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DETERMINING OF DIFFERENT INUNDATED LAND USE IN SALYAN PLAIN DURING 2010 THE KURA RIVER FLOOD THROUGH GIS AND REMOTE SENSING TOOLS

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ABSTRACT: People are struggling with floods, which are types of natural disasters. Floods are in the first place among natural disasters in terms of damage to the community and the number of victims. Acquisition data from reliable sources is one of the central issues in the assessment of the condition in areas with high probability of flooding and operative decision making in extreme situations. As the source of this kind of data Remote Sensing data is widely used which is interpreted by Geographical Information Systems technologies in a short time. In addition, accurate geographical linking is possible through modern satellite navigation technology, which makes it possible to spread information quickly and deliver obtained results to customers. Since the Kura River is the source of fresh water in Azerbaijan, most important and strategic importance, there are many settlements, industrial and economic facilities along the riverbed. That is why, as a result of the floods in the downstream of the Kura River, the environment, economic infrastructure, individual spatial areas and the population living in these areas are damaged. As an example of flood damage assesment, the recent flood in 2010 was analyzed. Different archival, field survey and digital materials were used. Maps of flooded areas and the potential infrastructure in flooded areas were determined through ArcGis 10.2.1 software. Among all flooded areas, settlements and pastures had the highest share. The study proved that integration of various spatial data could greatly support flood damage assessment.

Keywords: *Natural Disasters, Flood Hazard, The Salyan Plain, Inundated Areas, Damage Assessment, Remote Sensing (RS), Geographical Information Systems (GIS)*

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1. INTRODUCTION

Disaster is a natural or human-induced event that adversely affects the individual or the society (Şentürk, E. and Erener, A., 2017). Among natural disasters, floods are more hazardous and large-scaled. Floods are mainly caused by heavy rainfall, cyclone effects, and melting of snow and glaciers in the mountains.

Floods are among one and main natural disasters that occur frequently in Azerbaijan and damage to local people, agriculture and infrastructure, generally to the whole economy of the country (Ağayev A.T., 2016, Musayeva M.R., 2014). Especially, devastating floods occur in the Kura river basin, downstream of the Kura River where Shirvan, Mughan and Salyan plains situates. The most recent devastating flood in the Kura river occured in 2010. The flood differed from previous flood events significantly by its scope. Due to the large extent of the flood, I conducted the study only within the Salyan plain. The aim of the study was to test the possibility of determination flooded land use categories through the mapping of inundated areas using archival materials, aerial and satellite images.

Early property damage assessment and accurate modelling of flood events require that private-owned objects, agricultural land use and infrastructure are identified on a land cover map. Different application fields, such as earth sciences, natural resource management, environmental protection, urban and regional planning, defense, transport, tourism, statistics and education need geographic data, because they require regional or countrywide analyses (Yılmaz, A. and Canıberk, M., 2017). Earth observation techniques may contribute significantly to improve our efforts to model flood events, to develop proper mitigation strategies and to assess damage to residential properties, infrastructure and agricultural crops (C.J. van der Sande et al., 2003).

A lot of studies were conducted on the integration of GIS technology and RS data in worldwide practise and the analysis of natural and anthropogenic factors affecting the development of hydrologically hazardous situations has widely covered (Dano U.L. et al., 2011, Mateeul H. et al., 2012, Audisio C., 2011). Basically satelitte data from different period of time were used in those studies which allowed to assess the dynamics of flood accidents.

Large-scale investigations have been carried out in many privately owned and public institutions around the RS data and GIS technology assessment of Kura river floods. In the conducted studies the application of GIS technologies were achieved on the investigation of floods in the mountains of the southern slopes of Greater (Müttəlibova Ş.F. avtoref. 2007, Süleymanov T.İ. and Müttəlibova Ş.F., 2006, Сулейманов Т.И. and Мутталибова Ш.Ф., 2005, Süleymanov T.İ. and Müttəlibova Ş.F., 2004). In other studies, investigations have been carried out around real estate electronic cadastre issues and the method of operative determination of flooded areas and damaged property during the Kur River flood has been proposed (Alıyev E.M. avtoref. 2016, Süleymanov T.İ. and Alıyev E.M., 2009, Сулейманов Т. И. and Алыев Э.М., 2012, Aliyev E.M., 2013). Therefore, utilizing of results of the studies, suggestions and methods have been considered appropriate.

Thereby, it is necessary to determine the extent to which the different purpose lands are flooded and the operational assessment of the damage caused by the flood events on the basis of high-definition cosmic drawings and GIS technologies.

2. STUDY AREA DESCRIPTION

The Salyan plain, west of the Caspian Sea and situated downsteam the Kura river, was selected as a study area (Fig. 1). The primary reason to select this area for the study is a regular occurrence of floods.

The Salyan plain embraces the area from the right side of Kura river between the Kura and the Akusha rivers to the Caspian Sea (Aslanov, 2013). The plain is totally below the sea level (maximum -12.2 m and minimum -30.59 m). The Salyan plain is surrounded by the South-East Shirvan plain and the North Mughan plain from the north-west, the West Lankaran lowland from the south, and the Caspian Sea from the east.

Figure.1 Study area

2.1 History of floods

Historically, floods in the downstream of the Kura river were observed regularly, but written records cover the period after 1858. As can be seen from this information, devastating floods that caused damage to the agriculture and threaten the local population occurred in this part of the Kura river basin in the nineteenth century. For example, in 1896 the stream that depleted the soil barrier on the right bank of the Aras river in 1896 near the Saatli settlement created New Aras tributary, as people called it, and not only the Mughan plain, but also southeastern parts of the Salyan plain including the 160000 hectares were under floodwaters. The Kura river flood that occurred in May, 1915 was one of the most hazardous floods over 150 year. A large territory in the Shirvan plain within Aghdash, Goychay, Kurdamir districts were inundated by floodwaters which destroyed coastal barriers in Garadeyin (Aghdash), Gakhay (now Khinakhli village, Aghdash), Zardab (Zardab city), Mollakand (Kurdamir) and other riverside villages. The flood that occupied more than 200000 hectares area flew through left bank of the Kura river and run into the river near Shirvan settlement again (Aslanov, 2013). Besides these two historical facts, a lot of large-scale floods occurred in these lowland areas so far.

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Figure.2 A part of the railroad damaged as a result of flood waters in 1915 (Pashayev and Hasanov, 2010)

The next flood event was in 2003 in the area where Kura River floods occur regularly. During the flood, Kurgaragashli, Garachala, Karabakh (Tazakand), Arabgardashbayli, Khojaly and Jangan in Salyan district, including the town with the same name were mostly suffered settlements from the Kura River flood (Aslanov, 2013).

2.2 2010 flood

The most recent flood event occured in 2010 May and differed in extent from the previous flood events, significantly impacting the state budget. During the flood, 11 districts and approximately 150 settlements were damaged either completely or partly (Fig. 3).

Figure.3 Images from the 2010 flood (http://www.fhn.gov.az/index.php?aze/pages/33)

Figure.3 Continued

Imishli, Saatli and Sabirabad districts were most affected areas in 2010 flood. In total 110929 ha were flooded (Ağayev A.T., 2017). Although Salyan and Neftchala districts have a high flood risk, but during 2010 flood, the impact of flood water in those areas was relatively low. However, the Kura river flood affected these areas too. Totally 3415 ha area in Salyan and Neftchala districts were inundated.

After some flood mitigation measures for reducing flood impact, the consequences of that natural phenomena were mostly eliminated. Approximately 30 million AZN (equal to 15 mln EUR) was allocated from the state budget with the purpose to aid suffered families financially, to recontruct and rebuild destructed and damaged houses, replacing them with new ones. 26.5 million AZN was spent for financial aid and construction and restoration of houses (Table 1).

Table 1 A number of damaged houses, families and amount of funding allowance due to the flooding

№	Names of the districts	Planned reconstruction of private houses. Handed over houses	Number of families supported with financial aid	Paid amount, Total, AZN
1	Salyan	145	615	1156700
2	Neftchala	42	112	234300
3	Other districts	4078	13530	17867500
4	Additional aid, other districts	-	14344	7205969
	Total:	4265	28601	26484469

3. MATERIALS AND METHODS

To determine of flood extent, and delineate infrastructure and land use categories affected by flood various materials are needed, e.g., data from responsible agencies of government or freely available spatial data from internet archives. In this study I used official 1:100000 (published in 1991) and 1:10000 (published in 1989) topographic maps, orthophoto images in 1:5 000 scale compiled from aerial images (acquired in 2009)

(Fig. 4) and Landsat satellite data.

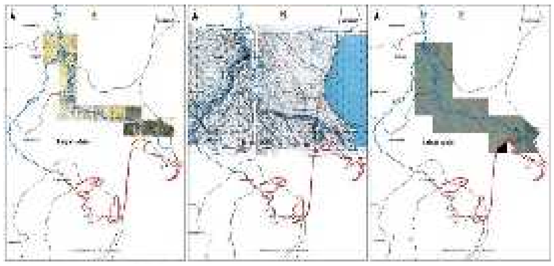

Figure.4 Data sources used in the study: a) 1:10000 topographic maps, b) 1:100000 topographic maps, c) 1:5000 orthophotos (Archival materials)

Recently, remote sensing data has increasingly been used in order to generate land use/land cover classifications (Tina Gerl et al., 2014). Maps and orthophoto images at high spatial resolution enabled the identification of urban and sub-urban objects (C.J. van der Sande et al., 2003, Ağayev A.T., 2015). Landsat satellite images are freely available satellite data with 30 m resolution and relatively high temporal frequency of acquisition, therefore they could help to capture the 2010 flood extent. To investigate flooded areas in Salyan plain during 2010 flood two acquisition dates were selected for the US Geological Survey Earth Explorer archive (http://earthexplorer.usgs.gov): 26 September 2009 and 24 May 2010, that is one pre-flood and one flood acquisition. Two standard scenes for each date were used, in total four images were analysed (Fig. 5, Table 2).

Table 2 Metadata of the satellite images

Data Set Attribute	Attribute Value			
	1	2	3	4
Spacecraft Identifier	LANDSAT_5			
WRS Path	167			
WRS Row	032	033	032	033
Date Acquired	2009/09/26		2010/05/24	
Quality Band 1-7	9			
Output Format	GEOTIFF			
Grid Cell Size Reflective	30			
Grid Cell Size Thermal	30			

Geographic Information Systems (GIS) and the remote sensing technology present the most powerful tools emerged in the hydrological field, which allow for the collection and analysis of environmental data as well as provide a platform for integrating space and ground-based data for flood monitoring and modelling (Galina Merkuryeva et al., 2014). I used several methods for the determination of 2010 flood extent and flooded land use categories. In the first stage, obtained satellite images were processed using on-screen manual vectorisation with ArcGIS software. Then, water courses in the study area within the scope of satellite image were delineated with the appropriate tools of the software. This procedure was implemented on the satellite image captured before the flood (in 2009). Riverbed and small water bodies along the river were included. Next the procedure was implemented on the satellite images taken during the 2010 flood. Delineated boundaries show the condition of the area before and after flood.

