

# MERSIN PHOTOGRAMMETRY JOURNAL



## **EDITOR IN CHIEF**

*Prof. Dr. Murat YAKAR*  
Mersin University, Engineering Faculty  
Turkey

## **CO-EDITORS**

*Assist. Prof. Dr. Ali ULVI*  
Mersin University, Engineering Faculty  
Turkey

*Assist. Prof. Dr. Osman ORHAN*  
Mersin University, Engineering Faculty  
Turkey

## **ADVISORY BOARD**

*Prof. Dr. Orhan ALTAN*  
Honorary Member of ISPRS, ICSU EB Member  
Turkey

*Prof. Dr. Naser El SHAMY*  
The University of Calgary Department of Geomatics Engineering,  
Canada

*Prof. Dr. Armin GRUEN*  
ETH Zurich University  
Switzerland

*Prof. Dr. Ferruh YILDIZ*  
Konya Technical University  
Faculty of Engineering and Natural Sciences  
Turkey

## **EDITORIAL BOARD**

*Prof. Dr. Alper YILMAZ*  
Environmental and Geodetic Engineering, The Ohio State University,  
USA

*Prof. Dr. Dieter FRITSCH*  
University of Stuttgart Institute for Photogrammetry  
Germany

*Prof. Dr. Petros PATIAS*  
The Aristotle University of Thessaloniki, Faculty of Rural & Surveying Engineering  
Greece

*Prof. Dr. Pierre GRUSSENMEYER*  
National Institute of Applied Science, Department of civil engineering and surveying  
France

*Prof. Dr. Xiaoli DING*  
The Hong Kong Polytechnic University, Faculty of Construction and Environment  
Hong Kong

*Dr. Hsiu-Wen CHANG*  
National Cheng Kung University, Department of Geomatics  
Taiwan

*Prof. Dr. Rey-Jer YOU*  
National Cheng Kung University, Tainan · Department of Geomatics,  
China

*Prof. Dr. Bülent BAYRAM*  
Yıldız Technical University Engineering Faculty,  
Turkey

*Prof. Dr. İbrahim YILMAZ*  
Afyon Kocatepe University Engineering Faculty,  
Turkey

*Prof. Dr. Ömer MUTLUOĞLU*  
Konya Technical University  
Faculty of Engineering and Natural Sciences,  
Turkey

*Dr. Öğr. Üyesi, Nizar POLAT*  
Harran University, Engineering Faculty,  
Turkey

*Dr. Öğr. Üyesi. Sefa BİLGİLİOĞLU*  
Aksaray University, Engineering Faculty,  
Turkey

#### **LANGUAGE EDITOR**

Prof. Dr. Orhan ALTAN  
Honorary Member of ISPRS, ICSU EB Member  
Turkey

#### **MEPHOJ TECHNICAL OFFICER**

Res. Asst. Aydın ALPTEKİN  
Mersin University, Engineering Faculty  
Turkey

#### **The MERSİN PHOTOGRAMMETRY JOURNAL (MEPHOJ)**

THE MERSİN PHOTOGRAMMETRY JOURNAL (MEPHOJ) publishes original and innovative contributions in photogrammetric applications ranging from the integration of instruments, methodologies, and technologies and their respective uses in the environmental sciences, engineering, and other natural sciences. Mersin Photogrammetry Journal is a branch of science that widely applied in many scientific disciplines. MEPHOJ aims to cover the entirety of Photogrammetry and Photogrammetric applications about Geosciences, including their application domains. MEPHOJ strives to encourage scientists to publish experimental, theoretical, and computational results as detailed as possible so that results can be easily reproduced.

MEPHOJ is a double peer-reviewed (blind) OPEN ACCESS JOURNAL that publishes professional level research articles and subject reviews exclusively in English. It allows authors to submit articles online and track his or her progress via its web interface. All manuscripts will undergo a refereeing process; acceptance for publication is based on at least two positive reviews. The journal publishes research and review papers, professional communication, and technical notes. MEPHOJ does not charge for any article submissions or for processing.

CORRESPONDENCE ADDRESS  
Journal Contact: [myakar@mersin.edu.tr](mailto:myakar@mersin.edu.tr)

# CONTENTS

## *Volume 2 - Issue 1*

### RESEARCH ARTICLES

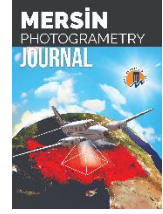
** The effect of different flight heights on generated digital products: Dsm and Orthophoto	
Mehmet Özgür Çelik, Aydın Alptekin, Fatma Bünyan Ünel, Lütfiye Kuşak, Engin Kanun	1
<hr/>	
** Automatic road detection from orthophoto images	
Abdurahman Yasin Yiğit, Murat Uysal	10
<hr/>	
** Light rail line design for East Black Sea region: A case study of Trabzon	
Hatice Catal Reis, Abdulkadir Birinci	18
<hr/>	
** Investigation of phenological stages of wheat plant using vegetation index	
Yunus Kaya, Nizar Polat	24
<hr/>	
** 3D Modelling of Kayseri Tekgöz Bridge	
Ali ULVİ, Abdurahman Yasin Yiğit	29
<hr/>	



## Mersin Photogrammetry Journal

<https://dergipark.org.tr/tr/pub/mephoj>

e- ISSN 2687-654X



# The effect of different flight heights on generated digital products: Dsm and Orthophoto

Mehmet Özgür Çelik\*<sup>1</sup>, Aydın Alptekin<sup>1</sup>, Fatma Bünyan Ünel<sup>1</sup>, Lütfiye Kuşak<sup>1</sup>, Engin Kanun<sup>1</sup>

<sup>1</sup>Mersin University, Engineering Faculty, Geomatics Engineering Department, Mersin, Turkey

### Keywords

UAV  
DSM  
Orthophoto  
Resolution  
GSD

### ABSTRACT

Unmanned Aerial Vehicle (UAV) allows you to create digital surface models (DSM) and orthophotos of an area in a short time by photogrammetric methods. In the last decade, UAV and Global Positioning System (GPS) have been used to create real, reliable and high-resolution maps. In this study, the effect of flight height on DSM and orthophoto was investigated. Two flight plans at a height of 30 to 50 meters were prepared. Images taken with UAV were used to produce DSM and orthophoto. Resolutions of maps were compared when models were produced. Compared to a flight height of 50 meters, a more detailed and high-resolution model was created with 30 meters. Although the flight data from 30 meters gave better results, the flight process took longer. Also, more photos were taken and the file size took up more space. As a result of this comparison, it was determined that the flight height should be determined according to the terrain structure, accuracy, precision and time-cost balance expected from the job.

## 1. INTRODUCTION

Using the unmanned aerial vehicle (UAV), flights at different heights were carried out within the same time frame. Firstly, the flights were made to be 0.82 cm/pixel GSD at a height of 30 meters and then 1.37 cm/pixel GSD at a height of 50 meters. Digital surface model (DSM) and orthophoto were produced from photos taken with UAV by photogrammetric methods. Different camera angles affect the point position accuracy and resolution of the digital products produced (Öztürk et al., 2017). To eliminate this effect, a 90-degree camera angle was used on both flights. In this study, the differences between orthophotos and DTMs with different height and ground sampling distance (GSD) were investigated. The effect of the change of GSD value on the DSM and orthophoto was investigated.

### 1.1. Photogrammetry

Photogrammetry is the science that enables the determination of the position, shape and size of objects on the earth utilizing overlapping pictures.

Photogrammetry with the developing technology gives faster and more accurate results compared to classical terrestrial measurements. Nowadays, air photogrammetry, which is the sub-branch of frequently preferred photogrammetry, can determine the shape, position and size of the objects in space through UAV. In this study, DSM and orthophoto were produced by using UAV. Photogrammetric methods were used to produce this data. With the development of computers, different photogrammetric approaches have started to be used for 3D model creation (Sarıtürk and Şeker, 2017). Of these, the Structure From Motion (SFM) approach is frequently preferred (Dellaert et al., 2000; Furukawa and Hernández, 2013; Sarıtürk and Şeker, 2017). SFM; 3D modelling is a classical photogrammetry approach that uses the stereo image technique to produce the model by detecting the common points of the desired object in the captured images (Dellaert et al., 2000; Furukawa and Hernández, 2013; Yakar and Doğan, 2017). The SFM enables 3D models to be produced from 2D images shot sequentially. It also enables low-cost operation with high resolution and large data sets. (Kolzenburg et al., 2016; Morgan and Brogan, 2016;

#### \* Corresponding Author

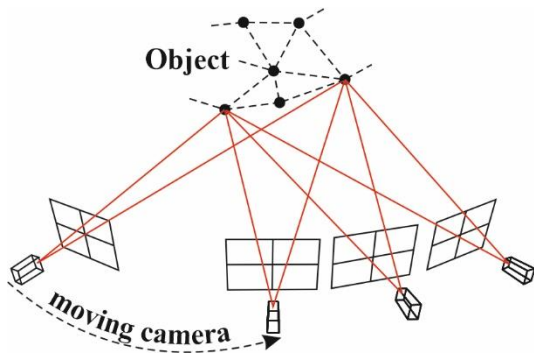
(mozgurcelik@mersin.edu.tr) ORCID ID 0000 – 0003 – 4569 888X  
(aydinalptekin@mersin.edu.tr) ORCID ID 0000-0002-5605- 0758  
(fatmabunel@mersin.edu.tr) ORCID ID 0000-0002-9949-640X  
(lutfiyekusak@mersin.edu.tr) ORCID ID 0000- 0002-7265 – 245X  
(ekanun@mersin.edu.tr) ORCID ID 0000-0002-2369-5322  
DOI: XXXXXXXXXXXX /Research Article

Cite this article

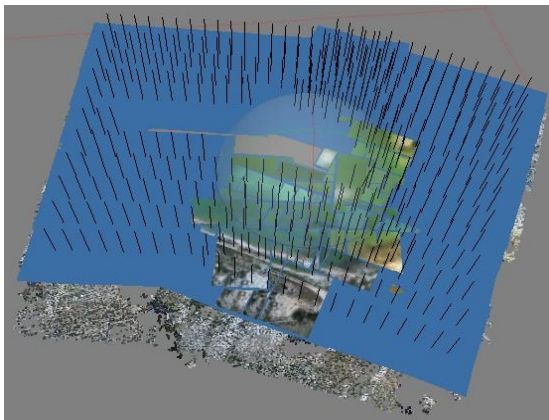
ÇELİK, M , ALPTEKİN, A , BÜNYAN ÜNEL, F , KUŞAK, L , KANUN, E . (2020). THE EFFECT OF DIFFERENT FLIGHT HEIGHTS ON GENERATED DIGITAL PRODUCTS: DSM AND ORTHOPHOTO. Mersin Photogrammetry Journal , 2 (1) , 1-9 . Retrieved from <https://dergipark.org.tr/tr/pub/mephoj/issue/52791/636366>

Received: 22/10/2019; Accepted: 25/11/2019

Sarıtürk and Şeker, 2017). Therefore, the main purpose of this approach is to create a 3D visualization rather than a map (Seren and Demirel, 2016). The 3D model obtained by photogrammetry technique is a reference point that will facilitate the decision-making process of managers (Şasi and Yakar, 2018). In this study, DSM and orthophoto images of the study area were produced with Agisoft Metashape Professional.1.5.0 program which uses the SFM algorithm (Fig.1, Fig.2).



**Figure 1.** Structure From Motion (It was adjusted from (Sweeney, 2016))



**Figure 2.** Sturcture From Motion (SFM) for Agisoft

### 1.2. Unmanned Aerial Vehicle (UAV)

UAV is a concept that emerged in the 70s (Newhall, 1969; Whittlesley, 1970). With advancing technology, helicopters, aircraft, rotary/fixed-wing UAVs were produced (Özemir and Uzar, 2016). UAV has contributed significantly to the process of making various maps for analysis, inquiry, 3D modelling and digital imaging (Özemir and Uzar, 2016; Nex and Remondino, 2013). The UAV is the remote control or the vehicle flying according to a flight plan (Eisenbeiss, 2009; Ceylan et al, 2014). UAV consists of a digital camera and GPS integration (Eisenbeiss, 2003; Yilmaz et al., 2018). Compared to other aircraft, the main difference is that there is no physical pilot (Eisenbeiss, 2004; Rawat and Lawrence, 2014). It is used in many fields such as

cartography, military activities, agricultural studies, and engineering projects (Fig.3).



**Figure 3.** UAV

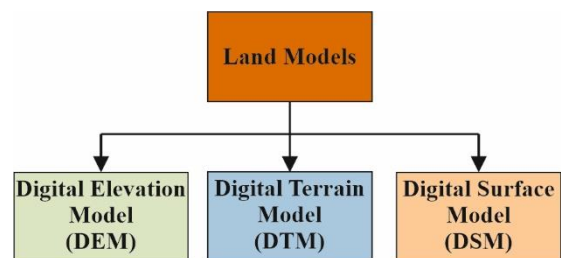
### 1.3. UAV Benefits

UAVs have high performance at low cost. It is integrated with various imaging devices with sensors such as thermal, infrared, hyper spectral, radar, chemical and biological. There are many advantages such as providing natural disasters to ground stations, coordinating the data instantly thanks to being integrated with GPS (Yilmaz et al., 2018). It also offers the opportunity to work in risky and inaccessible areas (Ulvi and Toprak, 2016). In addition to these advantages, it is used in mapping and architectural applications and in archaeological sites (Ulvi and Toprak, 2016).

In this study, it was used in order to produce precision, reliable and rapid production of the field's DSM and orthophoto.

### 1.4. Land Models

Land models are created to obtain reliable and accurate information on topography. The terrain models are basically expressed in three ways (Fig.4).



**Figure 4.** Land Models

DEM: X, Y and Z (Marangoz, 2014) is the model that expresses the soil most simply and barely with height values. Various remote sensing and photogrammetric (stereo photogrammetry (Hohle, 2009; Kraus, 2007), satellite and radar images, interferometry (Arun, 2013), airborne laser

scanning (Vosselman and Maas, 2010) and land surveying (Wilson and Gallant, 2000) methods are used to obtain DEM. The method used directly affects the accuracy, cost and duration of the DEMs produced.

**DTM:** It is the model that includes only the bare land surface and the morphology of the land where details such as vegetation, tree, lamppost and building are not shown (ATLIS Geomatics 2019; Yasayan, 2011; Marangoz, 2014).

**DSM:** It is a terrain model similar to DEM and DTM. The main difference includes building, tree, tower, pole and details. In other words, it is the model that includes the height of the detail in the field.

In this study, the flights were performed two different heights (30 and 50 m) with UAV. Using the SFM approach, DEM, orthophotos and DSMs were produced from DEM. The effect of altitude and correspondingly changing GSD values on DSM and orthophoto were investigated.

**GSD:** The distance between the centers of two neighboring pixels in a digital image or orthophoto is called the GSD. In other words, it is the value that indicates how much area or detail a pixel represents in the field. For example, in this study, GSD is 0.82 cm/pixel for the flight that performed 30 m height. This means that details less than 0.82 cm in the field are not shown on the map.

