cut–fill calculation using DTM data

4. Discussion and Conclusion

In an environment where technological progress and applications are rapidly developing, in almost all sectors; there are expectations especially for planning, project design and realization of high-efficiency targets. Transferring technological developments to planning and decision-making is an advantageous and sustainable approach. Since the forestry sector is at the center of such activities and targets, it is positively affected by technological developments. With the existence of sensitive, reliable and more detailed data necessary for implementers, plan makers and decision-makers to carry out more accurate activities, the need for quality information can be quickly met. With the combined use of Geographic Information Systems (GIS) and high-tech devices, it is a practically applicable rational approach to prioritize the most suitable one for business purposes among the alternatives in the forestry sector and move on to the projecting, planning and construction stages. In this study, the Digital Terrain Model (DTM), which is used as a base for the forest road project of the drone vehicle, is emphasized and it is revealed how much excavation and fill volumes, can be reached before the road is built by converting the data with a resolution of 0.05 m (5 cm) into quality information.

The basis of modelling studies is to process the information about the object/case and include the parameters selected in line with the determined purpose in the decision-making system. Obtaining a model with the least error and the highest accuracy rate in the computer environment, as if it were real life, affects the accuracy of the project design and calculation studies to the same extent. High-resolution and more accurate information play a key role in the successful implementation of planning. The presence of information that can turn into such quality information in land modelling studies provides an advantageous planning and decision-making environment. As a result of the comparison using the DEM-DTM data made in this study, it has been determined that the road line consists entirely of the excavation area and the total amount of excavation is 7804 m3. The net excavation amount after the calculation designed according to the existing road geometry on the DEM data was calculated as 5302 m3, and the net excavation amount after the calculation projected according to the existing road geometry on the DEM data was calculated as 550.9 m3.

The difference (7804 m3) between the field data of 2007 (DEM) and the field data of 2020 (DTM-2020) can give approximate excavation-filling information. However, more detailed information; When compared with the relevant operation chief, which follows all stages of the road construction work and keeps records with the help of tables, the evaluation made on the DTM data was calculated from the amount of excavation (5510.9 m3) obtained by the application of the existing road line. The biggest obstacle when making comparisons here; is the absence of coordinate points of the piles (like bridge piles, slope piles, etc.) used in the application of the road route to the land. After the application, which is a routine activity in every project, it is not possible to make a healthier evaluation in the computer environment, since the coordinates of the piles driven when the road construction is started are not taken. Before the start of the entire road construction in the enterprise, the coordinates of the piles belonging to the relevant route can be taken and the road route geometry can be effectively projected in the computer environment by overlaying them with the high-resolution field data. With the use of more detailed data, a more precise and less erroneous volume can be made. Considering today's technological possibilities, it is thought that Forest General Directorate will encourage the use of high-resolution field data and will prepare the environment that will enable more accurate calculations and more accurate planning. In future studies, the feasibility of project design studies can be demonstrated with the use of UAVs with different technical characteristics and different modelling approaches for plan makers, implementers and decision-makers.

Acknowledgements

This study, titled "Evaluation of Unmanned Aerial Vehicle Use Opportunities in Forest Road Project (Düzce Sample)" by Mustafa Görkem CİRİTCİOĞLU, who was carried out in the Department of Forest Engineering, Graduate School of Natural and Applied Sciences at Çankırı Karatekin University, is derived from Master's Thesis.

Authors Contribution

All authors contributed jointly to this article.

Conflict of Interest

The authors declared that there is no conflict of interest.

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