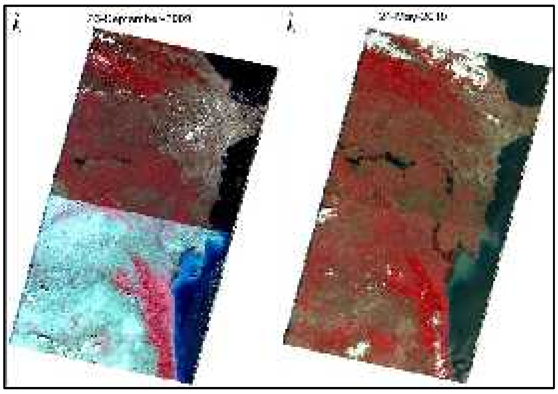

Figure.5 LANDSAT 5 satellite images before and during the 2010 flood (http://earthexplorer.usgs.gov)

After delineation of the 2010 flood extent it was possible to interpret infrastructure and land use in those areas (within the flooded area boundary). The scale and resolution of satellite images were not sufficient, and for that reason, I utilized archival topographic maps in the scale 1:100000 and 1:10000, and orthophoto images in the scale of 1:5000.

4. RESULT

Flooded areas obtained through the interpretation of satellite images, are clearly visible if two satellite maps are compared (Fig. 6). For the study area, the flooded area was estimated for 1336 ha.

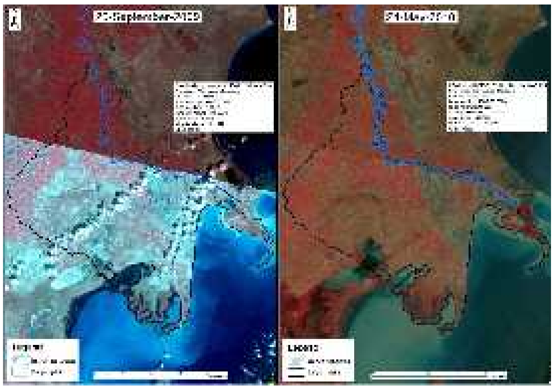

Figure 6. LANDSAT 5 satellite images before and after flood. Even in this scale inundated areas during 2010 flooding are clearly visible

Figure 7. Flood extent areas

By overlaying the boundaries of the settlements to the map, the partly inundated settlements can be visible.

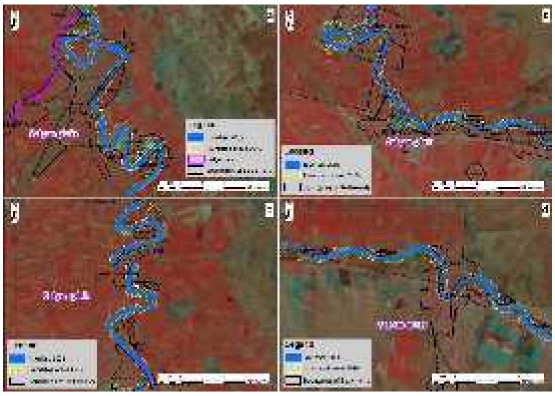

Figure 8. Settlements affected by floodwaters

For the flooded areas, various land use types were identified (Fig. 9, Table 3). Among them, pastures and settlements were the major categories occupying around 60% of the flooded land.

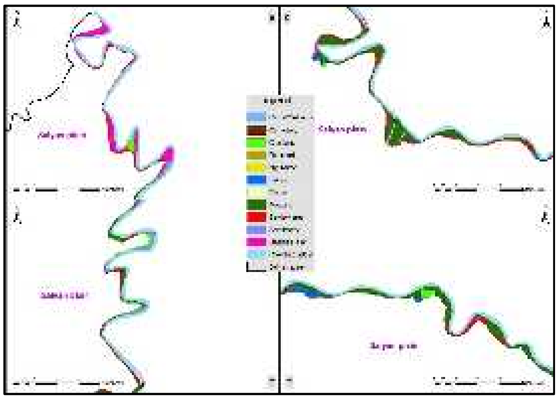

Figure 9. Land use categories under floodwaters

Table 3 Quantity of land use categories under floodwaters

№	Land use category	Area, ha
1	Pasture	617,73
2	Settlements	217,57
3	Useless land	192,13
4	Cropland	118,45
5	Shrubbery	65,67
6	Lakes	64,55
7	Dirt roads	37,3
8	Canal/Collector	16,41
9	Highways	3,28
10	Cemetery	2,47
11	Parks	0,72
Total:		1336,28 ha

One of the mostly inundated land use types were settlements. For settlements, high resolution orthophotos allowed to identify buildings that were flooded in 2010 (Fig. 10, Table 4). In total, more than 800 buildings were identified as flooded in the settlements of Salyan and Neftchala districts within the boundary of the Salyan plain.

Figure 10. Houses under floodwaters

Table 4 The number of flooded buildings over settlements

№	Districts	Settlements	Houses	Total
1	Salyan	Arabqardashbayli	47	316
2		Beshdali	25	
3		Jangan	18	
4		Khojali	14	
5		Kurgaragashli	52	
6		Salyan city	160	
7	Neftchala	1 Garali	5	498
8		2 Mayak	4	
9		Ashagi Garamanli	22	
10		Ashagi Surra	93	
11		Astanli	20	
12		Dordlar	23	
13		Gadimkand	19	
14		Khilli	141	
15		Kurgarabujag	35	
16		Mirzagurbanli	6	
17		Neftchala city	25	
18		Novovasilyevka	105	

5. DISCUSSION

Flood damage in the selected area was determined through GIS tools. Various spatial data within flood extent were integrated and processed through GIS tools, however, the methodology could be further improved, e.g., using automated flood delineation with satellite data.

Integration of various spatial data may lead to several problems, e.g., orthophoto was acquired in 2009, hence not at the same time as the flood and one year difference between the flood occurence and captured orthophotos dates reveals that there is not exception in the changes of infrastructure of the area. Another issue was that due to low resolution of satellite data, the flood extent boundaries had a certain error margin, which might impact the accuracy of flooded buildings delineation.

6. CONCLUSIONS

Integration of various types of spatial data allowed quick mapping of flooded areas that could establish a spatial database for subsequent flood damage assessment. Landsat satellite data were found useful in delineation of flood extent, although it should be noted that 2010 flood was a dynamic event, and flood extent varied in late May and early June, for example, to reduce the flood extent and eliminate consequences of the flood, new tributary of the river was opened by the government decision. In consequence, floodwaters decreased in some areas, but in other areas flood showed different pattern (Aghayev, 2017).

My study showed significant damage during the 2010 flood, which in particular affected pastures, settlements, useless land and cropland. For settlements, data and methodology allowed to identify flooded buildings and indicate the most flood-prone areas.

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DESIGNING A SUSTAINABLE RANGELAND INFORMATION SYSTEM FOR TURKEY

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ABSTRACT: The purpose of this study is to identify the deficiencies of the rangeland information system currently used in Turkey and, as an alternative, design a sustainable rangeland information system. In the study, both the extent of changes that occurred over time in the rangelands and the factors that caused such changes were identified, and solutions were suggested to eliminate those factors. The rangelands located in the Akçaabat district of Trabzon province were selected as the study area. Land use maps were produced by using the object-based classification method. According to the results of change analyses made with this information system, it was found out that, from 1973 to 2012, a surface area of 159.8 hectares had been degraded, demonstrating that the current information system had not been successful enough in the management of rangelands. For that reason, a sustainable rangeland information system free from all deficiencies was designed.

Keywords: *Rangeland Information System, Worldview-2, Unmanned Aerial Vehicle, Support Vector Machine, Object Based Classification*

1. INTRODUCTION

Meadows and rangelands are perennial herbaceous plant communities that usually occur naturally in various particular lands (Altın et al., 2011). According to estimates, the rangeland ecosystem covers approximately 50% of the lands of the world (Wang et al., 2014) and meets 70% of the planet’s needs for food for animals (Brown and Thorpe, 2008).

It is also widely accepted that, of all the lands in the world, rangelands have the most precious vegetation covers in terms of preventing global disasters such as erosion, vegetation fires, floods, and others (Avcıoğlu, 2012). Furthermore, grasslands store at least 10% of global carbon stocks (Eswaran et al., 1993) and play an important role in the global carbon cycle (Scurlock and Hall, 1998). Grasslands are not only a significant food source for wild and domestic animals and a source of soil protection, but also have a major influence on the functioning of the terrestrial biosphere, the regional climate, and the ecological quality (Huang et al., 2012; Liu et al., 2014).

The total area of rangelands, which are thought to prevent global disasters as well as to provide countless other benefits, has decreased in Turkey from roughly 38 million hectares to about 14.6 million hectares in the last 60 years (Avcıoğlu, 2012; Altın et al., 2011). If the extent of reduction in the total area of rangelands is taken into account, it is evident that rangelands have not been adequately controlled to ensure proper use and that improvements intended to remedy the degradation have not been fully implemented.

Unfortunately, in Turkey, the basic principles of rangeland management, such as determining the current grazing capacity and preparing and implementing rotational grazing plans, are generally not taken into consideration. As a result of such malpractice, rangelands today have lost much of their production potential (Ünal et al., 2012).

If images are not obtained, processed, and analyzed periodically, and if necessary interventions are not performed in a timely manner, an increasing number of deteriorations and losses in those areas is inevitable. The deterioration process affects all rangelands in the country of Turkey. Rangelands will inevitably become more like desert if the current situation continues.