### 1.5. Global Navigation Satellite System (GNSS)

GNSS is a system for determining the position of any object in the world with radio signals (Fig.5). In this study, it was used to determine the coordinates of the ground control points established before the flight with UAV. The coordinated photographs are coordinated with the photographs obtained from the flights performed at different heights (30 m and 50 m).

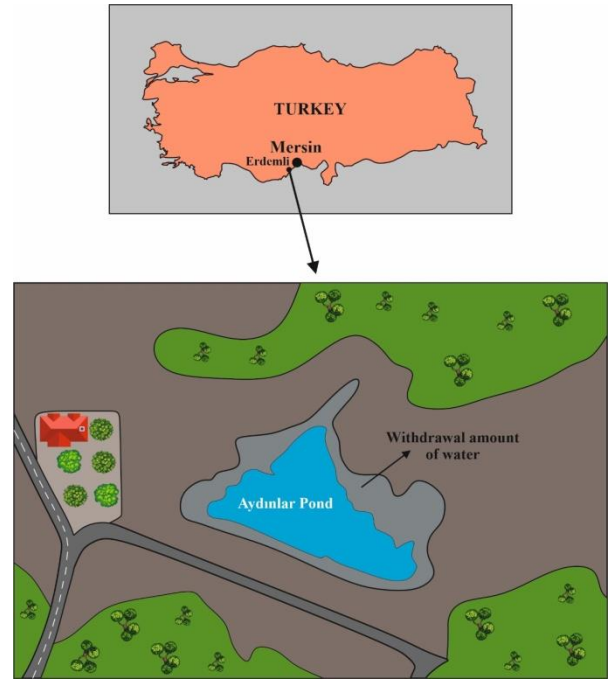


**Figure 5.** GNSS and receiver

## 2. STUDY AREA

The study area was determined in Aydınlar Pond located in Avgadı Neighborhood of Erdemli district of Mersin. Aydınlar Pond, which is the

working area, is located 35.5 km from Erdemli district and 90.3 km from Mersin city centre (Fig.6). The size of the area is approximately 15224.94 m<sup>2</sup>.



**Figure 6.** Aydınlar Pond

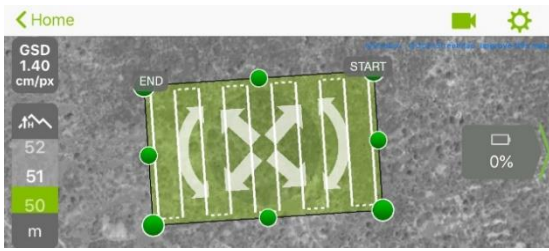
## 3. MATERIAL AND METHODS

### 3.1. Flight Planning

Flight plans were prepared in Pix4Dcapture application in the study area. For a flight at a height of 30 m, GSD is 0.82 cm/pixel (Fig.7) and for a 50 m height, GSD is 1.37 cm/pixel (Fig.8). The transverse and longitudinal overlap is set at 80% in flight plans. The camera angle is set to 90 degrees. In this study, it is planned to determine the effect of different heights on the DSM and orthophoto. Therefore, the camera angle was adjusted to 90 degrees on both flights and the angle effect was eliminated.



**Figure 7.** Flight plan for a height of 30 m



**Figure 8.** Flight plan for a height of 50 m

### 3.2. Field Study

#### 3.2.1. Measurement of Gcp

5 gcps was installed to cover the area (Fig.9). The coordinates of the gcps were measured to TUSAGA Active CORS-TR system with Satlab SL800 GNSS receiver in UTM projection, ITRF-96 datum (EPSG: 5255), GRS80 ellipsoid, 2005.0 epoch, 3 degree zone 33 (Fig.10).



**Figure 9.** Gcp marking



**Figure 10.** Gcp measurement

The coordinate values of the measured gcps are shown in table 1 and table 2.

**Table 1.** Gcp coordinate value

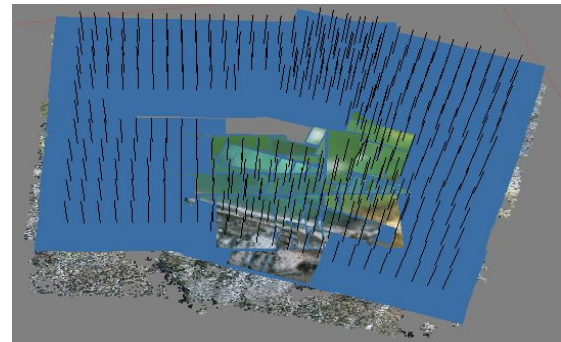
Point No	Uncertainty Solution Status	Antenna Height	Accuracy Coordinate (ITRF -TM 3° 33° E)	
			Y	X
1	FIXED*	2.000	600611.675	4072972.269
2	FIXED	2.000	600649.172	4072956.432
3	FIXED	2.000	600695.871	4072941.124
4	FIXED	2.000	600768.877	4072931.886
5	FIXED	2.000	600772.124	4073008.920

**Table 2.** Gcp coordinate value

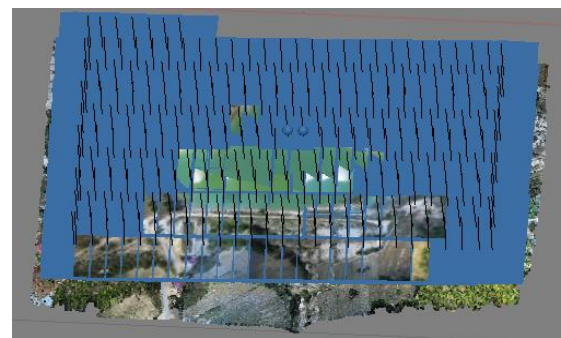
Point No	Ellipsoid height (h)	Orthometric height (H)
1	1401.586	1371.871
2	1401.422	1371.710
3	1400.809	1371.101
4	1400.103	1370.399
5	1399.614	1369.903

#### 3.2.2. Taking Photos

450 photographs were taken on 30 m high flight and 259 photographs were taken on 50 m high flight. The 21 MP camera on the Parrot Anafi UAV was used. Photographs of the entire study area were taken at regular intervals (Figure.11, Figure.12).



**Figure 11.** Photos taken at a height of 30 m



**Figure 12.** Photos taken at a height of 30 m



The table 3 shows the technical specifications of the Parrot Anafi UAV.

Table 3. Technical specifications of the Parrot Anafi UAV (Parrot, 2018)

Property	Value
Drone weight	320 g
Controller weight	386 g
Battery weight	126 g
Max. flight time	25 min
Max. horizontal speed	15.2 m /s
Max. vertical speed	4 m/s
Max. wind resistance	13.9 m/s
Max. transmission range	4000 m
Max. altitude	150 m
Operating temperature range	-10-40 C°
Camera	21 MP
Resolution	4608x3456
Focal length	4 mm
Pixel size	1.34 x 1.34 µm

### 3.3. Data Processing

With the photographs taken, Agisoft Metashape Professional.1.5.0 program was used. The photographs were directed in the program. The estimated shape of the 3D model was generated by a sparse point cloud. All photos containing the images were matched. Internal matching elements, camera calibration information and distortion errors were calculated by this matching process.

Table 4. Calibration coefficients and correlation matrix for 30 m

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	P1	P2
F	3057.11	1.5	1.00	-0.74	-0.03	-0.01	-0.03	-0.13	0.36	-0.49	0.69	0.11
Cx	22.0817	0.047		1.00	0.13	0.02	0.12	0.12	-0.27	0.36	-0.31	-0.05
Cy	3.27805	0.026			1.00	-0.11	0.01	0.01	-0.02	0.03	0.00	0.50
B1	-7.05016	0.019				1.00	-0.03	-0.01	-0.01	0.01	0.01	-0.07
B2	-0.0193734	0.021					1.00	0.02	-0.00	0.01	0.02	0.07
K1	-0.00370674	2.6e-005						1.00	-0.87	0.78	-0.09	-0.02
K2	0.0128301	7e-005							1.00	-0.97	0.22	0.05
K3	-0.00986092	6e-005								1.00	-0.31	-0.06
P1	0.00374189	2.7e-006									1.00	0.08
P2	0.000525402	2e-006										1.00

Table 5. Calibration coefficients and correlation matrix for 50 m

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	P1	P2
F	3031.44	1.2	1.00	-0.85	-0.84	-0.06	-0.04	-0.16	0.42	-0.54	0.70	0.06
Cx	23.1364	0.049		1.00	0.73	0.06	0.16	0.14	-0.36	0.46	-0.44	-0.03
Cy	2.59885	0.042			1.00	-0.10	0.05	0.13	-0.36	0.46	-0.58	0.19
B1	-4.0701	0.044				1.00	-0.00	0.00	-0.02	0.02	-0.03	-0.01
B2	0.328655	0.043					1.00	0.01	-0.01	0.02	-0.03	-0.03
K1	-0.00407434	2.1e-005						1.00	-0.79	0.71	-0.12	-0.05
K2	0.0142818	5.4e-005							1.00	-0.98	0.24	0.01
K3	-0.0104624	4.7e-005								1.00	-0.33	-0.01
P1	0.00368191	2.1e-006									1.00	0.08
P2	0.000513487	1.4e-006										1.00

Then, a dense point cloud was formed. DEMs and DSMs were generated from dense point clouds

(Fig.13, Fig.14) produced. Orthophoto (Fig.15, Fig.16) were generated from DEM.

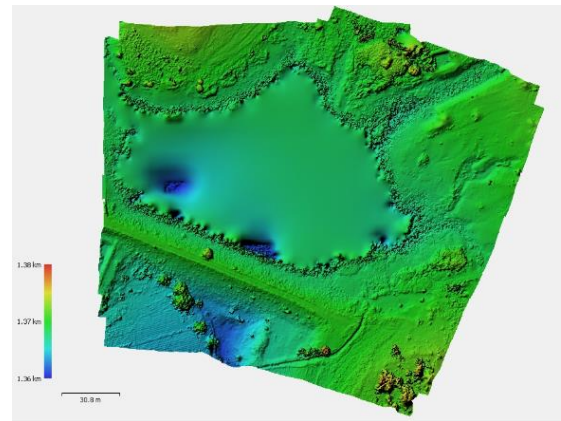


Figure 13. DSM for 30 meters.

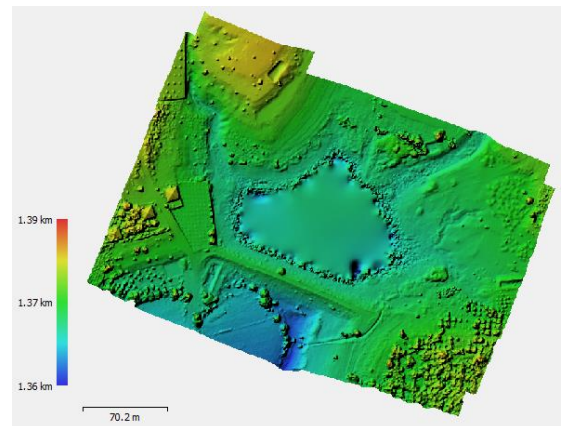


Figure 14. DSM for 50 meters.

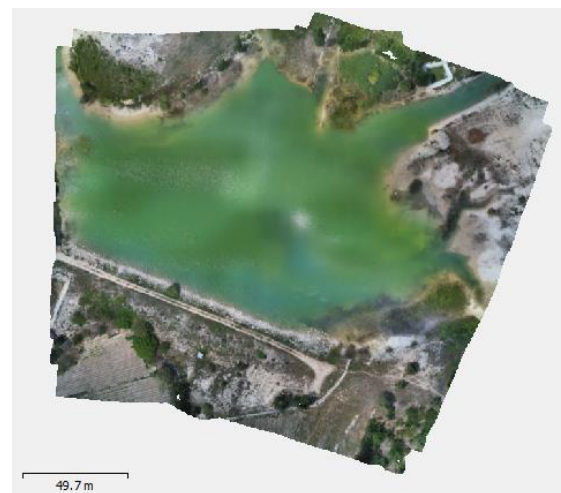
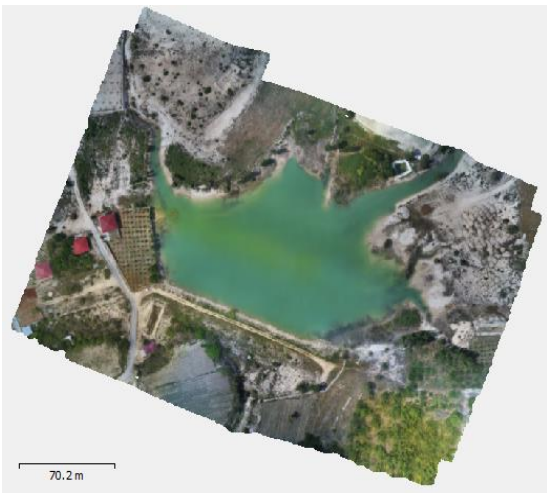
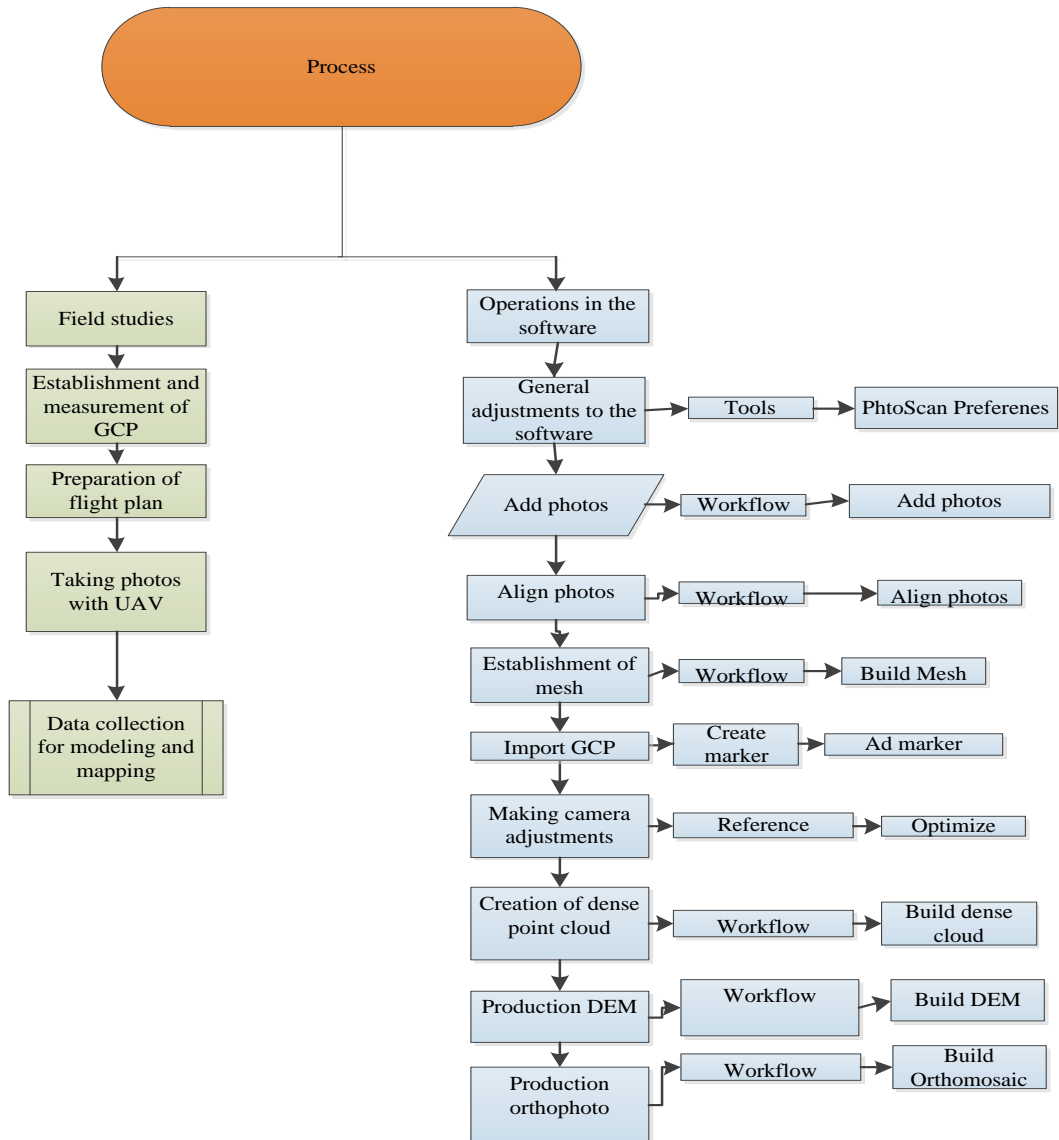


Figure 15. Orthophoto for 30 meters



**Figure 16.** Orthophoto for 50 meters

The process steps performed during the study are shown in the following figure (Fig. 17).