Up to the present time, a great number of studies have been conducted by the use of both topographic measurements and satellite images for the purpose of determining the changes occurring in rangelands. For instance, Huang and et al., (2012) used Landsat MSS, TM/ETM images from the years 1954 to 2000 for graslands changes in the Northern Songnen Plain, China. After processing these images, analyzed the extent of change in the rangelands with the help of the information system they created. As a result of their study, they found that the total area of rangelands had diminished by 17.6% in those 46 years. On the other hand, Liu et al., (2011) examined the changes that had occurred in rangelands, forests, and agricultural lands in the years between 1982 and 2008 for the Loess Plateau, China. In their study, they performed analyses by using scanned topographic maps, infrared color aerial photographs, digital orthophotos, and SPOT-5 data integrated with the Geographic Information System (GIS). In conclusion, they found that the number of parcel had increased, particularly between the years of 1982 and 1990, but, by force of rearranged land management policies, had decreased in the subsequent years. An et al., (2014) analyzed the change in rangelands from the years 1990 to 2004 by using NOAA/AVHRR-NDVI and MODIS-NDVI data, and a novel Local NPP Scaling (LNS) method for Qinghai, China. As a result of their study, they ascertained that the percentage of rangelands degradation had reached 36.7% during that 15-year period.

Mansour et al., (2016), using SPOT-5 satellite images and an Random Forest (RF) classifier, produced thematic maps showing rangelands with an accuracy of 88.60%. They claimed that the use of their thematic maps would be beneficial for developing policies for sustainable rangeland management.

With the development of unmanned aerial vehicles and the specifications of the cameras that have been used on such vehicles in recent years, those tools have begun to be commonly used for the monitoring of rangelands. For example, Rango et al., (2009) underlined that the Unmanned Aerial Vehicle (UAV) has yielded successful results in providing images and extraction of relevant features in the management and monitoring of rangelands. In their studies, Breckenridge and Dakins (2011) made bare ground determinations in the rangelands by using a helicopter UAV and a fixed-wing UAV. As a consequence of that study, they stated that a helicopter UAV would be suitable for studies that require many details and high-precision photographs and that a fixed-wing UAV would be more suitable for studies in which large surfaces need to be covered. For four different studies, Laliberte et al., (2011) produced flora maps of the rangelands with 78–92% precision by using object-based classification that utilized the maps obtained from the Unmanned Aircraft Systems (UAS). Their studies showed that UAS were suitable platforms for producing flora maps of the rangelands in terms of providing very-high-resolution images. McGwire et al., (2013) defined green leaf cover in the rangelands with their NDVI (Normalized Difference Vegetation Index) by using images taken from unmanned aerial vehicles that used hyperspectral cameras. They compared the satellite image of a LANDSAT TM (Landsat Thematic Mapper) to NDVI results obtained from UAV images with land measurements. In the study, they stated that, because of the very high resolution of the hyperspectral images, it would be more suitable to use them in those kinds of studies.

It is possible to identify the reasons why rangelands degrade over time and eventually disappear. Those reasons may become evident through the analysis of databases created with the data obtained by using different measurement techniques, such as remote sensing, which is an effective tool for land use/cover mapping (Chen et al., 2015) and photogrammetry. Furthermore, with GIS and computer-aided systems, land evaluations can be performed more accurately, and more realistic land use/cover data, which is a fundamental input for environmental planning, management, and rangeland health, can be prepared (Burrough and McDonnell, 1998; Wu et al., 2016; Chen et al., 2015; Boswell et al., 2017). So, in local governments GIS are able to be used as a very strong device (Iscan and Ilgaz, 2017).

Methodologically, remote sensing and photogrammetric techniques were used in the first section of this study, and the negative effects of problems encountered in rangelands were determined. In the next section, deficiencies in the current information system were identified. In the final section, a sustainable information system was designed to ensure efficient and proper management of the rangeland areas.

1.1.Study area and Dataset

The rangelands containing the borders of the Akçaabat district of the city of Trabzon were chosen as the field of study. Akçaabat, which is located on the northeastern coast of Turkey, is placed between 39^0 35’ East longitude and 41^0 01’ North latitude, at 10 meters altitude above sea level with a 353.66 km^2 surface area. It is just to the west of the city of Trabzon (Figure 1).

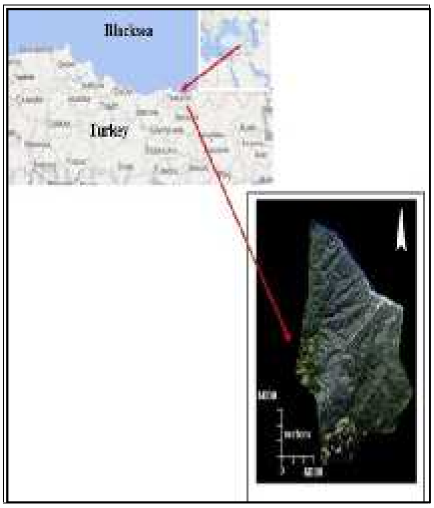

Figure 1. Study area

In the study area, to detect the changes occurring over time in the rangelands, aerial photos from the years 1973 and 1982, satellite images from the year 2012 and high resolution color photos obtained from a UAV were analysed. Aerial photos from 1973 with 58 cm spatial resolution and a scale of 1/23000 were composed of 71 pieces. Aerial photos from 1982 with the scale of 1/25000 were composed of 45 pieces. A total of 116 pieces of stereoscopic aerial photos were used in the study.

Thirty-two Ground Control Points (GCPs) were used for the orthophoto process, and the coordinates of the GCPs were measured by means of the Continuously Operating Reference Station—Turkey (CORS-TR) Global Positioning System (GPS) technique. Then the interior and exterior orientation processes of the photos were completed with the Leica Photogrammetry Suite 9.0 software. Orthophoto images were generated by the use of oriented images.

After the orthophoto process, the orthophoto images were digitized by using the ArcMap software. The layers of rangeland, forests, roads, and buildings were established on the images. Rangeland areas were then calculated by extracting the building, forest, and road areas from the total area. After the digitization process, attribute information (rangeland names, years, types) of those layers was uploaded to the database, and a spatial database was created for all the rangelands.

Another form of data used was high-resolution WV-2 MS (Multi Spectral) and PAN (Panchromatic) satellite images covering a 438 km^2 area of the Akçaabat district, which were acquired in 2012 A WV-2 MS image has eight multispectral bands—Blue (0.45–0.51 µm), Green (0.51–0.58 µm), Red (0.63–0.69 µm), Near Infrared 1 (0.77–0.90 µm), Coastal (0.40–0.45 µm), Yellow (0.59–0.63 µm), Red Edge (0.71–0.75 µm)) and Near Infrared 2 (0.86–1.04 µm)—with 2-meter spatial resolution and the PAN band (0.46–0.80 µm) with 50-cm high spatial resolution.

The radiometric and atmospheric corrections of the satellite images were made by the company that supplies the images. The geometric correction of the satellite images consisted of 42 points, measured by the CORS-TR (Continuously Operating Reference System—Turkey) GPS method.

The Digital Terrain Model (DTM) widely used in all geosciences and engineering tasks (Yılmaz and Uysal, 2017), was generated from a 1/25,000-scaled Standard Topographic Map (STM) by using a rubber sheeting method. Finally, the images were rectified with the WV-2 Rational Polynomial Coefficients (RPC) model, which contains an RPC of the WV-2 (MS) image in the ERDAS Imagine software (ERDAS Imagine, 2013), together with the produced DTM and GCPs. Overall, the Root Mean Square (RMS) errors were 1.31 m for the MS image and 0.39 m for the PAN image. RMS error is calculated with a distance equation (1)

$$\text{RMS error} = \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2} \quad (1)$$

where x_i and y_i define the coordinates of the input data and x_r and y_r define the retransformed coordinates.

The final data information was color aerial photos with 16-cm spatial resolution that were taken by the Gatewing X100 UAV for the Balıklı, Hıdırnebi, and Kuruçam rangelands, which are located in the district of Akçaabat, Trabzon. The study area consists of rangelands that are frequently used by the local community due to their closeness to the city centrum and to their popularity. Because of the vastness of the study area, it was divided into two sections. In the first section, 224, and in the second section, 144 photos were taken, making a total of 368 photos (Figure 2).

Figure 2. Color aerial photos with 16 cm spatial resolution that was taken by Gatewing X100 UAV

For the orthophoto processing of UAV images, 10 GCPs were established on the ground, and their positions were determined with the CORS-TR GPS technique. Aerial images were taken by the UAV, and then the photos were oriented by the Photoscan software. The RMS errors were found to be 0.11 m and 0.09 m for first and second sections, respectively. Then

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the DTM and ortho-image of the study area were generated.

2. METHODOLOGY

2.1. Image Fusion

The High-Pass Filter (HPF)technique, which was recommended by Schowengerdt (1980), was first used for reducing data volume and increasing the spatial resolution of Landsat MSS data (Carter, 1998). The HPF method is based on adding the high-frequency information from the high-resolution PAN image to each band of the low-resolution MS image to obtain the high-resolution MS image (González-Audícana et al., 2004; Wang et al., 2005; Rokni et al., 2015). The first step of the HPF method is to calculate the ratio between the spatial resolutions of the input MS and PAN images. A high-pass kernel and its dimensions are determined according to that ratio. Once it is extracted, the high-frequency information from the panchromatic image, obtained by using the HPF, is added to each band of the multispectral image. It should be noted that the HPF image is weighted relative to the global standard deviation of the multispectral bands by using the weight factors calculated from the ratio. Finally, the new multispectral image is stretched to match the mean and standard deviation values of the original input multispectral image (Klonus and Ehlers, 2009). HPF is described as follows:

$$HPF_{i,j,k} = (MS_{i,j,k} + FP_{i,j})/2 \qquad (2)$$

where MS is the multispectral image, HPF is the output image, i and j define the pixel location in the k_{th} band, and FP defines the high-pass filter (Han et al., 2008).

2.2. Object Based Classification

The principle of Object Based Image Analysis (OBIA) is to classify the image objects generated from the segmentation process (Kavzoğlu et al., 2015; Chen and Gao, 2014). OBIA includes several steps of image segmentation, training sample selection, and algorithm execution (Qian et al., 2015). First, the image is divided into image objects by a process of segmentation. Then, training samples for each class are collected from those image objects. The image objects are then classified with respect to a rule-based procedure or by using machine learning based on training samples, such as the K nearest-neighbor classifier, in which fuzzy membership functions are used to assign objects to the classes in the Cognition software (eCognition, 2012), decision tree, and Support Vector Machine (SVM) (Qian et al., 2015).

Image segmentation, which is first step of OBIA, is dividing an image into different types of regions or classes and recognizing the objects (Farnoosh and Zarpak, 2008). In other words, segmentation is the grouping of pixels to form meaningful objects with respect to spatial and spectral information (Li et al., 2011). Multi-resolution segmentation, which was developed by Baatz and Schäpe (2000) and has different homogeneity criteria for image objects based on spectral and/or spatial information, is the most widespread segmentation method in eCognition software (eCognition, 2012), The first step of this segmentation process is each pixel forming one image object or region. A pair of image objects is merged into one larger object at each step. The principle of the merging decision is the local homogeneity criterion, describing the similarity of adjacent image objects (Baatz and Schäpe, 2000). The criterion stops when heterogeneity among the objects is at a maximum and homogeneity among the objects is at a minimum (Li et al., 2011).

The homogeneousness criterion used in segmentation is defined by Equation 3:

$$h = w_{color} . h_{color} + (1 - w_{color}) . h_{shape} \qquad (3)$$

where fusion factor (h) contains object features, such as shape and color, w_{color} defines the weight of each spectral band, h_{shape} defines the spatial heterogeneity, and h_{color} defines the spectral heterogeneity.

$$h_{color} = \sum_c w_c(n_{o3}. \sigma_c^{o3} - (n_{o1}. \sigma_c^{o1} + n_{o2}. \sigma_c^{o2})) \qquad (4)$$

where w_c defines the weight of c spectral band, n_{o3} defines the number of pixels in the object to be merged, n_{o1} defines the number of pixels in Object 1, n_{o2} defines the number of pixels in Object 2, σ_c^{o3} defines the variance of the objects to be merged, σ_c^{o1} defines the variance of Object 1, and σ_c^{o2} defines the variance of Object 2 in Equation 4.

The shape of heterogeneity (h_{shape}) is calculated by compactness (h_{comp}) and smoothness (h_{smooth}) components (Equation 5).

$$h_{shape} = w_{comp} . h_{comp} + (1 - w_{comp}) . h_{smooth} \qquad (5)$$

The combination process stops when the f (scale parameter) reaches a pre-calculated threshold value. While a smaller-scale parameter yields smaller object sizes, a larger-scale parameter results in larger object sizes. The scale parameter is used to control the average image object size (Baatz and Schäpe, 2000).

2.3. Support Vector Machines

SVM classification based on statistical learning theory is a controlled classification algorithm (Karakus et al., 2017).The non-linear mapping of input data in a very high-dimensional space is the basis for Support Vector Machines (SVM) in both. Given a training data set of two separable classes, with samples represented by $(x_1, y_1) \dots (x_r, y_r)$, where $x \in R^N$ is an N-dimensional space, and $y \in \{+1, -1\}$ is the class label, a hyperplane separates two classes according to equation 6:

$$wx_i + b \leq -1 \text{ for } y_i = -1, \text{ and } wx_i + b \geq 1 \text{ for } y_i = 1 \qquad (6)$$

where, **w** is the weight vector ($\mathbf{w} = \{\mathbf{w_1}, \mathbf{w_2} \dots \mathbf{w_n}\}$), **n** defines the number of attributes, and **b** defines a constant.

The distance between two hyperplanes is determined by $\frac{2}{||w||}$. The optimum hyperplane, which separates two classes, can be determined by minimizing $||w||^2$. In case two classes are not linearly separable, ε_i slack variable is used to find the hyperplane with the maximum distance. (Equation 7):

$$y_i(wx_i+b) - 1 + \varepsilon_i \geq 0 \quad (7)$$

To make the classification error minimum and the distance between two hyperplanes maximum, a user-defined positive turning parameter, C, is used (Equation 8) (Song et al., 2012):

$$\min\{\frac{1}{2}\|w\|^2 + C\sum_{i=1}^{n}\varepsilon_i \quad (8)$$

Another parameter used is a kernel function, which is applied when the data are not separated linearly. These functions transform data to a higher-dimensional space where two classes are separated. The decision rule is obtained and defined as Equation 9. In this equation, α_i, $i = 1 \ldots r$ are Lagrange multipliers, and $K(x_i, x_j)$ is a kernel function (Tso and Mather, 2009):

$$f(x) = \mathrm{sign}\left(\sum_{i=1}^{n}\alpha_i y_i K(x_i, x_j) + b\right) \quad (9)$$

There are many well-known kernels, such as Polynomial, Radial, Gaussian and Sigmoid functions. Kavzoğlu and Çölkesen (2010) pointed out that the Radial-based kernel yields the best results of those kernels. A Radial-based kernel is defined as:

$$K(x_i, x_j, \sigma) = \exp\left(-\gamma\|x_i - x_j\|^2\right), \gamma > \quad (10)$$

2.4. Classification Process

There were many different land use classes, for example, building 1, concrete (white)-roofed building; building 2, tile (red)-roofed building; and building 3, sheet metal (black)-roofed building in the study area. The WorldView-2 satellite image used in the study was fused to better distinguish such land use classes. The HPF fusion method was preferred to preserve the spectral characteristics of images better and to produce better results (Gül et al., 2013; Nikolakopolos et al., 2015).

Segmentation and classification procedures are the two main steps of the object-based approach. First, the image is divided into sub-segments by segmentation. Each sub-segment is called an image object. Then, sample areas for each class are collected from these segments. The segments are then classified with respect to the collected segments.

In this study, optimal parameter values for segmentation, for example, scale parameter, shape, and compactness, were first defined by user trial-and-error. Optimal parameter values of scale parameter, shape, and compactness were 100, 0.5 and 0.1, respectively. Then, images were divided into segments according to the optimal parameters. Finally, those segments were classified by using the SVM algorithm in the eCognition software (Figure 3).

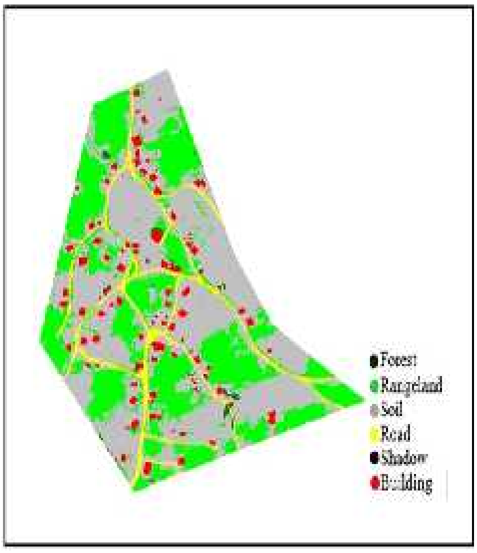

Figure 3. Classified image

To improve the classification accuracy, the classes that were mixed as a consequence of segmentation were separated from each other through rule sets. In those rule sets, the NDVI and ZABUD indexes were used to increase the segmentation accuracy as well as spectral information. NDVI values of the MS images of the study area were calculated by utilizing the formula below:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (11)$$

The green field and soil classifications, especially, were separated from each other through the use of the NDVI. In addition to this, for the separation of building and road classification, the ZABUD index, found in Lewinski (2006) was utilized. The ZABUD index used for the WV-2 satellite image was calculated by the equation of:

$$ZABUD = [(Green - Red)^2 + (Red - Red\_edge)^2 + (Red\_edge - NIR1)^2 + (NIR1 - NIR2)^2 + (NIR2 - PAN)^2]^{0.5} \quad (12)$$

Finally, shadow classes are included in those classes by combining them with the neighboring classes. Thematic images were obtained to produce land use maps. Those images were then added to the database after being converted to vector data. Change detection analyses were fulfilled through the queries of the database.

2.5. Accuracy Assessment

The multinomial distribution approach suggested by Congalton and Green (1999) was utilized for accuracy assessment. The confidence interval was selected as 95%, and the degree of freedom as 1. Class numbers in the study area were defined as 4 in the Ağaçlı and Limanoba rangelands, 6 in Karadağ and Simba rangelands, and 5 in other rangelands. Also, to determine a one-year change in the rangelands enjoying high popularity, class 9 was chosen in the accuracy assessment in the study undertaken. To use them in the

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accuracy assessment, numbers for each of the classes were randomly omitted in compliance with the “stratified random” method; namely, points were omitted in regard to the space that they occupied on maps. To create the error matrix in the multinomial distribution approach, omitting 30 points is sufficient on behalf of each class (Congalton, 2001). Thus, a minimum of 30 points was chosen for the analyses.

For the minimum number of points to be used in the accuracy analysis, equation 13 was used.

$$n = \frac{B}{4b^2} \quad (13)$$

In equation 13, B is the equivalent of the value calculated with $\frac{\alpha}{k}$ at a degree of freedom of 1 in the distribution table of χ^2 according to k number of classes and α margin of error. Here, b, stands for the margin of error, and n stands for the minimum number of samples. An error matrix is frequently used to assess the thematic accuracy of a land cover map (Stehman, 1997). For that purpose, error matrices were created to assess the accuracy of each classification result, using a minimum point number calculated with equation 13 according to class numbers (Table 1).

Table 1. Minimum points for accuracy assessment

Class Number	α/k	χ^2	Minimum point number
5	0.010	6.64	664
6	0.008	7.05	705
9	0.005	7.74	774

Overall, classification accuracies obtained with error matrices and kappa values calculated are given in Figure 4.

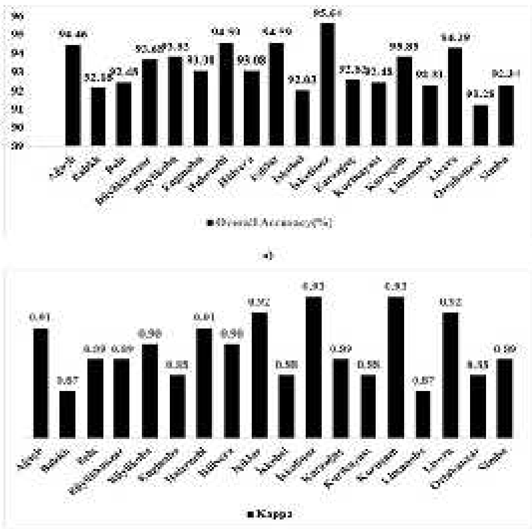

Figure 4. a) Overall classification accuracies b) Kappa values

Kappa values were calculated by using equation 14 (Keno et al., 2014).According to Figure 4, overall classification accuracies of between 91.28% and 95.64% were obtained for 19 rangelands.

$$\text{Kappa} = \frac{(\text{observed accuracy} - \text{chance agreement})}{(1 - \text{chance agreement})} \quad (14)$$

3. Result and Discussion

3.1. Change Detection

In the study, up-to-date and past land use maps were generated for change detection analysis of the rangelands. According to the change detection analysis, the building areas, which had been defined as 6 hectares, reached 6.9 hectares by increasing 15% by the year 1982, while the number of the buildings increased from 1085 to 1190. Road areas increased from 22.8 hectares to 30.6 hectares, the road length reached 83 kilometers, with an increase of 22% from 15 kilometers. Forestlands regressed to 74.5 hectares with a decrease of 0.9 hectare. As a consequence, it was determined that rangelands regressed to 1184.9 hectares, with a decrease of 7.8 hectares (Table 2).