**Figure 17.** Work flow

#### 4. FINDINGS

In the study conducted in a flight from a height of 30 m DSMGSD: 4.24cm/pixel, orthophotoGSD: 1.09 cm/pixel. In the 50 m flight, DSMGSD is 6.78 cm/pixel and orthophotoGSD is 1.74 cm/pixel. Based on these data, it was determined that flight height directly affected the resolution of digital products (such as DSM, orthophoto) depending on the terrain structure, desired accuracy and sensitivity (Fig.18, Fig.19). To obtain more detailed and reliable information about the terrain, it has been determined that low altitude flights should be performed. Although UAVs have many advantages, they have been determined as a result of the wind which is effective during the field study, including the shortness of time in the air and the inability to work optimally in windy weather.



**Figure 18.** An image from a 30 meters flight



**Figure 19.** An image from a 50 meters flight

#### 5. CONCLUSION

As a result of the study, it was found that high accuracy and precision data can be obtained with

UAV and digital products of unreachable areas can be created. It has been determined that with UAV, operations can be performed in a shorter time compared to terrestrial measurements. In addition, the use of UAV has been seen to be beneficial for users in terms of cost and accuracy (Akar, 2017).

The output products obtained as a result of the study DSM and orthophoto images; Horizontal position error for flight at 30 m height:  $\pm 1.30$  cm, vertical position error:  $\pm 0.32$  cm, total error:  $\pm 1.34$  cm was determined. For the flight at 50 m height, horizontal position error:  $\pm 3.80$  cm, vertical position error:  $\pm 0.56$  cm, total error:  $\pm 3.84$  cm was determined. It was seen that point position accuracy is higher at 30 m flight height. Different camera angles affect point position accuracy and resolution (Öztürk et al., 2017). In order to eliminate this effect, flights were performed with a 90-degree camera angle.

It has been determined that flight height directly affects the resolution of the output products to be obtained. Geomorphological structure of the study area, land use method, flight altitude should be changed depending on the accuracy and sensitivity expected from the work.

**NOTE:** This study is an extended version of the paper presented at the Ciset 2019 Symposium held between 10-12 October 2019 at Mersin University.

#### REFERENCES

- Akar, A . (2017). "Evaluation of Accuracy of Dems Obtained From Uav-Point Clouds for Different Topographical Areas." *International Journal of Engineering and Geosciences*, 2(3), 110-117. doi: 10.26833/ijeg.329717
- ATLIS Geomatics,  
<http://www.atlisgeo.com/expertise/process/dem-dtm/> [Accessed 17 Oct. 2019].
- Arun, P.V. (2013). "A comparative analysis of different DEM interpolation methods." *Geodesy and Cartography*, 39 (4), 171-177.
- Ceylan, M., Doner, F., & Ozdemir, S. (2014). "Use of unmanned aerial vehicle systems in data collection and mapping studies." 5. Remote Sensing-GIS symposium, Istanbul, Turkey.
- Dellaert, F. Seitz, S. M., Thorpe, C. E., & Thrun, S. (2000). "Structure from motion without correspondence. Proceedings." IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2000 (Cat. No.PR00662), Hilton Head Island, SC, 557-564 Vol. 2, doi: 10.1109/CVPR.2000.854916.
- Eisenbeiss, H. (2003). "Positionen und orientierungsbestimmung eines autonomen helikopters-vergleich zwischen direkter

- georeferenzierung und aerotriangulation mit videobilddaten." Diploma Thesis, Institute for Photogrammetry and remote sensing, University of Technology, Dresden, Germany.
- Eisenbeiss, H. (2004) "A mini unmanned aerial vehicle (UAV): system overview and image acquisition." *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 36, part 5/W1, on CD-ROM.
- Eisenbeiss, H. (2009). UAV Photogrammetry, ETH Zurich for the degree of Doctor of Science, ISSN 0252-9335, ISBN: 978-3-906467-86-3, Zurich, Switzerland.
- Furukawa, Y., and Hernández, C. (2013). "Multi-View Stereo: A Tutorial." *Foundations and Trends® in Computer Graphics and Vision*, Vol. 9, No. 1-2, 1-148.
- Hohle, J. (2009). "DEM generation using a digital large format frame camera." *Photogrammetric Engineering and Remote Sensing*, 75 (1), 87-93.
- Kraus, K. (2007). "Photogrammetry, Geometry from Images and Laser Scans (2nd edition)" Walter de Gruyter, Berlin, Germany, 459.
- Kolzenburg, S., Favalli, M., Fornaciai, A., Isola, I., Harris, A. J. L., Nannipieri, L., & Giordano, D. (2016). "Rapid updating and improvement of airborne lidar DEMs through ground-based sfm 3-d modelling of volcanic features." *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 54, No. 11, 6687-6699.
- Marangoz, A., M. (2014). "Lecture notes on photogrammetry II". Bülent Ecevit University, Zonguldak, Turkey.
- Morgan, J. A., and Brogan, D. J. (2016). "How to Visual SFM". Department of Civil & Environmental Engineering Colorado State University Fort Collins, Colorado.
- Newhall, B. (1969). "Airborne camera: The world from the air and outer space." Hasting House Trowbridge&London, 144.
- Nex, F., and Remondino, F. (2014). "UAV for 3D mapping applications: a review." *Applied Geomatics*, Vol. 6, Issue 1, 1-15.
- Özemir, I., and Uzar, M. (2016). "The generation of photogrammetric data with unmanned aerial vehicle." 6. Remote Sensing-GIS Symposium, Adana, Turkey, 245-254.
- Öztürk, O., Bilgilioğlu, B., Çelik, M., Bilgilioğlu, S., & Uluğ, R. (2017). "Investigation of the Effect of Height and Camera Angle on Accuracy in Orthophoto Production with Unmanned Aircraft (UAV) Images." *Geomatik*, 2(3), pp. 135-142. doi: 10.29128/Geomatik.327049.
- Parrot (2018) "Anafi User Manual v2.2." pp.1-73.
- Rawat K. S., and Lawrence E. E. (2014). "A mini-UAV VTOL Platform for Surveying Applications." *International Journal of Robotics and Automation (IJRA)* Vol. 3, No. 4, 259-267.
- Sarıtürk, B., and Şeker D.Z. (2017) "Comparison Of Commercial And Open-Source Software Used In 3d Object Modeling With Sfm Technique." *Afyon Kocatepe University Journal of Science and Engineering, Special Issue*, 126-131.
- Şasi, A., and Yakar, M. (2018). "Photogrammetric Modelling Of Hasbey Dar'ülhuffaz (Masjid) Using An Unmanned Aerial Vehicle." *International Journal of Engineering and Geosciences*, 3(1), 6-11. doi: 10.26833/ijeg.328919
- Seren, A. M., and Demirel, H. (2016). "3 Dimensional Modelling of Large Objects in Open-Space: A Comparison of Recent Methodologies in Geomatics Engineering." 8. National Engineering Surveys Symposium, Yıldız Technical University, Istanbul, Turkey.
- Sweeney, C. (2016). Theia Visison Library <http://www.theia-sfm.org/sfm.html> [Accessed 11 Oct. 2019].
- Ulvi, A., and Toprak, A.S. (2016). "Investigation Of Three-Dimensional Modelling Availability Taken Photograph Of The Unmanned Aerial Vehicle; Sample Of Kanlidivane Church." *International Journal Of Engineering and Geosciences*, 1(1), 1-7. doi: 10.26833/ijeg.285216.
- Vosselman, G., and Maas, H.G. (2010). "Airborne and Terrestrial Laser Scanning." CRC: Boca Raton, FL, USA, 318.
- Whittlesley, J. H. (1970). "Tethered Balloon for Archaeological Photos, In Photogrammetric Engineering." 36 2, 181-186.
- Wilson, J.P., and Gallant, J.C. (2000). Secondary Topographic Attribute. in: Wilson, J.P., and Gallant, J.C. (Eds.), "Terrain Analysis: Principles and Applications." John Wiley, and Sons., New York, 87-131.

- Yılmaz, H. M., Mutluoglu, O., Ulvi, A., Yaman, A., & Bilgilioglu, S. S. (2018). "Created Tree Dimensional Model of Aksaray University Campus with Unmanned Aerial Vehicle." *Journal of Geomatics*, No. 2018; 3(2), 129-136.
- Yakar, M., and Dogan, Y. (2017). "3D Modelling of Silifke Asagi Dunya Sinkhole by Using UAV." *Afyon Kocatepe University Journal of Science and Engineering*, Special Issue, 94-101.
- Yasayan, A. (2011). "Photogrammetry." T.C. Anatolia University Publications, No. 2295. Open Education Faculty Publication No: 1292, Eskisehir, Turkey.



## Mersin Photogrammetry Journal

<https://dergipark.org.tr/tr/pub/mephoj>

e-ISSN 2687-654X



### Automatic road detection from orthophoto images

Abdurahman Yasin Yiğit<sup>\*1</sup>, Murat Uysal<sup>2</sup>

<sup>1</sup>Mersin University, Faculty of Engineering, Geomatic Engineering, Mersin, Turkey

<sup>2</sup>Afyon Kocatepe University, Engineering Faculty, Department of Geomatics Engineering, Afyonkarahisar, Turkey

#### Keywords

Object-based  
Automatic Road Detection  
Classification  
UAV  
Road

#### ABSTRACT

Aerial photos and satellite images tell us about the land surface. It provides a variety of information such as particularly human-built objects such as buildings, roads and bridges and the location and characteristics of the vegetation. Except for aerial photographs and satellite imagery, the collection, evaluation, and updating of the required data with other data collection methods is a time-consuming process and more costly. Data from aerial photographs and satellite images have long been detected manually by conventional methods and by operators. The automatically of these detections increases the speed of the project process and contributes to the reduction of the expenses spent. The projects carried out within the scope of the extraction and classification of objects are mostly concentrated on buildings and roads. Because roads and buildings; Due to the characteristic features such as having sharp lines and easy determination of the geometric shape, the identification of the detail lines in the objects is easier than determining the details of other objects. In this study, aerial photographs of a certain area of Afyon/Turkey were obtained by using unmanned aerial vehicles (UAV). The raw data obtained were evaluated and the object-based classification approach was used to automatic detection and classify the roads of the university in the digital environment.

### 1. INTRODUCTION

The information available in high-resolution images in many areas such as urban planning, meteorology, forestry, agricultural geology, and landscape detection are needed for various purposes. In order to investigate the full value of this data, useful information must be extracted in a standard manner. Previously, the extraction of the required details was done manually by the operators. This situation had a negative effect on time and cost. Automatic detection of the required objects has become faster and easier thanks to improved detail extraction methods.

In recent years, important developments in digital photogrammetry and remote sensing technologies and satellite sensors/camera systems have led to the emergence of new and different

research topics and applications. With the development of digital camera technology since the 1950s, the production of orthophotos with high spatial resolution and positional accuracy has become possible. To obtain information from images such as Orthophoto, digital surface model (DSM) and digital terrain model (DTM) acquired with high-resolution satellite imagery and UAV, we need to use spatial and contextual knowledge of an object and its surroundings. These orthophotos are used successfully in the extraction of detail and thematic classification. Due to the high spatial resolution, the object-based approach has gained importance and became widespread in the thematic classification instead of the traditional pixel-based classification approach (Sabuncu et al., 2017).

In most of the studies, the pixel-based classification method has been used. In this method,

\* Corresponding Author

(ayasinyigit@mersin.edu.tr) ORCID ID 0000-0002-9407-8022  
(muysal@aku.edu.tr) ORCID ID 0000-0001-5202-4387

Cite this article

YİĞİT, A., UYSAL, M. (2020). AUTOMATIC ROAD DETECTION FROM ORTHOPHOTO IMAGES. Mersin Photogrammetry Journal, 2 (1), 10-17. Retrieved from <https://dergipark.org.tr/tr/pub/mephoj/issue/52791/636533>

the color values of the pixels and the neighboring relations of the pixels are evaluated. The main purpose of this method is to automatically combine each pixel in the image according to terrain characteristics. Pixel-based approaches only use spectral information. Therefore, Pixel-based approaches cannot meet the classification of high-resolution satellite images and orthophotos, and information extraction is based solely on gray level thresholding methods. This results in a large amount of data. To overcome this situation, an object-based approach is applied. Therefore, in today's image processing technologies, in addition to classical methods, object-based methods are frequently used.

The object-based method interprets an image not only with respect to a single-pixel but also with meaningful image objects and interrelations. Object-based information extraction depends not only on the spectrum character but also on the geometry and structure information (Wenxia et al., 2005). Although the object-based method appears to be an alternative to the pixel-based method, it is, in fact, complementary to the pixel-based method.

In the object-based approach, spectral values are based on fuzzy logic, which enables the completion of a broad spectrum of different object properties such as shape, texture, and density. The basic processing unit of object-based image analysis is image segments or objects. In the object-based approach, classification is done through image objects (Hofmann, 2001a). The classification step begins by converting neighboring pixels into meaningful regions that can be considered in the next step of the classification. Such segmentation and topology occurrences should be adjusted according to the resolution and scale of the objects. This method not only classifies individual pixels but also creates homogeneous image objects during the previous segmentation step. While this segmentation can be performed at different resolutions, it also allows distinguishing layers of object categories. In addition, the conventional pixel-based method performs the extraction of details based on the gray value of the pixel. For this reason, only spectral information is used effectively in the classification stage. The object-based image approach is preferred to eliminate these and other limitations (Kanber ve Yavuz, 2015).