Table 2. The total amount changes of all the rangelands over the years.

Year	Building		Road		Rangeland + Soil	Forest	Lake
	Area (ha)	Number	Area (ha)	Length (km)	Area (ha)	Area (ha)	Area (ha)
1973	6	1085	22.8	68	1192.7	75.4	0
1982	6.9	1190	30.6	83	1184.9	74.5	0
2012	17.5	2156	60	138	10329	186.6	0.9

According to the analysis of the extent of change between the years of 1982 and 2012, the building areas increased from 6.9 hectares to 17.5 hectares, with a 154% increase. In addition, the number of buildings increased from 1190 to 2156, with an 81% increase. According to the analysis of the extent of change between the years of 1973 and 2012, road area and length also increased in proportion to the number of buildings. Road areas increased from 30.6 hectares to 60 hectares, while the road length value increased from 83 km to 138 km. Similarly, the forestlands in rangelands in which there was no placement increased from 74.5 hectares to 186.6 hectares. Reforestation in the rangelands contributed to that increase. When those areas (building, road, forest, and lake areas) were subtracted from the total areas, rangeland areas regressed from 1184.9 hectares to 1032.9 hectares (Table 2).

Furthermore, the annual changes between the years 2012 and 2013 were examined for the Hıdırnebi, Kuruçam, and Balıklı rangelands, which are close to the city center and commonly used. According to the annual change in those rangelands, the number of buildings reached 447, with an increase of 39 buildings. The total of the building areas was 3.89 hectares,with an increase of 0.28 hectares. Also, when the road area increased by 0.64 hectare, the road length increased by 2 kilometers. The soil area decreased by 0.26 hectares, and the forest

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land decreased by 1.04 hectares. A large portion of the decreased soil area was made up of areas that were converted into fields, planted in 2012, and then non-planted in 2013. Consequently, the total extent of decrease in those three rangelands was determined to be 2.86 hectares (Table 3).

Table 3. The one year change in the pilot stud

Year	Building		Road	Rang.	Soil	Field	Forest
	Area (ha)	Number	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)
2012	3.61	408	6.5	95.41	3.13	21.69	8.37
2013	3.89	447	7.14	92.55	2.87	24.93	7.33

As seen above, the decrease in rangelands continues each passing day. In the process seen from last year, the rapid increase in the number of the buildings demonstrates this. The destruction will be parallel with the increased number of buildings, and destruction of the rangeland areas will increase.

3.2. Current Rangeland Information System

The existing rangeland information system has been built in an attempt to ensure centralized management of rangelands by preventing data confusion and protecting rangelands. The current information system contains information about not only the surface areas and borders of rangelands, but also the properties of rangelands (inclination, land use class, and number of livestock). The majority of the data about the condition of lands recorded in the current system is obtained through field studies. Studies conducted on areas having very large surface areas cannot be frequently conducted or updated. As a consequence, changes in the areas cannot be detected in a timely manner.

If the data infrastructure of the current rangeland information system shown in Figure 5 is reviewed, it is evident that the system is used for archiving the information entered and for querying the existing information rather than for identifying problems related to rangelands, suggesting solutions, or performing processes and analyses to that end.

If the extent of change ascertained within the scope of the study is analyzed, it is understood that those areas have not been used properly and that controls have not been carried out to their full extent. Persistence of these problems can be explained by mismanagement and incapability.

3.3. Designing A Sustainable Rangeland Information System

Given the change analysis results, it is thought that the destruction of rangelands persists to the present day, and, if necessary measures are not taken, will continue to a greater degree.

Thus, deficiencies of the information system currently used in the management of rangelands were identified, and a sustainable rangeland information system directed to solve these problems was suggested. The system designed in Figure 6 is based on the images of rangelands, which are obtained by remote sensing and photogrammetric techniques, and on thematic maps, which are produced from these data by image processing techniques. Furthermore, vector and raster data that need to be used or produced for different analyses, which can be conducted in the information system and attribute information, are demonstrated in the model.

A major part of the data that can be used in analysis and evaluation studies was produced in the information system designed within the framework of the study. For example, previous and current land use maps, forming the basis of the model, and maps of change, formed for the purpose of determining the change in land use, were produced. Also, a digital terrain model was produced by using high-resolution aerial photographs.

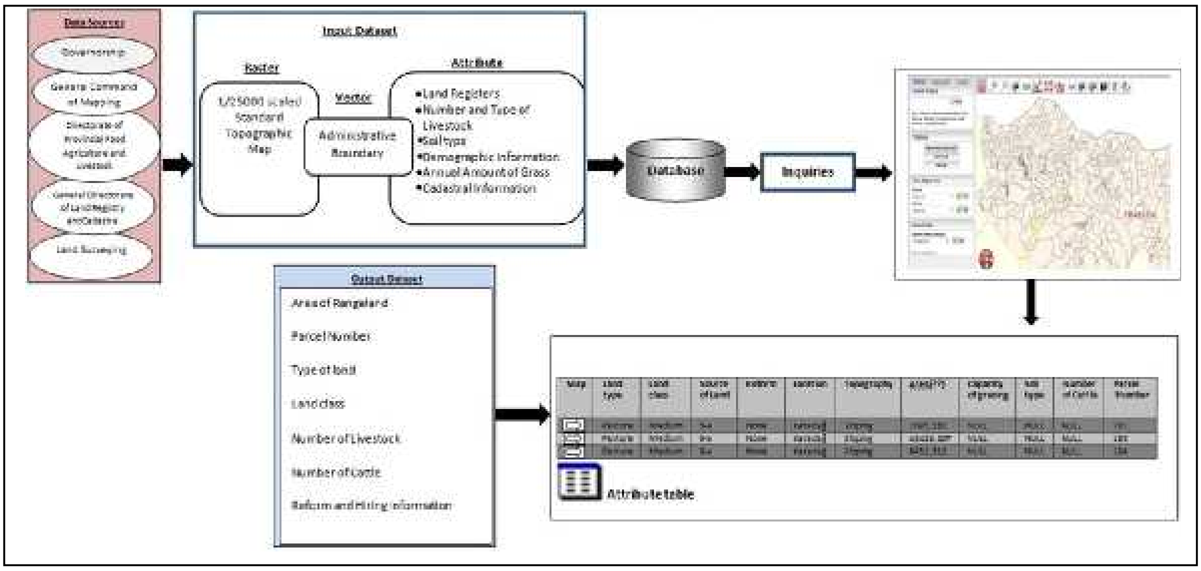

Figure 5. Current rangeland information system

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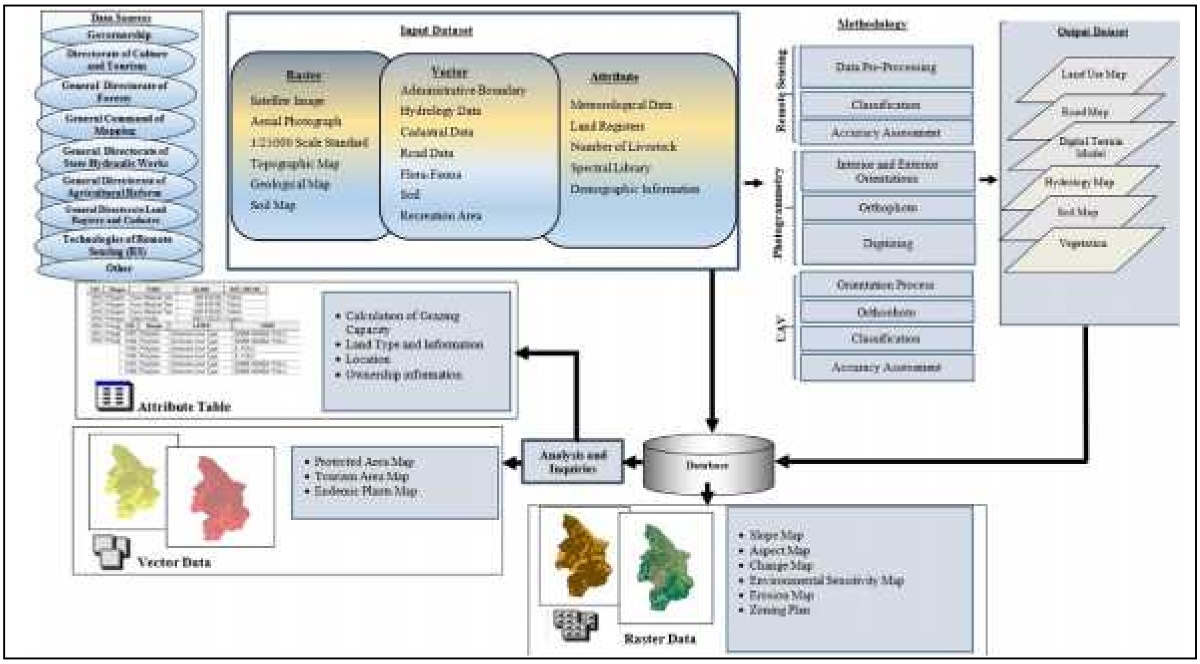

Figure 6. A new rangeland information system

Furthermore, a present-time map was generated by using UAV images, and up-to-date road network maps were generated by using WV-2 images (Figures 7 and 8).

The most important feature of the information system designed is that it is sustainable, because data is obtained periodically, and it has a dynamic structure. It allows for making all kinds of analyses and evaluations. When maps are produced following classification of the images obtained periodically, any change that occurs in the land will be detected, and problems will be responded to in a timely manner.

For instance, with these maps it will be possible to detect shanty settlements in rangelands, as well as accompanying problems, deterioration in land structure, and conditions of the rangelands in a short time. As rangelands are periodically monitored, diseases and deteriorations in rangelands will be identified, and the thematic maps produced will greatly contribute to the determination of the areas that need to be prioritized in the intended improvement projects.

It will also be possible to make analyses and evaluations in digital environments for many different study areas by using the data generated from the information system. Result maps may also be produced, including those of studies intended to determine the most suitable locations for areas to be offered to tourism. The information system may also produce environmental protection maps, erosion maps, current road maps and road network plans for new roads to be built, grazing plan maps (to be generated by using aspect maps), endemic species maps, and maps for determining plant species protection areas.

In addition to those, further studies that are of great importance for rangelands and must be included in the information system need to be conducted. One of the most significant studies to be conducted is the recalculation of rangeland grazing capacities by the use of remote sensing techniques and data about current land conditions to generate maps showing the rangelands' grass diversity. Those studies must utilize satellite images taken periodically or hyperband images taken by a UAV, as well as data obtained as a result of field studies performed simultaneously with the imaging.

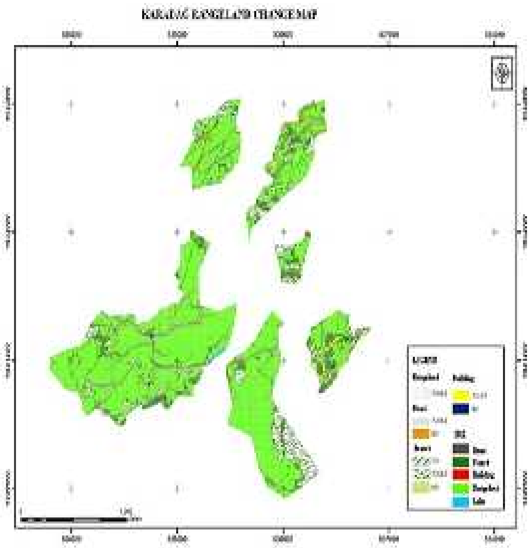

Figure7. Karadag rangeland change map

Ultimately, with this designed information system, a single institution will again have power and responsibility. In addition, the ability to obtain a major part of the data quickly and periodically by means of remote sensing technologies will introduce to the information system the capabilities of query, sustainability, and analysis and evaluation, along with principles of objectivity. With such a rangeland management system, rangelands will be protected, and the national economy will improve by increasing rangeland productivity.

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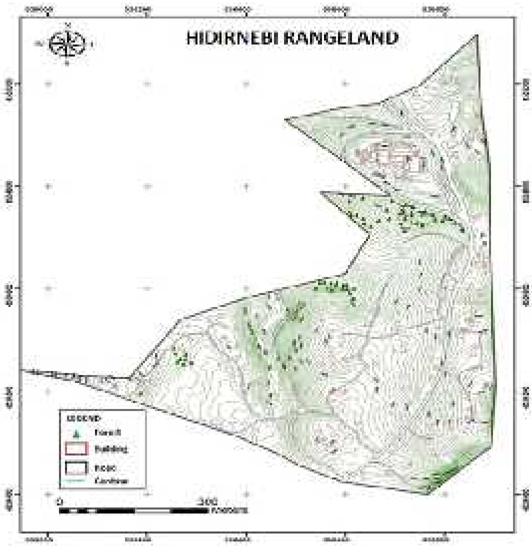

Figure 8. Hıdırnebi present time map

4. CONCLUSION

In the scope of this study, land use maps of rangelands were generated for past and current years. Then, by using these maps, temporal changes in rangelands were determined. A database was created with information about the rangelands in the study area for analyses and queries. According to the results of the study, the structure of the current rangeland information system was examined, deficiencies were identified, and a sustainable rangeland information system was designed with the aim of eliminating the deficiencies.

The results of the study demonstrate that, in the event necessary inspections and controls are not carried out in rangelands, negative effects will occur in increasing proportions. To protect and maintain those areas, it is very important to periodically monitor the areas, to promptly respond to the problems identified, and to recover any damage that occurs—all of which are possible only through sustainable rangeland management.

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DESIGNING HIGH RESOLUTION COUNTRYWIDE DEM FOR TURKEY

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ABSTRACT: Digital Elevation Models (DEM) are widely used in many different applications such as orthophoto production, 3D city models, hydrological modeling, visibility, flood, flood analysis and etc. The densest grid spacing DEM covering Turkey is the DTED-2 data produced by the General Command of Mapping with a grid spacing of 1 second (approximately 30 m). Denser and more accurate DEM is produced by several institutions in only required areas but not covering whole country. Governmental institutions need denser, more accurate, homogeneous and countrywide DEM. This study is conducted to meet DEM demands with optimum accuracy and density by stereo aerial photos. In order to investigate the optimal resolution for a countrywide DEM, test DEMs are produced in three different areas representing the general topographic structure of Turkey by using 45 cm ground sampling distance stereo aerial photos. The Root Mean Square Error (RMSE) of the heights of three areas are respectively ± 2.51 m, ± 1.38 m and ± 1.30 m. The proposed grid spacing by INSPIRE with these accuracies is 3-30 m in flat terrain and 3-15 m in mountainous terrain. It is concluded that 5 m grid spacing will be suitable for a countrywide DEM with the above mentioned accuracies. It is also proposed that production format of DEM should be 32 Bit Floating GeoTiff.

Keywords: *Digital Elevation Model, aerial photos, automatic image matching, countrywide DEM*

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1. INTRODUCTION

Terrain surface elevations are the most commonly used geographic information. These data are distributed as Digital Elevation Model (DEM) and their derivatives are used in a wide range of applications such as orthophoto production, 3D city models, hydrological modeling, visibility and flood analysis (Fisher et al., 2006).

Grid structure is the most common geographic data model used in modeling terrain and underwater heights. Grids are represented by a set of regular or evenly distributed points. Because the altitudes are at regular intervals, only an elevation value is stored on a horizontal coordinate. By taking advantage of this point, the horizontal position of the other points can be determined together with the reference coordinate information. Grid is also an easy structure for data processing. The grid spacing can be chosen to be most effective according to the size and the density of the land surface to be modeled (Federal Geographic Data Committee, 2008).

DEMs are divided into two according to the topographic features they represent. Digital Surface Model (DSM) refers to DEM which covers human made structure and vegetation cover. Digital Terrain Model (DTM) refers to the remaining surface of the bare earth when the above mentioned details are omitted (Figure 1) (Höhle, 2009).

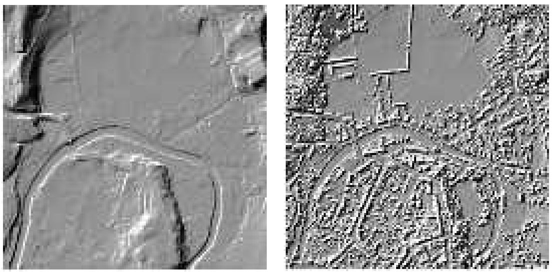

Figure 1. DSM (on the left) and DTM (on the right)

DEM is the product of a series of modeling and processing steps. DEM can be obtained from sources such as terrestrial measurements, contours, vector data, aerial photos and satellite images, aerial and space radar data (synthetic aperture) and laser scanning (LIDAR). DEM contains mistakes due to the source and method of production. The fact that these errors are known in DEM is also important in terms of identifying the mistakes caused by the use of DEM in various applications.

Fisher et.al., (2006) put forward three main error sources for DEM: one from the source data including accuracy, density and distribution; the other from production method the DEM from the source; and lastly from the topography of the terrain being modelled.

Höhle (2009) found ±13 cm standard deviation vertical accuracy for the DEM produced from different digital aerial cameras with 60% overlap and 6 cm Ground Sampling Distance (GSD) aerial photos. He related the known elevation error formula with the image matching accuracy which is also a function of photogrammetric software system and the GSD of the aerial photos used.

Pulighe et al., (2013) used 1:34,000 scale analog aerial photos scanned at 1200 dpi resolution (which means 0.70 cm GSD) for DEM production. He produced 5 m grid spacing DEM autocorrelation and obtained ±4.90 m Root Mean Square Error (RMSE) at checkpoints.

In Turkey; the first DEM productions were carried out in the 1980's by General Command of Mapping (GCM). These DEMs were produced with a spacing of 15 "x 20" by reading the elevation values from hardcopy maps. In 1989, the contours were digitized from hardcopy maps. This product, called YÜKPAF, is a vector created by transferring the sea, lake and wide bed creeks, altitude and landmark points in the topographic maps to the computer environment together with altitudes from sea level. Two different resolution DEMs were produced: one from 10 m spacing contours for 1: 25.000 scale (YUIKPAF 25) and the other from 100 m spacing contours for 1: 250.000 scale (YUKPAF250). Production of 1:25.000 scale YUKPAF was carried out between 1989 and 1999, 1:50.000 scale YUKPAF production was carried out between 1994 and 2005, and 1:250.000 scale YUKPAF production was carried out between 1992 and 2001.

Production of first level DTED (Digital Terrain Elevation Data) which can be used in various weapons systems, engineering services, field applications and simulators with a 3 second interval, second level DTED production with 1 second intervals and second version of second level DTED production were completed in 1994, 1998 and 2001 respectively from YUKPAF. DTED is a land height value in the form of a uniform matrix that is developed by the National Geospatial-Intelligence Agency of USA (NGA) to support military applications, providing basic data on systems or applications that require information such as land height, slope and/or surface roughness. DTED Level 0; 30 arc-seconds spacing (nominal 1 km), DTED Level 1; 3 arc-seconds spacing (nominal 100 m) and DTED Level 2; 1 arc-arc spacing (nominal 30 m) height data (NATO STANAG MIL-PDF-89020B). In the production of DTED, topographic map data was used first and then Space Shuttle RADAR Topography Mission (SRTM) was used. Other remote sensing techniques, aerial photos, field survey and LIDAR systems can also be used to generate DTED data. The accuracy criteria for DTED-2 in NATO STANAG MIL-PDF-89020B are 23 m horizontally and 18 m vertically.

The accuracy of DTED-2 and SRTM-1 are investigated in a study conducted on İzmir Region. They are compared with accurate 308 geodetic control points. It is found that DTED-2 has ± 3.85 m RMSE and SRTM1 has ± 4.45 m RMSE (Fırat et al., 2015).

Over time, DTED-2 has not been able to meet the high accuracy and resolution DEM requirements of users. General Command of Mapping which is the responsible institution for countrywide mapping for middle and small scales mapping for Turkey, has begun to investigate how to produce digital elevation models in the most appropriate accuracy and grid spacing to meet the user needs. In order to find a medium to resolve the accuracy and grid spacing, digital surface and terrain models were produced with dense image matching in three different regions. The accuracy of DTED-2 and SRTM-1 data for the same regions were also investigated and optimal resolution was suggested within the scope of INSPIRE criteria according to the accuracy of automatically generated DEM.

The aim of this paper is not to make an accuracy assessment of DEM produced from stereo digital aerial photos, but to investigate the optimal resolution for a countrywide DEM regarding the accuracy of automatically generated DEM. In the following sections, the countrywide DEM production of different countries is analyzed at the beginning; then the accuracy and optimal grid spacing of DEM produced in three different areas are investigated; lastly some conclusions are drawn.