The most important factor affecting the accuracy of the methods used in detail extraction studies is the resolution of the orthophoto. Image resolution has a significant and powerful effect in determining roads and other objects. Objects that can be identified in high-resolution orthophotos may not be clearly identified in low-resolution orthophotos. Especially in high-resolution images, the roads have a certain width and the roads are interrupted due to the effect of trees, buildings, and vehicles. On the other hand, low-resolution images are observed in a single line, so no breaks occur. For these and other reasons, object-based classification is better based on pixel-based classification for

object extraction from high-resolution images in settlements.

Object-based information extraction consists of two main steps: segmentation and classification. For a successful segmentation step, several test applications are performed in the image data of the workspace. After the segmentation step, classification is made by setting different parameters for the image data used and the desired detail extraction is performed.

In this study, image data obtained by UAV were evaluated photogrammetrical and automatic road extraction was performed by the object-based classification method.

## 2. OBJECT-BASED CLASSIFICATION

The object-based approach considers the structure, textures and spectral information. This classification step begins with the grouping of neighboring pixels into meaningful regions that can be considered in the next step of the classification. Such segmentation and topology formation should be adjusted according to the resolution and scale of the objects to be removed. With this method, not only the individual pixels are classified, but also homogeneous image objects are created during the previous segmentation step. This segmentation can be performed at different resolutions, while at the same time distinguishing layers of object categories. In addition, since pixel-based classification is based solely on a statistical analysis of pixels, the object-based classification method, which groups the pixels in the segmentation stage and uses many features such as color, frequency, and nearest neighborhood, gives more meaningful and positive results for the thematic class. At the same time, the object-based classification process can be continuously updated with ruleset or fuzzy logic algorithms. Definiens eCognition, which is the most widely used object-based image analysis software, offers a similar approach to the pixel-based approach with its nearest neighbor classification method and gives the same meaningful results in a more practical way (Kalkan et al., 2010).

## 3. WHY OBJECT-BASED CLASSIFICATION METHOD IS NEEDED?

The conventional pixel-based method performs the extraction of details based on the gray value of the pixel. For this reason, only the spectral information is used effectively in the classification stage. The object-based image approach is preferred to eliminate these and other limitations. In the object-based approach, spectral values are based on fuzzy logic, which makes it possible to complete the broad spectrum of different object properties such as shape, texture, and density. In contrast to conventional image processing methods, the basic processing unit of object-based image analysis is image segments or objects, not individual pixels.

Here, the classification is done via image objects. One reason for the object-based approach is that most image analysis applications are expected to have real-world objects in actual classification and actual shapes. This expectation cannot be achieved by conventional pixel-based approaches (Hofmann, 2001a, b, c).

In addition, the object-based classification method allows for fuzzy logic classification compared to the pixel-based classification method. In this case, each object can have more than one class membership. Class memberships are represented by a number ranging from 0 to 1. In this value scale, 1 represents the full membership of the pixel for that class, and 0 indicates no membership. Values between 0 and 1 indicate that members will be in proportion to their size (Boyacı, 2012). Another reason why the object-based method is preferred is that in most image analysis applications, the expected result is that objects are assigned to the real class and are in their actual shape. This expectation cannot be met by conventional pixel-based approaches (Hofmann, 2001a).

#### 4. MATERIALS AND METHODS

##### 4.1. Study Area

This study was conducted in a designated area in Afyon Province shown in Figure 1.

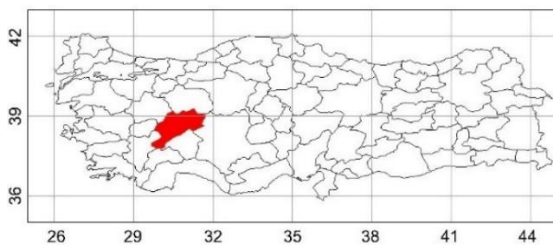


Figure 1. Study area

The work flow chart of the study is shown in Figure 2.

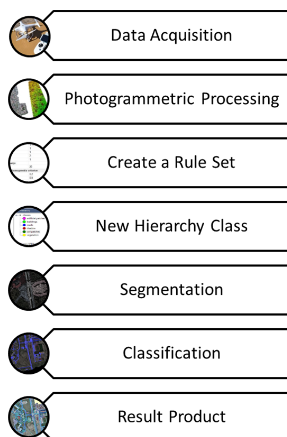


Figure 2. Work flow charts

##### 4.2. Collection of Data

One of the methods adopted to obtain the spatial data needed in recent years is the use of unmanned aerial vehicles (Yılmaz et al., 2018). With the development of technology, UAV technology is being used more efficiently especially in the field of mapping.

Unmanned aerial vehicles are designed for special purposes, capable of taking off and landing from any area, remote-controlled, semi-automatic or fully automatic flight capability. These vehicles can be airplanes, helicopters or zeppelin according to their flight capabilities (Eisenbeiss, 2009; Cömert et al., 2012).

In this study, the photographic data of the field were obtained with the help of Phantom 3 Pro UAV (figure 3).



Figure 3. UAV used in study (URL-1)

A total of 800 photographic images were obtained from different angles and overlays from a height of 120 meters. 6 ground control points were surveying for reference purposes.

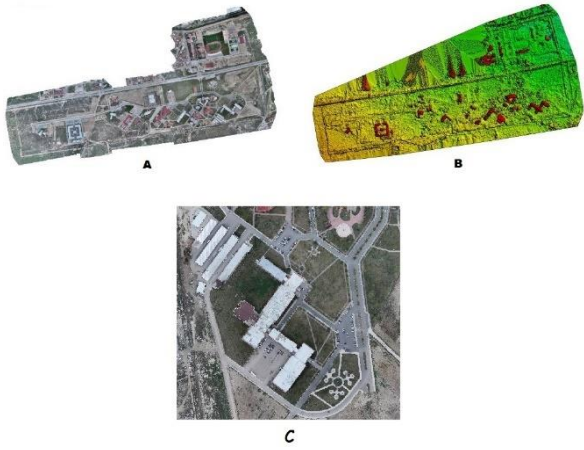
##### 4.3. Methods

In this study, the object-based method which is explained in detail in Chapter 2 was preferred.

#### 5. PROCESS of UAV DATA

Using the images collected with the help of UAV, the orthophoto of the study area was produced in Pix4D software. The Ground Sample Distance of the orthophotos produced has a resolution of 3.7 cm. The orthophoto and digital surface model (DSM) of the study area are shown in figure 4.





**Figure 4.** A) Orthophoto of the study area B) DSM of the study area C) The area designated for study

Afterward, detail extraction process steps were performed by using the object-based classification method with the help of Definiens eCognition software over the produced orthophoto.

## 6. TECHNICAL INFORMATION ABOUT SEGMENTATION

The most important and first step in object-based classification is segmentation. Segmentation is the process of grouping pixels with similar spectral properties and creating image objects. The purpose of segmentation is to divide the image into different subsections and create meaningful objects from the image (Baatz et al., 2000). It is also among the objectives of segmentation that in most cases it is possible to automatically extract the desired objects of interest in an image for a task. Segmentation works as two different methods from top to bottom and from bottom to top (Definiens, 2012).

The basis of top-down management is the process of splitting the whole into small parts. There are 3 different top-down segmentation methods. These; chessboard segmentation, quadtree-based segmentation, and contrast split segmentation algorithms. The second strategy of segmentation is bottom-up segmentation. In this approach, small pieces are obtained as large pieces taking certain criteria into consideration. The most important method used for bottom-up strategy is the multi-resolution segmentation method (Benz et al., 2004).

In the multi-resolution segmentation algorithm, the parameters are set by the user. These parameters are scale, color/shape, and softness/density. The parameters should be entered as close to the truth as possible. The most important of the 3 parameters entered is the scale parameter. The softness/density and Color/shape parameters complement each other to 1.

The Color and Shape criteria generate image objects consisting of relatively homogeneous pixels using the general Segmentation Function (SF) formulated in equation (1).

$$Sf = w_{color} h_{color} (1 - w_{color}) h_{shape} \quad (1)$$

where the user-defined weight for spectral color or shape is  $0 < w_{color} < 1$ .

Spectral (i.e., color) heterogeneity ( $h$ ) of an image object is computed as the sum of the standard deviations of spectral values of each layer ( $\sigma_k$ ) (i.e., band) multiplied by the weights for each layer ( $w_k$ ):

$$h = \sum_{k=1}^m w_k \cdot \sigma_k \quad (2)$$

The color criterion is computed as the weighted mean of all changes in standard deviation for each band  $k$  of the  $m$  bands of remote sensing dataset. The standard deviation is  $\sigma_k$  weighted by the object sizes  $n_{ob}$  (i.e. the number of pixels):

$$h_{color} = \sum_{k=1}^m w_k [n_{mg} \cdot \sigma_{kmg} - (n_{ab1} \cdot \sigma_{kab1} + n_{ab2} \cdot \sigma_{kab2})] \quad (3)$$

(where  $mg$  means merge).

Compactness:

$$cpt = \frac{l}{\sqrt{n}} \quad (4)$$

Smoothness:

$$smooth = \frac{l}{b} \quad (5)$$

(Karakış et al., 2006)

$n$  is number of pixels in the object,  $l$  is the perimeter,  $b$  is shortest possible border length of a box bounding the object

$$h_{cpt} = n_{mg} \cdot \frac{l_{mg}}{\sqrt{n_{mg}}} - \left( n_{ob1} \cdot \frac{l_{ab1}}{\sqrt{n_{ab1}}} + n_{ab2} \cdot \frac{l_{ab2}}{\sqrt{n_{ab2}}} \right) \quad (6)$$

$$h_{smooth} = n_{mg} \cdot \frac{l_{mg}}{b_{mg}} - \left( n_{ob1} \cdot \frac{l_{ab1}}{\sqrt{n_{ab1}}} + n_{ab2} \cdot \frac{l_{ab2}}{\sqrt{n_{ab2}}} \right) \quad (7)$$

$$h_{shape} = w_{cpt} \cdot h_{cpt} + (1 - w_{cpt}) \cdot h_{smooth} \quad (8)$$

## 7. TECHNICAL INFORMATION ABOUT CLASSIFICATION

The main purpose of the classification process is to analyze multiple georeferenced images or bands together and to form groups of groups with similar statistical characteristics in these images (Geçen et al., 2007).

The classification is divided into a numerical and a contextual part, that are applied one after another. The context analysis is used as additional information to support the numerical classification. Classification algorithms analyze image objects

according to defined criteria and assign them to a class that best meets them.

### 8. DETAIL OBJECT DETECTION FROM ORTHOPHOTO IMAGES

After orthophoto was produced from UAV data, the detail extraction process was started in Definiens eCognition software. In the Definiens eCognition software, segmentation is performed first. The most important and first step in object-based classification is segmentation. Segmentation is the process of grouping pixels with similar spectral properties and creating image objects. Segmentation is applied to create meaningful objects from the image data used. The multiresolution segmentation approach is often used for the segmentation algorithm. Before starting the segmentation process; scale, softness/density, and color/shape.

**Scale Parameter:** This parameter indirectly affects the average object size. In fact, this parameter specifies the maximum value that permits the heterogeneity of objects. The larger the scale parameter, the larger the objects.

**Smoothness/Compactness:** When the shape criterion is greater than 0, the user can decide whether the objects should be more complete (dense) or softer.

**Color/Shape:** With these parameters, the effect of homogeneity of color and shape conflict on object production can be corrected. The higher the shape criterion, the less the effect of spectral homogeneity on object production (Marangoz et al., 2005).

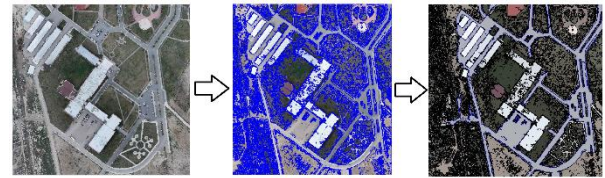
These 3 parameters entered in the segmentation stage were tried under different criteria and 60 were selected for scale parameter, 0.8 for softness/density parameter and 0.2 for color/shape parameters. The defined segmentation parameters are shown in table 1.

Each classification process depends on an exact scale. For this reason, it is very important that the average resolution of image objects corresponds to the desired scale. The image information can be presented at different scales depending on the average size of the image objects (Marangoz, 2009).

**Table 1.** Segmentation parameters

Parameters	Value
Scale	60
Shape	0.2
Compactness	0.8

The segmentation result of the selected parameters is shown in figure 5.



**Figure 5.** Segmentation result product

After the segmentation process, the classification process was started in Definiens eCognition software. The software has two basic classifications. These are fuzzy membership and nearest neighborhood functions. In the nearest neighbor classification function, the user defines classes using sample objects for each class. In the fuzzy membership classification function, the ranges of the properties of objects belonging to a certain class or where they do not belong are defined.

In the classification stage, the values of the road class were determined first. Then the roads were determined by identifying and extracting the properties of the objects that do not belong to this class. After the roads were determined, it was seen that some segments that should be in the road class were not assigned to the road class. A new range has been assigned for objects that must be in the road class and the roads have been assigned to the class to which they belong. After determining the road class, merge and border reshape operations were applied. Some indexes used in the classification process are shown in Table 2.

**Table 2.** Some indexes used in classification

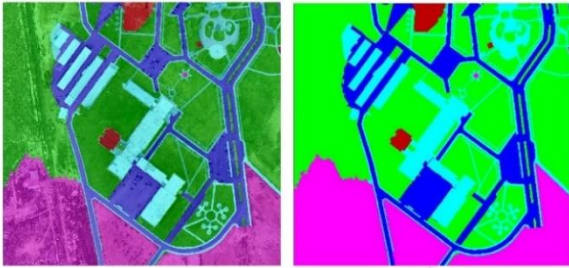
Name	Index Name	Formula
GRVI	Green-red vegetation index	$\frac{(Green-Red)}{(Green+Red)}$
RRI	Red ratio index	$\frac{(Red)}{(Blue+Green+Red)}$
GRI	Green ratio index	$\frac{(Green)}{(Blue+Green+Red)}$
Brgt	Brightness	$\frac{Blue+Green+Red}{3}$

The class assignments created are shown in table 3.

**Table 3.** Class assignments

Class	Class Color
Road	Blue
Red Roofed Building-Camelia	Red
White Roofed Building-Sidewalk	Turquoise
Vegetable	Green
Other objects	Pink

After the necessary parameters have been defined, the objects whose detail is extracted are assigned to the class they belong to. The assigned classes are shown in Figure 6.



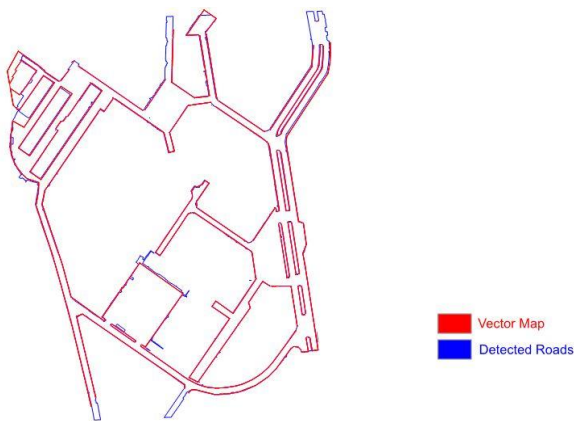
**Figure 6.** Roads detected on orthophoto

The detected road classes are shown in Figure 7.



**Figure 7.** Roads detected on orthophoto

The data extracted from the eCognition software and the vector data generated by the geodetic methods of the study area are compared in Figure 8.



**Figure 8.** Comparison of vector data with detection of road detail

The road areas calculated from the vector map of the study area are 3.30 hectares. Road areas determined by the object-based classification method are 2.92 hectares. According to the field data, there is an 88% consistency between the vector map road areas and the detected road areas.

In addition, the road line shown in red in Figure 9 was measured 71.67 meters on the vector map. The same road line was measured 70.80 meters at the end of the detail determination study.



**Figure 9.** Length-based comparison of the road line

As a result of the length comparison of the road line, there is a consistency of 98%.

## 9. CONCLUSION

From our study, classification and detail extraction are largely successful with the object-based approach. Furthermore, it can be said that the object-based approach is efficient and feasible for the following reasons.

- First, the use of multiple properties of the object, including spectrum, shape, texture, shadow, context, spatial location.
- Second, the object-based information extraction approach ensures the accuracy of classification by making full use of high-resolution image information.
- Third, it is possible to make multi-scale, image object resolution adaptable to specific requirements, data and tasks by manually setting different parameters.

As a result of segmentation by using the object-based approach algorithm which replaces the pixel-based approach used for many years, the classification of the objects is largely accomplished. With the object-based classification software Definiens eCognition, the classification process can be performed faster and more up-to-date. In addition, mistakes or wrong class assignments can be corrected quickly, and the classification result can be converted to vector format and integrated with geographical information systems.

As a result, it has been observed that the classification of the objects with the object-based approach has been done successfully, but there are deficiencies like every algorithm. For example, there were difficulties in distinguishing roads and pavements with close attributes. In future studies, these deficiencies and difficulties can be solved by using data such as digital elevation model (DEM), DSM and DTM in addition to orthophotos. Or, when collecting image data from the field, using image data

with close infrared (NIR) bands in addition to RGB (Red-Green-Blue) bands may contribute to the elimination of the problems encountered.

## REFERENCES

- Baatz M. and Schape A. (2000). Multi resolution segmentation: an optimization approach for high quality multi scale image segmentation, Proceedings of Twelfth Angewandte Geographische Informationsverarbeitung, Wichmann-Verlag, Heidelberg, ss.12–23.
- Benz U.C., Hofmann P., Willhauck G., Lingenfelder I. and Heynen M. (2004). Multi-resolution object-oriented fuzzy analysis of remote sensing data for GIS- ready information, ISPRS Journal of Photogrammetry and Remote Sensing, 58 (3-4), 239-258.
- Boyacı, D. (2012). Cbs-Uzaktan Algılama entegrasyonu ve örnek uygulama: uydu görüntülerinden detay ve otomatik öznitelik tespiti, Doktora Tezi, Selçuk
- Cömert R., Avdan U. and Şenkal E. (2012). İnsansız Hava Araçlarının Kullanım Alanları Ve Gelecekteki Beklentiler, IV. Uzaktan Algılama ve Coğrafi Bilgi Sistemleri Sempozyumu (UZAL-CBS 2012), 16-19.
- Definiens. (2012). Definiens Developer XD 2.0.4. Reference Book, Definiens AG, München, Germany, <https://www.imperial.ac.uk/media/imperialcollege/medicine/facilities/film/Definiens-Developer-Reference-Book-XD-2.0.4.pdf> , (21.10.2019).
- Eisenbeiss, H. (2009). UAV Photogrammetry, *ETH Zurich for the degree of Doctor of Science*, ISSN 0252-9335 . ISBN: 978-3-906467-86-3.
- Geçen R. and Sarp G. (2007). Yüksek ve düşük çözünürlüklü uydu görüntülerinden yolların tayini, *TMMOB Harita ve Kadastro Mühendisleri Odası Ulusal Coğrafi Bilgi Sistemleri Kongresi*, 30 Ekim –02 Kasım 2007, KTÜ, Trabzon
- Hofmann, P. (2001a). Detecting Urban Features from IKONOS Data Using an Object-Oriented Approach, *First Annual Conference of the Remote Sensing & Photogrammetry Society*, 12-14 September 2001, 28-33.
- Hofmann, P. (2001b). Detecting Buildings and Roads from IKONOS Data Using Additional Elevation Information. GIS GeoInformation-System, 2001:6.
- Hofmann, P. (2001c). Detecting Informal Settlements from IKONOS Image Data Using Methods of Object-Oriented Image Analysis -An Example from Cape Town”, *Remote Sensing of Urban Areas*. edited by Jürgens, Carsten (Regensburg)
- Kalkan, K. and Maktav, D. (2010). Nesne Tabanlı ve Piksel Tabanlı Sınıflandırma Yöntemlerinin Karşılaştırılması (IKONOS Örneği), *III. Uzaktan Algılama ve Coğrafi Bilgi Sistemleri Sempozyumu*, Ocak 2010
- Kanber, B. and Yavuz, M. (2015). Object-Oriented Programming in Meshfree Analysis of Elastostatic Problems. *International Journal of Engineering and Applied Sciences*, 7 (2), 1-18. DOI: 10.24107/ijeas.251244
- Karakış, S., Marangoz A. Murat and Gürcan B. (2006). Analysis of Segmentation Parameters in Ecognition Softwareusing High Resolution Quickbird Ms Imagery, *Isprs Ankara Workshop, 2006, Wg I/5 & I/6 Workshop On Topographic Mapping From Space (With Special Emphasis On Small Satellites)*
- Marangoz, A.M., Şekertekin, A., Görmüş, K.S. and Oruç, M. (2016). Coastal Evaluation of 125-Year Zonguldak City Region Using Object-Based Image Analysis, *16th International Multidisciplinary Scientific Geoconference & Expo,-Sgem 2016, 28 June – 06 July 2016, Albena, Varna, Bulgaria*.
- Marangz, A.M., Karakış S., Oruç M. and Büyüksalih G. (2005). Nesne-tabanlı görüntü analizi ve ikonos pan-sharpened görüntüsünü kullanarak yol ve binaların çıkarımı, *10. Türkiye Harita Bilimsel ve Teknik Kurultayı*, 28 Mart-1 Nisan 2005, Ankara
- Marangoz, A.M. (2009). Uydu Görüntülerinden Kentsel Ayrıntıların Nesne-Tabanlı Sınıflandırma Yöntemiyle Belirlenmesi ve Cbs Ortamında Bütünleştirilmesi. *Yayınlanmış Doktora Tezi*, Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Türkiye.
- Sabuncu, A. and Sunar, F. (2017). Ortofotolar ile Nesne Tabanlı Görüntü Sınıflandırma Uygulaması: Van-Erciş Depremi Örneği, *Artvin Çoruh Üniversitesi Doğal Afetler Uygulama ve Araştırma Merkezi Doğal Afetler ve Çevre Dergisi*, Cilt:3, Sayı:1, Ocak 2017 (1-8)
- Wenxia WEI, Xiuwan Chen and Aina Ma. (2005). Object-Oriented Information Extraction and Application in High-Resolution Remote Sensing Image, *IEEE International Geoscience & Remote Sensing*, Vol. 6, pp. 3803-3806, 2005.
- Yılmaz, H.M., Mutluoğlu, Ö., Ulvi, A., Yaman, A. and Bilgilioğlu, S.S. (2018). İnsansız Hava Aracı İle Ortofoto Üretimi Ve Aksaray Üniversitesi

Kampüsü Örneđi. *Geomatik Dergisi*, 2018;  
3(2);103-110.

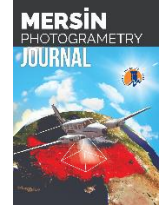
URL-1 <https://www.dji.com/phantom-4-pro>  
Accessed: 20.10.2019



## Mersin Photogrammetry Journal

<https://dergipark.org.tr/tr/pub/mephoj>

e- ISSN 2687-654X



### Light rail line design for East Black Sea region: A case study of Trabzon

Hatice Catal Reis \*1, Abdulkadir Birinci<sup>1</sup>

<sup>1</sup>Gumushane University, Faculty of Engineering and Natural Sciences, Department of Geomatics Engineering, Gumushane, Turkey

#### Keywords

Light Rail System  
Orthophoto  
Landsat  
GIS  
Trabzon

#### ABSTRACT

Growing cities need to improve transportation in response to the accessibility needs of ever-expanding urban and metropolitan populations. Metropolitan Municipalities have to find low-cost, nature friendly, bus/train/subway transfer, and socially responsible transportation solutions that can meet the accessibility needs of urban residents and assist future economic development in urban areas. In this study, the light rail network was designed for the province of Trabzon by using orthophoto and Landsat satellite images. While this light rail network is being constructed, many criteria such as regional population density, slope, minimum service interval, integration with other transportation networks, geological structure, and proximity to public institutions and organizations have been used together. These criteria are shown with a GIS-based design model. Analysis maps were created by using the conditions/criteria and synthesis maps used in the design model. The 102 km route features 205 stops, extending from Of along to Besikduzu. A combined bus and light rail network will significantly improve public transport access to major public institutions and organizations, sporting and entertainment facilities, universities, schools, health precincts, bazaars, shopping malls. It is foreseen that the light rail system will provide the most suitable, modern, fast, comfortable and safe transportation in the long term considering the number of passengers and many other criteria. This light rail system designed for the province of Trabzon is thought to be a pioneering work for the Black Sea region through the interpretation of the resulting map and route networks.

#### 1. INTRODUCTION

Traffic is one of the most important problems in developing cities. In particular, if the urbanization and geographical barriers constitute the basis of this problem, different approaches to transportation should be provided to solve the problem. In this case, municipalities need to design new transport networks for public transport. Light rail system is only one of many modes of rapid transit, some of which, including high-capacity bus transit and train/subway, can supply like levels of service to that of rail in certain contexts (Pulido et al., 2018) The Light rail system is an important method of transport

all through the world. Every day, it transports a great amount of passengers from one point to another. Light rail networks can be the solution to permanent conversion and traffic. It is basic that passengers use all the accessible and shortest methods of transport to take with a specific end. This new system brings a number of complex cases. Light rail networks have spatial, geographical, technical, economic, political and social aspects. Therefore, it is important to be able to design systems in which multiple conditions are evaluated together.

There are several studies on rail systems in the literature. These studies were mostly conducted on cost, performance, environmental impact, property

\* Corresponding Author

(hcatal@gumushane.edu.tr) ORCID ID 0000-0003-2696-2446  
(abdulkadirbirinci1461@gmail.com) ORCID ID 0000-0002-9503-7660

Cite this article

ÇATAL REİS, H., BİRİNCİ, A. (2020). LIGHT RAIL LINE DESIGN FOR EAST BLACK SEA REGION: A CASE STUDY OF TRABZON. Mersin Photogrammetry Journal, 2 (1), 18-23

DOI: XXXXXXXXXXXX / Research Article

Retrieved from <https://dergipark.org.tr/tr/pub/mephoj/issue/52791/650320>

Received: 24/11/2019; Accepted: 22/12/2019

impact (Esakov and Vandegrift, 2018) and feasibility (Kołos and Taczanowski, 2016). Love et al. has conducted a research on cost performance evaluation of light rail projects (Love et al., 2017). In another presented study, the demographic and economic characteristics of the city were analyzed before and after the Dallas (Texas) light rail system “DART” (Heilmann, 2018). A green transportation system along the rail line was aimed by creating public transport-oriented settlement system “TOD” and calculating the location, number of stops and size of the region (Peng et al., 2017). In another study, the effect of light rail system on price increase in nearby houses was investigated in Sydney (Mulley et al., 2018). The “URTSOPE” approach to be implemented in China has been prepared by evaluating different criteria. In the study, the operational performance of the rail transportation system is discussed by associating the perspectives of the operator, passenger and the state (Huang et al., 2018). It is possible to reach some studies in the literature about transportation network. These are tram route planning (Alkubaisi, 2014), route selection for light rail system (Banai, 2006; Banai, 2010), metro line design (Ahmed and Asmael, 2016; Dana and Tecim 2007), location selection for metro line (Farkas, 2009) station location selection for rail system network (Blainey and Preston, 2013), Monorail routes for Ankara (Hamurcu and Eren, 2018).

Due to the high demand for travel and the lack of sufficient public transport infrastructure to meet this demand, there are great problems in transportation in the developing Trabzon, which has become a metropolitan city recently. The mountainous structure of the city and the lack of sufficient land bring some problems. Narrow roads that do not meet the needs of the population and the lack of an alternative to these roads bring many problems such as traffic congestion, psychological effects on people, time spent in traffic and expensive transportation.

With all this in mind, it is important to design a fast and comfortable transportation network and project that will reach all the neighbourhoods of the city in an optimum level, which will eliminate traffic congestion. (Arikan et al., 2018) Rail systems are seen as one of the solution methods for reducing the problems in transportation and clean environment.

In this study, light rail system design has been prepared in the most accurate way considering the physical and human geographical conditions of Trabzon. The data used by Geographic Information Technology (GIS) was harmonized in a spatial environment to achieve a consistent scale, extent and uniform co-ordinate system so that the data could be seamlessly integrated prior to analysis. Landsat and orthophoto images were used as a base and rail system route network was created with a Statistical and GIS based model (Kirlangicoglu, 2016), population map, slope map, aspect map, stream map, road map and the use of this

information by creating a unique light railway line was designed. The light rail system is crucial for the growing city. This study was therefore undertaken to determine optimal light rail line using orthophoto-Landsat and GIS modelling for the light rail in Trabzon.

The study consists of introduction, material and method, and results sections.

## 2. MATERIAL AND METHODS

### 2.1. Study Area

Trabzon is located between  $38^{\circ} 30' - 40^{\circ} 30'$  eastern meridians and  $40^{\circ} 30' - 41^{\circ} 30'$  northern parallels in the Eastern Black Sea Region (URL1) (Fig. 1). Behind a narrow coastline, it has a mountainous terrain extending vertically to the sea. The city has a surface area of  $4,685 \text{ km}^2$  and a population of approximately 813,044 people (Turkish Statistical Institute-2019) (URL2).