2. COUNTRYWIDE DEM PRODUCTION APPLICATIONS IN DIFFERENT COUNTRIES

The German Federal Cartography and Geodesy Agency (BKG) has introduced digital elevation models across the country between 1: 50.000 and 1: 1.000.000 scales and approx. ± 20 m vertical accuracy by 2003, while the federal states in the same period have digital elevation models between 1: 5.000 and 1: 50.000 scales and with ± 0.3 m and ± 5 m accuracy. However, there was no national high-precision digital elevation model. For this purpose, firstly a digital elevation model was produced with accuracy between ± 1 m and ± 3 m on 1:25.000 map scale. Subsequently, BKG had to combine digital elevation models produced at different intervals, in different coordinate systems, with different accuracies and with different production methods (laser scanning, photogrammetry, digitization of analogue maps), and quality controls were carried out with GNSS measurements in the relevant areas (Hovenbitzer, 2004). The BKG now presents elevation models at 10 m, 25 m, 50 m, 200 m and 1.000 m grid intervals. From these data, 200 m and 1.000 m grid spacing DEMS were produced from contours obtained from 1: 500.000 scaled maps; those with 10 m, 25 m and 50 m grid spacing were obtained from laser scanning, photogrammetric methods and contours. The elevation accuracy of the 10 m grid spacing digital elevation model is between ± 0.5 m and ± 2 m (Bundesamt für Kartographie und Geodäsie (BKG), 2012).

The Canadian Topographic Information Center (CTI) produces the Canadian Digital Elevation Database (CDED) jointly with federal and regional government agencies and the private sector. The data is presented as Geobase Level 1, which is represented between 1:10,000 and 1:250.000 average scales in resolutions according to the region. The main source for CDED is the hypsographic and hydrographic data of the National Topographic Database. The grid spacing for the 1: 50,000 scale CDED is 0.75 arc-seconds in the north-south direction (approximately 23 m). In the west-east direction, it ranges from 0.75-3 arc-sec (about 16-11 m). The accuracy of the data is less than ±5 m in vertical, depending on the production method and area. CDED is presented in a grid of 1201 rows and columns (Canada Center for Topographic Information, 2007).

The National Elevation Data Framework (NEDF) has been established in Australia to provide easier access to existing elevation data and to provide the most appropriate solution for collecting new data. The project started with the aim that use of the data from all sources with the highest resolution available and find out the need for the digital elevation model in all public levels. The first review of the data was made in 2008. The data consists of digital elevation models from the SRTM with 1 and 3 second intervals covering the entire continent, and digital elevation model with 9 second intervals, and also increasing high resolution elevation data available in residential areas and open coastal areas in danger (Geoscience Australia, 2011).

The National Elevation Dataset (NED) is the base elevation data generated and distributed by the U.S. Geological Survey (USGS). The NED provides uninterrupted grid elevation data in the United States, Alaska, Hawaii, and the islands. NED consists of data produced from different sources according to a specified resolution, coordinate system, and elevation unit, horizontal and vertical datum. The production steps of the data are shown in Figure 2 (Gesch et al., 2002).

The NED data is presented at grid intervals of 1 arc-second seamlessly for the entire United States, and at 1/3 and 1/9 arc-bases intervals for some parts of the United States. There is also a layer of metadata that can be accessed via web as a separate layer with elevation data, such as data source, production style, coordinate system, horizontal and vertical datum, and elevation unit. NED data accuracy is tested by geodetic control points used by the US National Geodetic Survey Unit in gravity and geoid modeling studies. In 2003, it was determined that the accuracy of the whole data was ±3.99 m absolute vertical accuracy at the 90% confidence interval carried out with 13.305 point. The NED is provided through a web service and the users can download the data using an interface. Data covering very large areas are provided to the user via external storage units (U.S. Geological Survey (Gesch et al., 2002).

To support a splendid knowledge about the vertical accuracy of the NED, 2013 version of the dataset was tested with 25,000 survey points in centimeter level accuracy. It was found that RMSE of ±1.5 m vertical accuracy at 95th percentile. Also NED was compared with other large area elevation datasets, i.e. SRTM data and ASTER Global Digital Elevation Model (GDEM). The NED was proved to be more accurate than SRTM and ASTER GDEM with a RMSE of 4.01 meters for SRTM and 8.68 meters for ASTER GDEM in spite of RMSE of 1.84 meters for the NED (Gesch et al., 2014).

Several studies are carried out about the accuracy of SRTM-1 and ASTER GDEM. Bildirici et al., (2017) compared SRTM and ASTER GDEM with the DEM produced from 1:25K Turkish standard topographic maps. They found that SRTM-1 gives better accuracies according to ASTER GDEM on test areas. Bildirici et al., (2013) also tested SRTM-3 accuracy over Turkey and found that SRTM-3 is about 13 m in accordance with 1:25K national DEM.

Yue et al. (2017) combined SRTM-1, ASTER GDEM and ICESat DEM in order to produce a more accurate void filled data over China. The results show that combined dataset has a better data quality compared with the original dataset.

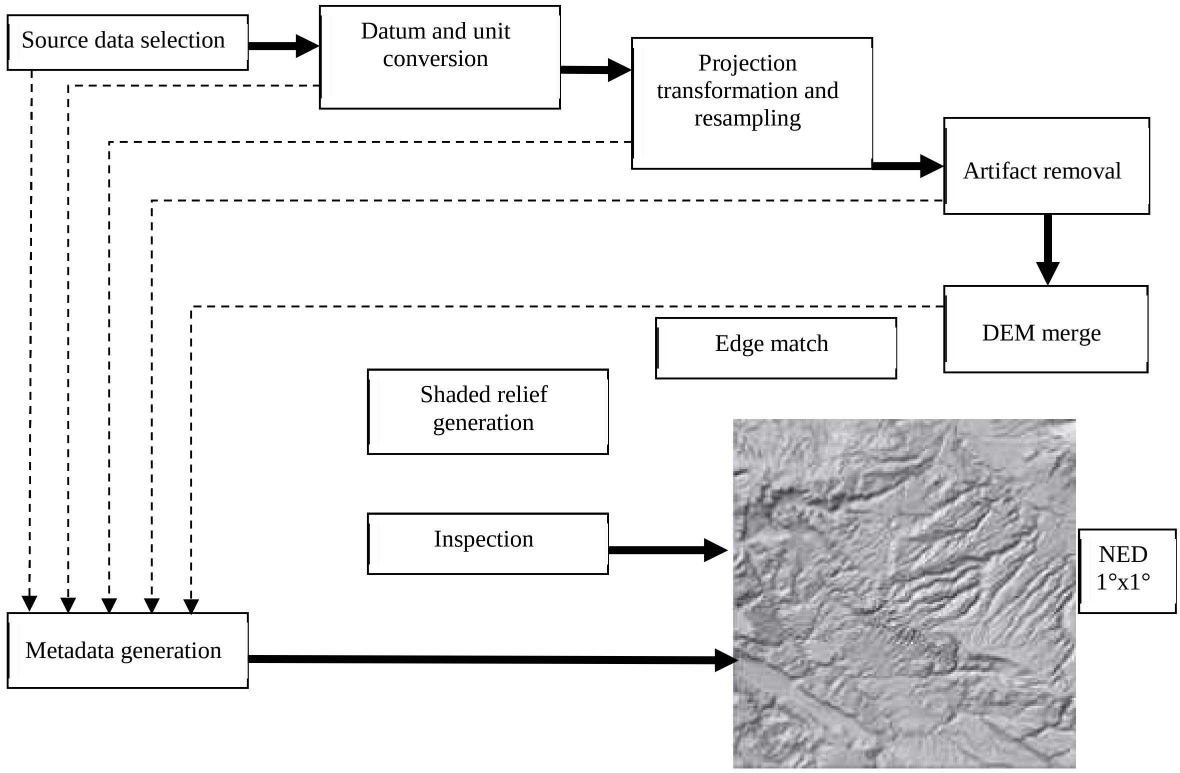

Figure 2. NED production workflow (Gesch et al., 2002)

3. HIGH RESOLUTION DEM PRODUCTION ANALYSIS

With the introduction of digital aerial cameras, the radiometric and spatial resolutions of the images have increased, and automatic matching algorithms of the software have been developed. In particular, dense image matching (Haala, 2012) or semi-global matching (Hirschmüller, 2011) algorithms provide a significant improvement in the accuracy of automatically generated DEMs. Depending on these developments, DEM can be produced almost automatically on a pixel-by-pixel basis.

It was in 2008 that first digital aerial camera was being used for aerial photo acquisition by GCM. The aerial photo acquisition began with capturing 45 cm GSD photos, but then the GSD has increased to 30 cm regarding the countrywide high resolution image requirements. Although there are more high resolution aerial photo requirements for residential areas 10 to 5 cm GSD, countrywide mapping goes on 30 cm GSD aerial photo acquisition nearly in every three years for Turkey. The aerial photos are mainly used for topographic map updating, orthophoto and DEM production. In order to meet the growing needs for a high resolution DEM, 30 cm GSD aerial photos are determined as source data.

In order to analyze the existing elevation data, 20 Ground Control Points (GCP) marked on the ground and determined the position with GNSS at ±7 cm positioning accuracy in elevation and 76 stereo Check Points (CP) read from aerial photo stereo models at identifiable points in Ankara region. DTED-2, SRTM-1 and 5 m resolution DEM produced from stereo aerial photos with autocorrelation (DEM5m) are the test datasets for this region. The elevation of GCPs and CPs are compared with the elevations of DTED-2, SRTM-1 and DEM5m. Vertical datum is EGM96 for SRTM-1 and TUDKA-99 (Turkish National Vertical Control Network) for other datasets. Since the datum difference between EGM96 and TUDKA-99 is about 0.5 m, it is neglected in the calculations (Tepeköylü et al., 2008). This difference decreases to nearly 30 cm for EGM2008 (Yilmaz et al, 2016). The mean difference, standard deviation (σ) at 68% and 90% Confidence Interval (C.I.) are given in Table 1. When Table 1 is examined, it is clear that DEM5m is superior to other DEM products even without editing.

Table 1. Accuracy assessment of existing DEMs

Source	# and Type of Control Points	Mean Diff. (m)	σ (± m) (% 68 C.I.)	σ (± m) (% 90 C.I.)
DTED-2	20 GCP	-0.73	3.21	5.28
	76 CP	-1.45	4.79	8.23
SRTM-1	20 GCP	1.23	2.29	4.27
	76 CP	1.72	2.65	5.21
DEM5m	20 GCP	-0.24	1.7	2.83
	79 CP	0.16	2.47	4.27

In order to test the accuracy of DEM5m, three test areas, which are Uşak L23-b3, Aksaray L30-a1 and Doğubayazıt J51-a1 are selected to represent the different types of topography over Turkey.