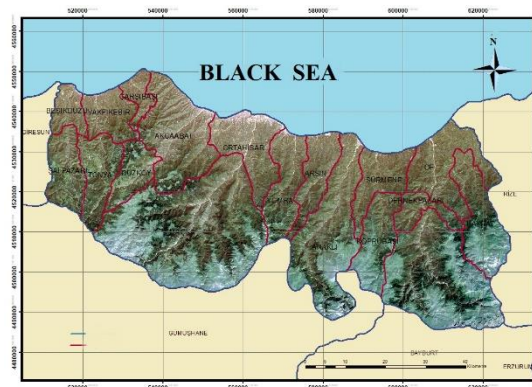
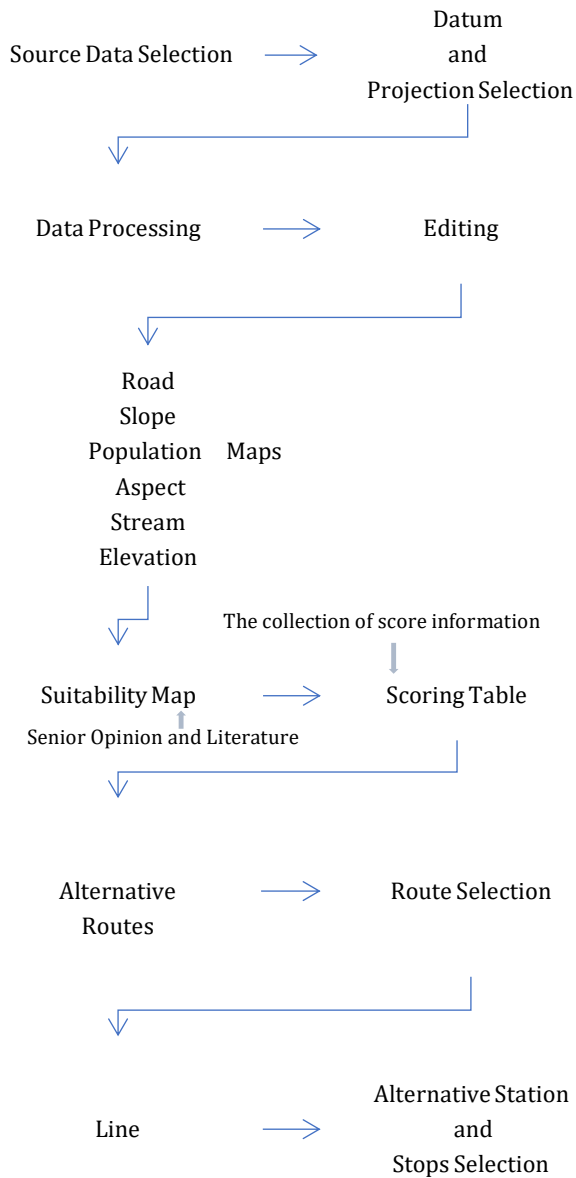


Figure 1. Study Area

### 2.2. Data Set and Image Processing

Landsat-8 (2018) and orthophoto (2015) were used in the study. It is aimed to design a light rail network by using Multi-Criteria Decision Making methods. Using the GIS and CAD software, all the factors affecting the system were evaluated together and the route was revealed. In determining the optimal light rail line using GIS various constraints and criteria were used to develop a model (Fig.2). We used free maps which were produced by General Directorate of Mapping (GDM). The 1/5000 scale photogrammetric map generated reference data for the Digital Elevation Model. In this study, public institutions and organizations, schools, hospitals, stadiums etc. were determined using the help of google maps. This information was used for line identification, stop selection, bus transfer. The population of Trabzon was downloaded from Turkish Statistical Institute. In the study, the criteria with the highest importance levels are land structure, population density, slope, elevation, and construction cost.



Road, slope, population, aspect, stream, elevation maps (Fig. 3) for the study were formed using the scoring system.

In this study, it is aimed to be a noiseless, environmentalist, climate and geological structure suitability, safe, and economical for a light rail network. The criteria such as regional population density, slope, minimum service interval, integration with other transportation networks, geological structure, proximity to public institutions and organizations were used in the rail system planning.

Figure 2. Workflow

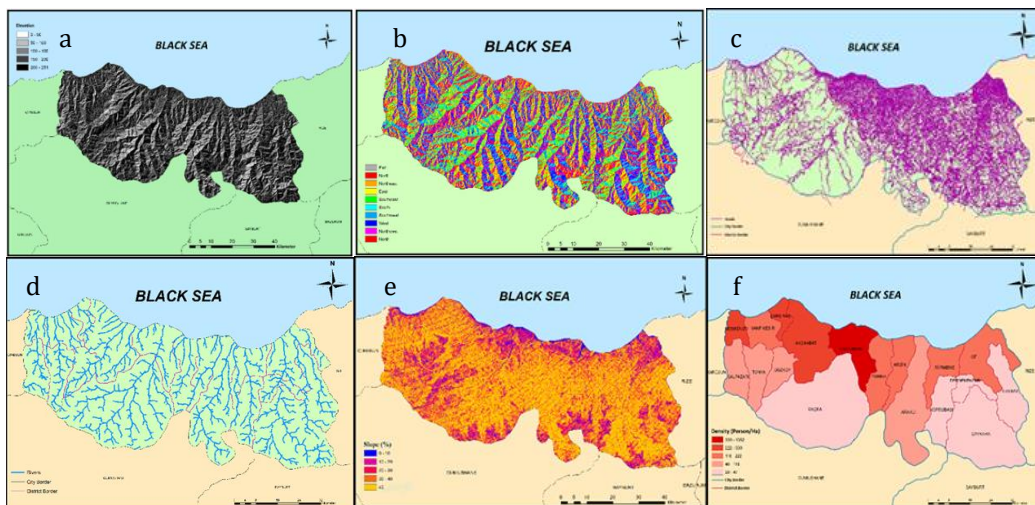
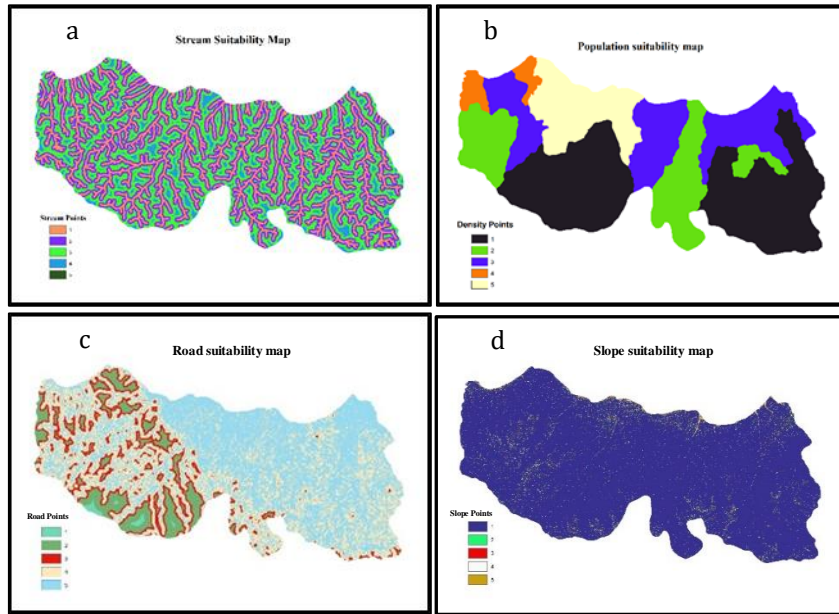


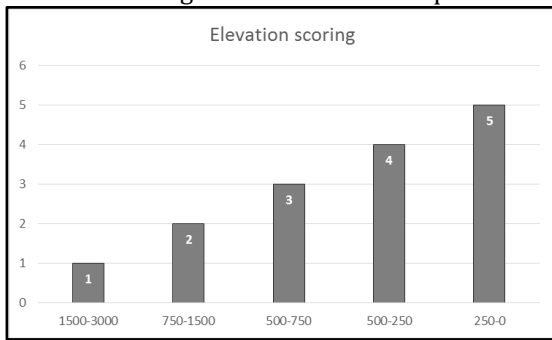
Figure 3. a) The elevation map, b) The aspect map, c) The road map, d) The stream map, e) The slope map, f) The population map (Catal Reis et al., 2019)





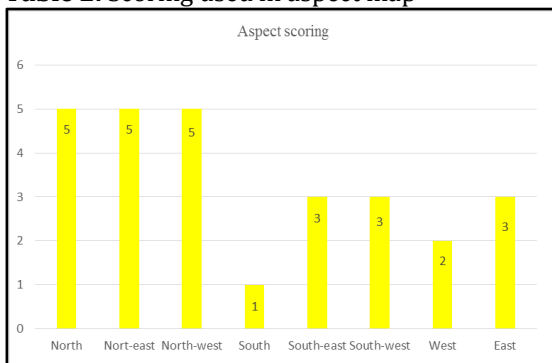
**Figure 4.** a) Stream suitability map, b) Population suitability map, c) Road suitability map, d) Slope suitability map (Catal Reis et al., 2019)

**Table 1.** Scoring used in elevation map

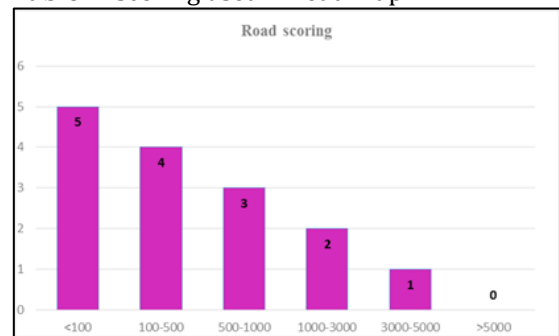


In this study; elevation, slope, road, stream, population and aspect maps were created. Then, the score tables were calculated (Fig.4, Table 1, Table 2, Table 3, Table 4, Table 5, Table 6). In this study, 1 point represents the worst and 5 points the best. Places with an elevation between 0 and 250 meters have received 5 points (Fig.3a). It has been observed that the north, northeast and northwest directions have the most favorable aspects (Fig. 3b). Highway, urban roads, and rural roads were considered (Fig. 3c). Streams were detected (Fig. 3d). The places with a population of between 330 and 1352 people/km were calculated as 5 points (Fig. 3f).

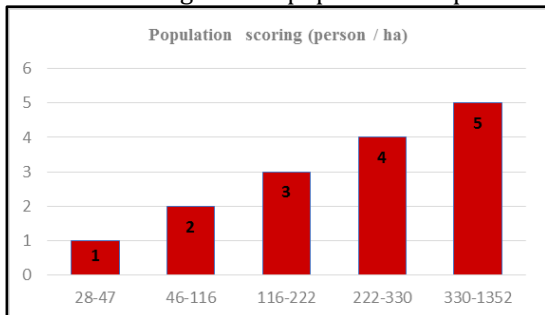
**Table 2.** Scoring used in aspect map



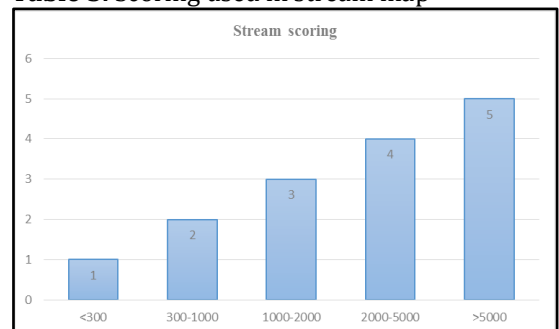
**Table 4.** Scoring used in road map



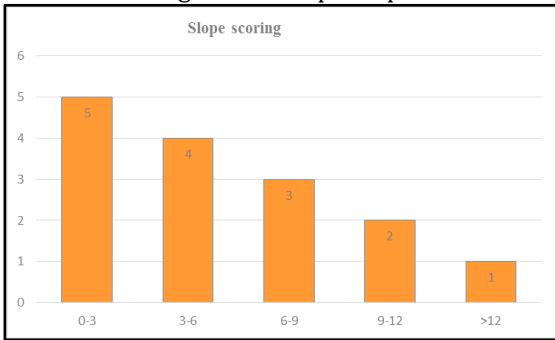
**Table 3.** Scoring used in population map



**Table 5.** Scoring used in stream map



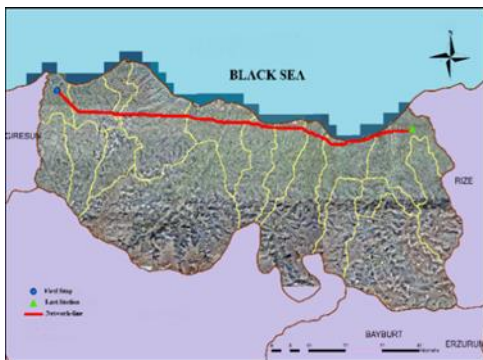
**Table 6.** Scoring used in slope map



The slope between 0% and 3% indicates the most suitable places for the line and these places are defined as 5 points (Fig.3e, Table 6).

### 3. RESULTS

The rapid population growth in Trabzon, the rapid urbanization rate and recent interest in highland tourism have increased transportation problems. It is important to design the light rail system urgently as a result of the inability to prevent mountainous terrain and warped urbanization. In this study, a light rail route was designed using orthophoto, which reduces traffic density, is environmentally friendly and suitable for the geological structure of the region (Fig.5 and Fig.6). Additional light rail services will provide extra capacity for major events. Suitability and scoring maps were produced from Landsat images. The Trabzon light rail network (or Trabzon light rail) is a light rail system planning of Trabzon. The network currently has a passenger route, Of-Besikduzu Line. The Trabzon light rail line 102 km and 205 stops were planned.



**Figure 5.** Proposed light rail line (Catal Reis et al., 2019)



**Figure 6.** Planned light rail stops (Akcaabat-Ortahisar-Yomra/77 stops)

Light rail lines are the most efficient, cost-effective and environmentally friendly means of transport for humans. The research considered a number of criteria that included roads, stream, land cover, geology, elevation, population, aspect, and slope. Used remotely sensed data, orthophoto, and GIS for light rail routing in a small section of the proposed Trabzon network. It has also been demonstrated how an innovative approach, assisted by a GIS was used to analyse the multiple route options to determine an intended line network. If Trabzon light rail system is designed, Of-Besikduzu Line will be Trabzon first passenger route.

Land structure, slope and population are the most important factors affecting project feasibility. Trabzon has got mountainous terrain parallel to the coast, therefore, the province's light rail line has to be close to the coast. In this study, a line of light rail route was designed to cover the whole province but the light rail system should primarily cover Yomra, Ortahisar and Akcaabat districts (77 stops). The light rail network can help to reduce both traffic congestion and vehicular emissions. As suitably planned and properly applied as part of a larger public transport network, light rail systems can help rapid urban mobility and critical access to city centres from surrounding districts. Light rail projects are not only as infrastructure projects, but also as important opportunities for urban improvement.

This study highlights the dynamics of the light rail line and demonstrates the interrelationship among various factors. The effects of geological and public demand can be considered at an important scale and classes of main factors can be incorporated to refine the model and the expected results.

### ACKNOWLEDMENT

Some part of this study has been presented at the X. TUFUAB 2019 Symposium.

### REFERENCES

- Ahmed, N.G., and Asmael, N.M. (2015). A GIS-assisted optimal BAGHDAD metro route selection based on multi criteria decision making. *J. Eng. Sustain. Dev.* 19, 44–58.
- Alkubaisi, M.I.T. (2014). Predefined evaluating criteria to select the best tramway route. *Journal of Traffic and Logistics Engineering*, 2(3).
- Arikan, Y., Akkas, O.P., & Cam, E. (2018). Realization of Kirikkale light rail system study. *International Journal of Engineering Research and Development*, 10 (3), 6-11.
- Banai, R. (2006). Public transportation decision-making: A case analysis of the Memphis light rail

- corridor and route selection with analytic hierarchy process. *J. Public Transp.* 9, 1–24.
- Banai, R. (2010). Evaluation of land use-transportation systems with the Analytic Network Process. *J. Transp. Land Use*, 3, 85–112.
- Blainey, S.P., and Preston, J.M. (2013). A GIS-based appraisal framework for new local railway stations and services. *Transp. Policy*, 25, 41–51.
- Camins-Esakov, J., and Vandegrift, D. (2018). Impact of a light rail extension on residential property values. *Research in Transportation Economics*, 67, 11-18.
- Catal Reis, H., Yazici, H., & Birinci, A. (2019). Design of light rail system network using orthophoto and remote sensing images: A Case study of Trabzon. X. TUFUAB Symposium, Aksaray, Turkey, 25-27 Apr 2019, 575-581.
- Dane, G.Z., and Tecim, V. (2007). GIS based route determination for light rail systems: A case study in Izmir, Turkey. In Local governance and sustainable development. In Proceedings of the Joint Congress of the European Regional Science Association (47th) and ASRDLF (44th), Paris, France, 29 August–2 September 2007, 1–14.
- Farkas, A. (2009). Route/site selection of urban transportation facilities: An integrated GIS/MCDM approach. In Proceedings of the 7th International Conference on Management, Enterprise and Benchmarking, Budapest, Hungary, 5–6 June 2009, 5–6.
- Heilmann, K. (2018). Transit access and neighbourhood segregation. Evidence from the Dallas light rail system. *Regional Science and Urban Economics*, 73, 237–250.
- Huanga, W., Shuaia, B., Suna, Y., Wang, Y., & Antwi, E. (2018). Using entropy-TOPSIS method to evaluate urban rail transit system operation performance: The China case. *Transportation Research Part A*, 111, 292–303.
- Kirlangicoglu, C. (2016). Urban Criteria Decision Making Methods with urban rail system corridor planning. *Istanbul University Faculty of Letters Journal of Geography*, 33, 53-71.
- Kołos, A., and Taczanowski, J. (2016). The feasibility of introducing light rail systems in medium-sized towns in Central Europe. *Journal of Transport Geography*, 54, 400–413.
- Love, P.E.D., Ahiaga-Dagbui, D., Welde, M., & Odeck, J. (2017). Light rail transit cost performance: Opportunities for future-proofing. *Transportation Research Part A*, 100, 27–39.
- Mulley, C., (Patrick) Tsai, C., & Ma, L. (2018). Does residential property price benefit from light rail in Sydney?. *Research in Transportation Economics*, 67, 3-10.
- Peng, Y., Li, Z., & Choi, K. (2017). Transit-oriented development in an urban rail transportation corridor. *Transportation Research Part B*, 103, 269–290.
- Pulido, D., Darido, G., Munoz-Raskin, R., & Moody, J. (2018). The urban rail development handbook. The World Bank Group, ISBN (electronic): 978-1-4648-1273-6, Washington, USA.
- URL-1 <http://www.trabzon.gov.tr/cography-features>, Access Date: 15.11.2019.
- URL-2 <https://en.wikipedia.org/wiki/Trabzon>, Access Date: 15.11.2019.



## Mersin Photogrammetry Journal

<https://dergipark.org.tr/tr/pub/mephoj>

e-ISSN 2687-654X



### Investigation of phenological stages of wheat plant using vegetation index

Yunus Kaya\*<sup>1</sup>, Nizar Polat<sup>1</sup>

<sup>1</sup>Harran University, Faculty of Engineering, Geomatics Engineering, Şanlıurfa, Turkey

#### Keywords

Agriculture  
Wheat  
Remote sensing  
Satellite Data  
Vegetation Index

#### ABSTRACT

Agriculture has a significant place in our country's economy because of its ecology and climatic conditions suitable for agriculture and having rich lands. Among the agricultural products in Turkey, the most produced crop is wheat. Therefore, wheat has a significant contribution to the national economy and food resource. Today, due to the rapid growth of the population in the global and regional scale and the insufficiency of agricultural areas, it has become very important to obtain maximum efficiency in the existing agricultural areas. For this reason, it is necessary to monitor and record the phenological stages of agricultural plants. At this point, multi-band satellite images provide serious convenience during the collection and analysis of the necessary data. In this study, the phenological stages of the cultivated wheat plants were investigated in the General Directorate of Agricultural Enterprises located in the Ceylanpınar district of Şanlıurfa province. In this context, using the data of Landsat-8 and Sentinel-2A multi-band satellite data for 2017 and 2018, the vegetation index for phenological stages were examined.

#### 1. INTRODUCTION

The world's population is increasing rapidly, especially through developing countries. Improvement of the health conditions and the development of the level of consciousness of people play an important role in this increase.

The increase in the population and the decrease in natural resources have made the measurement and monitoring of the environment important (Yılmaz et al., 2018). At this point, agricultural areas have extensive importance. Because while the world population is constantly increasing, our agricultural areas remain the same and even our agricultural areas are decreasing due to some irregular urbanization. In this case, the existing agricultural areas should be used at an optimum level. Wheat is the most important agricultural product in Turkey. Wheat plant is a one-year plant and has different species that can grow under any climate conditions. Therefore, wheat is produced in many parts of the world. According to the Turkey Statistical Institute

(TSI) data; between 2001 and 2017, wheat accounted for 62 percent of the crops planted. Also, between 2001 and 2017, 39 percent of the amount of the product obtained is wheat (URL-1). According to the statistics of TSI data, the place and importance of the wheat plant in Turkey agriculture is seen clearly. Various studies have been carried out for many years to obtain maximum yield from the wheat plant.

In agricultural production, it is very important to estimate the pre-harvest yields of the product, especially in the direction of domestic and foreign market conditions. In field and yield determination studies performed with classical measurement techniques, reliable results are often not obtained, and an extremely high cost and a long time is spent. New techniques and technologies developed in recent years have made it possible to perform these processes in a cheaper, faster and more reliable way. Among these new technologies, remote sensing technique (Karakus et al., 2017) is the most important one (Sönmez and Sarı, 2005).

\* Corresponding Author

(yunuskaya@harran.edu.tr) ORCID ID 0000-0003-2319-4998  
(nizarpolat@harran.edu.tr) ORCID ID 0000-0002-6061-7796

KAYA, Y., POLAT, N. (2020). INVESTIGATION OF PHENOLOGICAL STAGES OF WHEAT PLANT USING VEGETATION INDEX. Mersin Photogrammetry Journal , 2 (1) , 24-28  
Retrieved from <https://dergipark.org.tr/tr/pub/mephoj/issue/52791/651700>

Cite this article

By analyzing the satellite data, comments can be made about the plant in the field. As is known, plants absorb most of the energy in the blue and red wavelengths and reflect most of the energy in the green and near-infrared (NIR) band (Esetlili et al., 2015).

In this study, phenological stages of the wheat plant were investigated with the help of Normalized Difference Vegetation Index (NDVI) values. The development stages of the wheat plant consist of 4 main periods (germination/seedling stage, tillering & stem extension, heading & flowering (pollination) and maturity). The wheat plant is generally planted in November. The stages of wheat vary according to climate change and precipitation, but on average they are as in the table below (Table 1).

**Table 1.** Phenological stages of wheat plant

STAGE	
Germination/Seedling stage	February
Tillering & Stem extension	March
Heading&Flowering (pollination)	April
Maturity	May
Harvest start	End of May

Chandel et al. (2019) used the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI) to determine the relationship between crop-biomass and nitrogen levels in the growth stages of wheat-based on the coefficient of variability. In the study, the highest NDVI value was observed in the heading stage. In addition, 96% agreement was observed between NDVI and product-biomass at the maturation stage. Both NDVI and NDWI regression models correlate positively with grain yield and can be used to estimate the yield of wheat crop.

## 2. METHOD

### 2.1. Satellite Data

In this study, 20 satellite images with different spatial resolutions were used to examine the phenological stages of the wheat plant. LANDSAT 8 (URL-1) and SENTINEL-2A (URL-2) data were used in the study.

### 2.2. Vegetation Index

There are numerous vegetation indices in the literature to determine vegetation using satellite imagery. NDVI (Normalized difference vegetation index), SAVI (Soil adjusted vegetation index), OSAVI (Optimized soil-adjusted vegetation index), EVI (Enhanced vegetation index) are some of them. NDVI is the most commonly used vegetation index (Comert et al., 2019; Orhan et al., 2019). Plants absorb most of the energy in the blue and red

wavelengths while reflecting most of the energy in the green and near-infrared (NIR) band so that the plant can be easily distinguished from other land covers. This can be formulated with NDVI (Çatal Reis and Bayram, 2015). The NDVI value is calculated by the equation (1) and takes a value between -1 and +1.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (1)$$

If the NDVI value approaches -1, the vegetation density decreases and if it approaches +1, the vegetation density increases. NDVI is high when green plants completely cover the pixel and low when no green plants are present. Being normalized also eliminates different sun angle effects (Kayahan, 2013).

## 3. APPLICATION

The study area is 'The General Directorate of Agricultural Enterprises' located in the Ceylanpınar district of Şanlıurfa (Figure 1).



**Figure 1.** Study area

In this study, wheat plant analysis for 2016-2017 and 2017-2018 seasons was performed. LANDSAT-8 and SENTINEL-2 satellite images downloaded from the internet were used by selecting images in which the study area was clear and cloudless. 8 LANDSAT-8 satellite images and 12 SENTINEL 2 satellite images were used in the application (Table 2). NDVI values; It was created in SNAP software for ENVI and SENTINEL-2 images for LANDSAT-8 images.

**Table 2.** Dates of used satellite images (S: Sentinel, L: Landsat)

MONTH	2016-2017	2017-2018
<b>December</b>	9.12.2016(S)	8.12.2017(L)
<b>January</b>	8.01.2017(S)	9.01.2018(L)
	18.01.2017(S)	
<b>February</b>	23.02.2017(L)	2.02.2018(S)
<b>March</b>	9.03.2017(S)	9.03.2018(S)
		19.03.2018(S)
<b>April</b>	28.04.2017(S)	3.04.2018(S)
		8.04.2018(S)
		13.04.2018(S)
		23.04.2018(S)
<b>May</b>	14.05.2017(L)	17.05.2018(L)
	30.05.2017(L)	
<b>June</b>	15.06.2017(L)	18.06.2018(L)

In this study; 6 sample wheat fields were selected (Figure 2-6) and NDVI values were calculated. The minimum, maximum and average NDVI values calculated for both seasons were compared (Figure 7, 8 and 9).



Figure 2. Sample areas



Figure 3. RGB images of wheat field at different dates for 2016-2017 season



Figure 4. NDVI images of wheat field at different dates for 2016-2017 season



Figure 5. RGB images of wheat field at different dates for 2017-2018 season

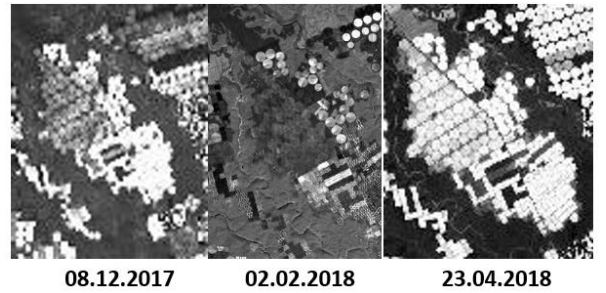


Figure 6. NDVI images of wheat field at different dates for 2017-2018 season

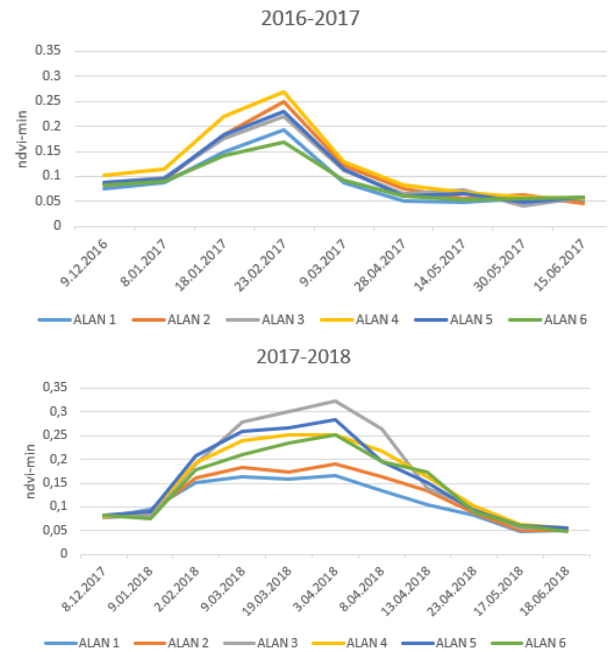
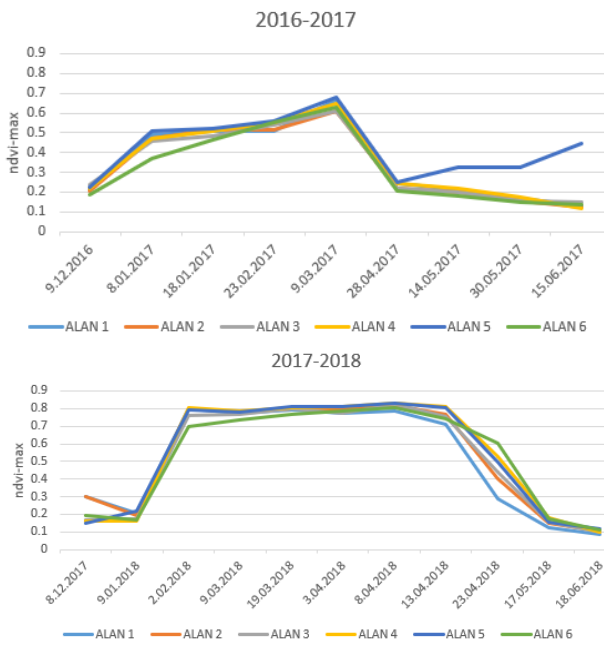
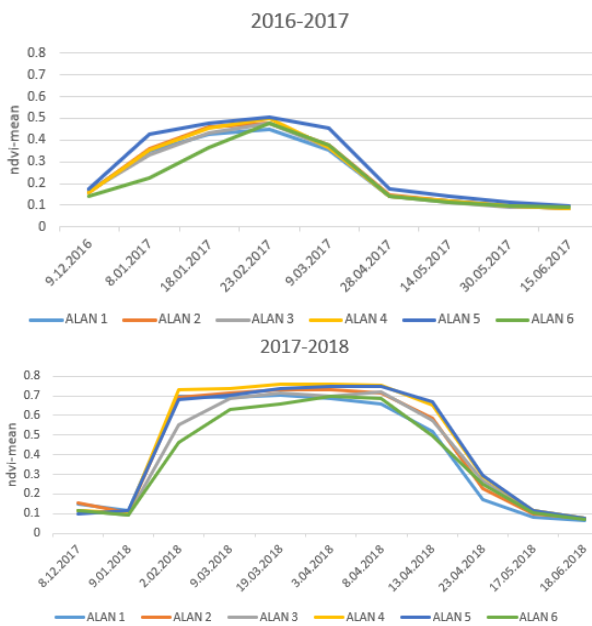


Figure 7. Minimum NDVI values for the 2016-2017 and 2017-2018 seasons



**Figure 8.** Maximum NDVI values for the 2016-2017 and 2017-2018 seasons



**Figure 9.** Mean NDVI values for the 2016-2017 and 2017-2018 seasons

#### 4. RESULTS

In this study, NDVI values generated from satellite images of two different seasons were examined. The highest NDVI value in the 2016-2017 season was observed in the stage of tillering. NDVI started to rise during the germination stage and decreased during the heading stage. In 2017-2018 season, the mean NDVI value reached its highest value during germination and tillering period. However, the highest NDVI value in the 2016-2017 season was 0.5069 on 23 February and 0.7599 on 19 March in the 2017-2018 season. This difference may

be due to reasons such as the quality and quantity of fertilizer, amount of rainfall, climate diversity.

#### REFERENCES

- Chandel, N. S., Tiwari, P. S., Singh, K. P., Jat, D., Gaikwad, B. B., Tripathi, H. & Golhani, K., (2019). Yield prediction in wheat (*Triticum aestivum* L.) using spectral reflectance indices. *Current Science*, 116(2).
- Comert, R., Kucuk Matcı, D., & Avdan, U., (2019). Object Based Burned Area Mapping with Random Forest Algorithm. *International Journal of Engineering and Geosciences*, 4(2),78-87.
- Çatal Reis, H., & Bayram, B., (2015). Landsat Uydu Görüntüleri Kullanılarak Kontrolsüz Sınıflandırma Yöntemi ile Bitki Örtüsü Değişimi: Konya Yunak Örneği. *15.Türkiye Harita Bilimsel ve Teknik Kurultayı*, Ankara, Türkiye.
- Esetlili, M.T., Özen, F., Akyürek, B.N., Kurucu, Y., & Bolca, M., (2015). Uzaktan Algılama Tekniği ile Pamuk Tarla Verimi Tahmin Doğruluğunun Arttırılmasında Kırmızı Kenar (Rededge) Band Kullanımının Katkısı. *Journal of Agriculture Faculty of Ege University*, 52(2),161-169.
- Kayahan, N., (2013). Uzaktan Algılama Kullanılarak Silajlık Mısır Veriminin Tahminlenmesi. *Master's Thesis*, Konya, Turkey.
- Karakus, P., Karabork, H., & Kaya, S., (2017). A Comparison of the Classification Accuracies in Determining the Land Cover Of Kadirli Region of Turkey by Using the Pixel Based and Object Based Classification Algorithms. *International Journal of Engineering and Geosciences*, 2(2),52-60.
- Orhan, O., Dadaser-Celik, F., & Ekercin, S., (2019). Investigating Land Surface Temperature Changes Using Landsat-5 Data and Real-Time Infrared Thermometer Measurements at Konya Closed Basin in Turkey. *International Journal of Engineering and Geosciences*, 4(1),16-27.
- Sönmez, N.K., Sarı, M. (2005). Verim Tahmini Çalışmalarında Yeni Yaklaşımlar, Uzaktan Algılama ve Agrometeorolojik Yöntemler, *Derim*, 21(2), 5-18.
- Yılmaz, H.M., Mutluoğlu, Ö., Ulvi, A., Yaman, A., & Bilgilioğlu, S.S. (2018). İnsansız Hava Aracı ile Ortofoto Üretimi ve Aksaray Üniversitesi Kampüsü Örneği. *Geomatik Journal* 2018; 3(2);103-110.

URL 1: <http://tuik.gov.tr> (Last access: 13.04.2019)

URL 2: <https://earthexplorer.usgs.gov/> (Last access: 13.04.2019)

URL 3: <https://scihub.copernicus.eu/dhus/#/home> (Last access: 13.04.2019)





## Mersin Photogrammetry Journal

<https://dergipark.org.tr/tr/pub/mephoj>

e- ISSN 2687-654X



### 3D Modelling of Kayseri Tekgöz Bridge

Ali ULVI\*<sup>1</sup>, Abdurahman Yasin Yiğit<sup>2</sup>

<sup>1</sup>Mersin University, Institute of Science / Remote Sensing and Geographic Information Systems, Mersin, Turkey

<sup>2</sup>Mersin University, Faculty of Engineering, Geomatic Engineering, Mersin, Turkey

#### Keywords

Tekgöz Bridge  
Photogrammetry  
Documentation  
Cultural heritage

#### ABSTRACT

Thousands of years of civilization and history as an activity, created by both people, and nature and is called Cultural Heritage studies today, is an important event for all humanity. Metric, written and visual documentation, It can be used as basic data protection in any study to identify cultural heritage and current situation and problems and to solve these problems. In addition, these works are transferred to future generations by documenting cultural heritage. Today, the close picture photogrammetry method is also frequently used in the documentation of cultural heritage. In this study, the survey study of Tekgöz Bridge, which is located 30 km northwest of Kayseri province, was done by the photogrammetric method. As a result, the three-dimensional model and drawings of the facade of the bridge were obtained. The study shows that the close picture photogrammetry method provides great convenience in the documentation studies of historical and cultural works. With the photogrammetry method, both field and office studies are completed in a short time. As a result of the study, it is concluded that the photogrammetry method can be effective in documenting historical artifacts.

#### 1. INTRODUCTION

Turkey has hosted many civilizations throughout history. It is possible to encounter historical and cultural monuments in almost every area. Kayseri is one of the richest cities in terms of historical and cultural monuments. According to the Ministry of Culture and Tourism's 2009 data, the number of cultural heritage registered in Kayseri is 829. In this geography with many cultures, a social bridge is established between the past and the future (Şasi and Yakar, 2018). In order to strengthen this social bond, the whole world should support the protection of cultural heritage.

Georgopoulos and Ionnidis (2004). In their study; He defined the documentation of historical and cultural works as a study that aims to investigate the historical or cultural structure of the current work, to determine and re-evaluate the changes in its shape and size. Historical and cultural heritage must be carefully documented to transfer historical artifacts to future generations and

preserve human history. Various methods are used to document historical artifacts.

These methods generally classical documentation method, topographic methods, photogrammetric methods and scanning methods (Böhler & Heinz, 1999; Scherer, 2002).

The method of documenting by writing is one of the oldest methods used to document historical and cultural heritage studies. Three-dimensional documentation methods have started to be used with the advances in technology. As the three-dimensional documentation method, the most effective method is the laser scanning method. However, the laser scanning method is not preferred in terms of cost. The photogrammetry method, which shows superior performance in terms of cost and speed, is often preferred in three-dimensional documentation. The photogrammetry method is subdivided like many methods. In this study, close picture photogrammetry, a photogrammetry method, was used.

\* Corresponding Author

\*(aliulvi@mersin.edu.tr) ORCID ID 0000-0003-3005-8011

(ayasinyigit@mersin.edu.tr) ORCID ID 0000-0002-9407-8022

Cite this article

ULVI, A., YİĞİT, A. (2020). 3D MODELLING OF KAYSERI TEKGOZ BRIDGE. Mersin Photogrammetry Journal, 2 (1), 29-32.

Retrieved from <https://dergipark.org.tr/tr/pub/mephoj/issue/52791/676334>

Received: 16/01/2019; Accepted: 24/02/2020

DOI: XXXXXXXXXXXX / Research Article

The close picture photogrammetry method is used in many areas such as determining the structure of historical and archaeological sites, making scale drawings of the building facade, preparing and applying the urban conservation plan, crack and deterioration analysis, damage, and deformation assessment, architectural restoration. (Yilmaz et al, 2000; Sienz et al, 2000).

In this study, the historical Tekgöz Bridge documentation study in Kayseri province was carried out with the close picture photogrammetry method. Drawings and three-dimensional models of both sides of the bridge were obtained.

## 2. STUDY AREA

The Tekgöz Bridge in the northwest of Kayseri is built on the Kızılırmak River, 30 km from the city center (Figure 1). The bridge was built by Sultan Süleyman Şah Rükneddin (1202). It is one of the most important works in Kayseri, an important industrial and commercial center in Central Anatolia. Thanks to the repairs made at various times, it has survived to the present day.



**Figure 1.** Tekgöz Location – Kayseri/TURKEY

No inscription belonging to the bridge was found (Figure 2). However, according to the inscription found during the restoration of the bridge in 1538, the bridge was built by Dulkadiroğlu Bey Şahruh and restored by his son Mehmet. The arch part of the bridge was established on the Kızılırmak River, its length is 161 meters (528 ft) and its width is 6.2 meters (20 ft). The highest point of the bridge is 11 (36 ft) meters long. The bridge is still actively used.



**Figure 2.** Tekgöz Bridge

## 3. METHODS

The photogrammetry method was preferred to document the historical Tekgöz bridge in 3D. Photogrammetry is a method that allows to re-determine the properties of the object in 3D without contact with the object (Kraus, 2007).

Photogrammetry is an independent method in the documentation process. This method is based on at least two images with overlapping data to guarantee the surface passing process (Yakar & Doğan, 2017). Therefore, there is a need for at least two pictures taken from different angles of the object to be applied photogrammetry. The first and the most important stage for the object to be documented to be successful is the stage of photographing.

After providing good photo data, the photogrammetry method can be applied. There are several ways to obtain photo data. The most basic of these is to take photos locally. The processing of photographs taken terrestrially by digital photogrammetry makes important contributions in terms of cost and speed. Digital photogrammetry can produce a precise three-dimensional model of an object or part of the world, depending on the image quality (Akçay et al., 2017).

Historical and cultural heritage documentation works are carried out in two stages: the study of field study and office.

During the field study, the coordinate system is defined to identify the measured object. After measuring the characteristics of the object, photographs of the object are taken.

The first thing to do in the office is to calibrate the camera. Then the coordinates of the object are entered on the photo data. The 3D model is obtained from 2D images by the photogrammetry method. Finally, the necessary detailed drawings and surface coating are made.

### 3.1 Studies of Field

First, necessary discovery activities are carried out around the bridge. Then measurement points are determined where appropriate. The measurement device shown in figure 3 is installed in the designated places and necessary detail measurements are made. After the detail measurement is made, the photo data of the object is collected. Photos were taken with the digital handheld camera shown in figure 4. The photo data of the object was taken in an overlay with each other. 28 detail points of the bridge were measured in the land. The photo data of the bridge is 220 pieces.



Figure 3. Topcon 3007 totalstation



Figure 4. Canon digital camera

### 3.2 Study of Office

Various software is available to apply the photogrammetry method used to document historical artifacts. In this study, Photomodeler software was preferred as photogrammetry software. The most important reason for choosing this software is that a detailed drawing can be made after the 3D model is created.

Photomodeler software can automatically perform most of the steps that form the basis of the photogrammetry method. First, the software is introduced to the camera calibration parameters. Then, the measurements made from the field are added to the photographic data. Thanks to these measurements, the real position, and dimensions of the object are provided. Balancing is required to obtain a 3D model from 2D photos.

Photomodeler software can perform the balancing process according to the reference points you have determined. The 3D model is obtained after the balancing process has been completed successfully. After creating a 3D model in real dimensions and location of the work, the detail drawing is started. Documentation work is completed after drawing the details that contain the characteristic features of the historical bridge (Figure 5).

But textural data and basic facade or surface models must be added to create a real model. Finally, texture and surface coating is made on the 3D model with detailed drawings (Figure 6).

Objects that have a 3D model on the digital platform can then be transferred to internationally supported computer-aided formats (DXF, CAD, etc.) for use in other studies.

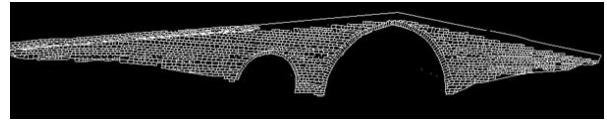


Figure 4. Tekgöz Bridge wireframe model

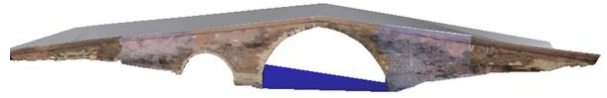


Figure 5. Textured model

## 4. CONCLUSION

In countries such as Turkey, the historical process and damage caused by natural disasters are a danger both to destroy the cultural heritage.

Preservation of these works is a very important issue in terms of human history. Documentation work should be done not only to be restored but also to create a digital archive of cultural heritage.

The digital close-range photogrammetry method, recently in parallel with the developments in electronics and computers have shown great improvement. Thanks to this method can be easily solved complex problems and processes can be completed in a short time. Therefore, it is a highly effective and efficient method commonly used in the documentation of cultural heritage.

The photogrammetry method is successfully applied in the rapid and accurate creation of a three-dimensional model in the desired scale of cultural heritage and archaeological sites. With this method, three-dimensional models documented by adding texture data can be covered with real texture. The preservation of historical and cultural monuments and documentation studies that will prevent extinction frequently benefit from photogrammetric methods. The whole process can be done in a short time and accurately with the photogrammetry method. Considering all these features, it shows that 3D modeling with the photogrammetry method can be easily used in documentation studies.

In this study, Historical Tekgöz Bridge was documented by the photogrammetry method. In the study, 25 photographs of the work were used. 8 of the measured points were used.

With this study, it is mentioned that documentation studies can be done with a small but enough data.

## REFERENCES

- Akcay, O., Erenoglu, R. C. and Avsar, E. O. (2017). The effect of jpeg compression in close range photogrammetry, *International Journal of Engineering and Geosciences (IJEG)*, Vol;2, Issue;01, pp. 35-40, February, 2017, ISSN 2548-0960, Turkey, DOI: 10.26833/ijeg.287308

- Böhler W. and G. Heinz (1999). *Documentation, surveying, photogrammetry, XVII CIPA Symposium. Recife, Olinda.Brazil, 1999.* DOI: 10.26833/ijeg.328919
- Georgopoulos A. and G. Ionnidis (2004). Photogrammetric and surveying methods for the geometric recording of archaeological monuments, archaeological surveys, *FIG Working Week 2004 Athens, Greece, May 22-27, 2004.*
- Kraus K. (2007). Fotogrametri, Fotoğraflardan ve Lazer Tarama Verilerinden Geometrik Bilgiler, Çeviri, İTÜ, (Çevirenler M.O.Altan vd.)
- Scherer M. (2002). About the synthesis of different methods in surveying, *XVIII International Symposium of CIPA, Posdam, Germany, 2002.*
- Sienz J., Szarvasy I., Hinton E. and Andrade M.L. (2000). Computational modelling of 3D objects by using fitting techniques and subsequent mesh generation, *Computers and Structures* 78, 2000, 397-413
- Şasi, A. and Yakar M. (2018). Photogrammetric modelling of hasbey dar'ülhuffaz (masjid) using an unmanned aerial vehicle, *International Journal of Engineering and Geosciences (IJEG)*, Vol; 3; , Issue; 1, pp. 006-011, February, 2018, ISSN 2548-0960, Turkey
- Yakar, M. and Doğan, Y. (2017). GIS and three-dimensional modeling for cultural heritages, *International Journal of Engineering and Geosciences (IJEG)*, Vol; 3; Issue; 2, pp. 050-055, June, 2018, ISSN 2548-0960, Turkey, DOI: 10.26833/ijeg.378257 Research Article
- Yılmaz H. M., Karabörk H. and Yakar M. (2000). Yersel Fotogrametrinin Kullanım Alanları, *Niğde Üniversitesi Mühendislik Bilimleri Dergisi* 4, 2000, 18-28.