3.1. The Accuracy Assessment in 1:25,000 Scale UŞAK L23-b3 Map Sheet

UŞAK L23-b3 consists of medium density residential and wooded area (1/3 of the map sheet is dense forest); it reflects Turkey's topography with overall height differences (800 m - 2800 m); it contains flat and undulating terrain (Figure 3).

Figure 3. L23-b3 DEM (left) and orthoimage (right)

8,000 3D control points are precisely read from stereo models for accuracy assessment of the DEM. These 3D control points are evenly distributed to the test area representing all different characteristics of the topography. The accuracy of the stereo models after standard photogrammetric triangulation is ± 0.5 m in horizontal and ± 0.75 m. in vertical.

The streams from the photogrammetric compilation and breakelines have been used for the production of point cloud for the DEM. Also, other the parts of the terrain where the elevation changes abruptly are compiled as vectors and incorporated into the point cloud.

First, the existing DTED-2 and SRTM-1 data of the study area were investigated with 3D control points and the results were given in Table 2. During the photogrammetric revision made in this map sheet, contours were also improved. A DTM was generated from the improved contours and other vector data (creek, lake, etc.) which may contribute to the height. The accuracy of the vector DTM was also included in Table 2. After comparing the accuracy of the DTM generated from the improved contours with the existing DTED-2 data, the improved contours provides an improvement of about 2 meters in DTM accuracy.

Table 2. L23-b3 DTED-2, SRTM-1 and Vector DTM accuracy assessment

Data	#of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
DTED-2	109	-1.04	7.19	11.95
SRTM-1	152	-1.81	6.55	11.18
Vector DTM	107	-0.39	5.74	9.47

Note: C.I.: Confidence Interval.

For the production of DTM with higher accuracy and resolution, the existing stereo aerial photos were used for automatic DTM production with 5 m grid spacing; streams, creeks and breakelines were used as ancillary data. Inpho Match-T software is used in automatic DTM production.

After the DTM point cloud produced in Inpho MatchT software is controlled on stereo aerial photos in DTMaster Stereo software it is inferred that;

- DTM produced in bare surface areas represents the topography very well,
- In the wooded and forested areas, it represents the topography as surface but passes over the forest and wooded areas,
- Mistaken points can be automatically eliminated,
- It is important that the inclusion of breakelines (streams, creeks etc.) in DTM production is essential for the contour production (Figure 4),

Figure 4. Contours produced with streams included

- The inclusion of ridge lines is not appropriate as breakelines because the system sharpens the ridge slope in these regions and this data should be included as softlines (Figure 5),

Figure 5. Ridge lines and produced contours

- It is necessary to pre-draw lines perpendicular to the ridge lines in order to include the bare ground in the wooded areas,
- Extremely wide wooded areas can be corrected with operator intervention simply by the Stereo Editing software (Figure 6),
- The editing made with the Stereo Editing software are the result of the new situation reflecting the "on the fly"
- If the tree dimensions are close to each other in the forest areas, the height of the selected area can be

lowered to the ground,

- Since the tree sizes usually differ in the forested areas, it is necessary to make corrections by drawing the lines of the breakelines in the places where the ground can be seen in the Stereo Editing software.

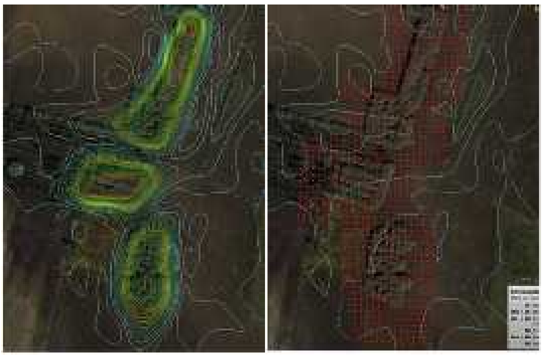

Figure 6. Mistaken point cloud for trees (left) and corrected point cloud for DTM (right)

The above ground points in the automatically generated DTM, such as buildings, trees and etc., were dropped down to the bare ground in stereo editing software either by using additional vector data on the ground or automatic correction tools of the software. Then 5 m, 10 m, 15 m and 20 m grid spacing DTMs were obtained and compared with 8,000 control points. The result of the accuracy assessment is presented in Table 3. When Table 3 is examined, it is seen that the grid spacing of 5 m or 10 m does not significantly affect the accuracy. It is seen that increasing the interval to 20 meters decreases both the accuracy and the number of points passing 3σ.

Table 3. L23-b3 accuracy assessment of different grid spacing for edited DTMs.

Grid Spacing (m)	# of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
5	341	-0.17	1.52	2.51
10	362	-0.13	1.59	2.62
15	554	-0.01	1.66	2.72
20	637	0.05	1.86	3.07

The 32 bit GeoTIFFfile sizes of 5 m and 10 m spacing are 25 MB and 6 MB respectively.

According to USA "Geospatial Positioning Accuracy Standards - FGDC-STD-007.3-1998"; the coefficient of 1.6449 is applied in the 90% confidence interval for the height accuracy that fits to the normal distribution.

$VMAS=1.6449 \times RMSE_Z$ (VMAS = Vertical Map Accuracy Standard)

$AccuracyZ=1.9600/1.6449 \times VMAS=1.1916 \times VMAS$

$VMAS = 1.6449 \times 1.52 = 2.50$ m

$AccuracyZ = 1.1916 \times 2.50 = 2.98$ m (95% Confidence Interval)

INSPIRE sets forth the formula given in Table 4 for determining grid spacing for elevation data.

Table 4. INSPIRE grid spacing standards

Proposed Grid Spacing	Ground Type
$3xRMSE_z \leq$ Grid Spacing $\leq 20xRMSE_z$	Flat and undulating terrain
$3xRMSE_z \leq$ Grid Spacing$\leq 10xRMSE_z$	Hilly and mountainous terrain

The recommended grid spacing according to the $RMSE_Z$ ($RMSE_Z \approx 1.6$ m) is calculated and given in Table 5.

Table 5. DTM grid spacing calculation

Proposed Grid Spacing	Ground Type
4.8 m ≤ Grid Spacing ≤ 32 m	Flat and undulating terrain
4.8 m ≤ Grid Spacing≤ 16 m	Hilly and mountainous terrain

When examining the grid spacing standards recommended by INSPIRE, one of the grid spacing of 5 m and 10 m for DTM would be appropriate to accurately reflect the characteristics of the topography from the digital stereo aerial photos and to be of sufficient accuracy.

The editing of the produced DTM (in a medium difficulty level) at an acceptable level takes 5 days, and additionally the editing of the contours takes 3 days. It is estimated that the correction of DTM of a 1:25.000 scale map sheet area completely covered with forest or dense buildup can last at least 10 days.

3.2. The Accuracy Assessment in 1:25,000 Scale Aksaray L30-a1 Map Sheet

The L30-a1 map sheet was chosen to reflect the little differences in altitude, high vegetation cover and settlement site density. The altitudes vary from 920 to 1008 meters (Figure 7). The map is located in the south west of the Salt Lake. It contains mostly flat terrain.

250 three-dimensional control points from stereo models are read precisely for the accuracy assessment of DEMs. The horizontal accuracy that can be obtained from the stereo models after standard photogrammetric triangulation applied to the used photos is ±0.5 m and the vertical accuracy is ±1.0 m.

First, the existing DTED-2 and SRTM-1 data of the study area were tested with three-dimensional coordinates read through the stereo models and the results are given in Table 6.

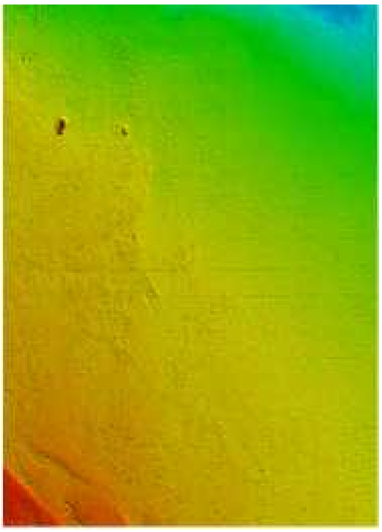

Figure 7. L30-a1 Digital Surface Model

Table 6. L30-a1 DTED-2 and SRTM-1 accuracy assessment

Data	#of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
DTED-2	2	-1.19	1.86	3.63
SRTM-1	0	1.26	1.25	2.93

Point cloud was collected as DTM using Inpho Match-T software in L30-a1 map sheet area and the automatically unfiltered terrain details were edited in stereo editing software. Resulting DTM was sampled as 5 m, 10 m, 15 m and 20 m in 32 bit Geotiff and accuracy assessment was carried out. The results obtained from the accuracy assessment are given in Table 7. When Table 7 is examined, there is no difference in accuracy levels between 5 m and 20 m grid spacing due to the fact that the land is very flat.

Table 7. L30-a1 accuracy assessment of different grid spacing for edited DTMs

Grid Spacing (m)	# of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
5	0	-0.71	0.45	1.38
10	2	-0.69	0.43	1.33
15	2	-0.69	0.43	1.34
20	1	-0.69	0.44	1.33

The total production of L30-a1 map sheet from DSM to DTM and DTM to contours lasted for two days, including editing works. The automatic production of contours (Figure 8) is not directly suitable due to terrain flatness. An operator intervention is required to edit the automatically produced contours in order to properly represent the topography with a cartographic sense.

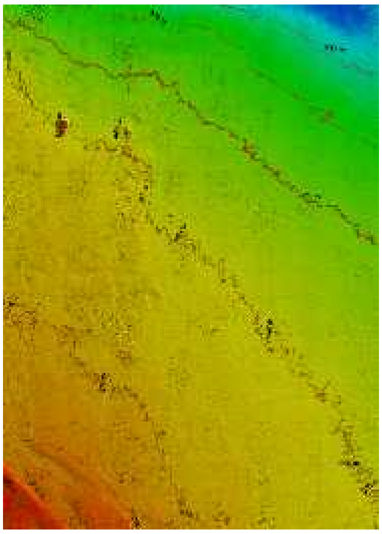

Figure 8. L30-a1 automatic contour production

3.3. The Accuracy Assessment in 1:25,000 Scale Doğubayazıt J51-a1 Map Sheet

J51-a1 map sheet is chosen for it represents the great height differences and deep valleys, high vegetation cover, and areas where the density of settlement is low. Heights in the field vary between 1930 and 3300 m (Figure 9). It contains hilly and mountainous terrain. The area is located in the north east of Van Lake.

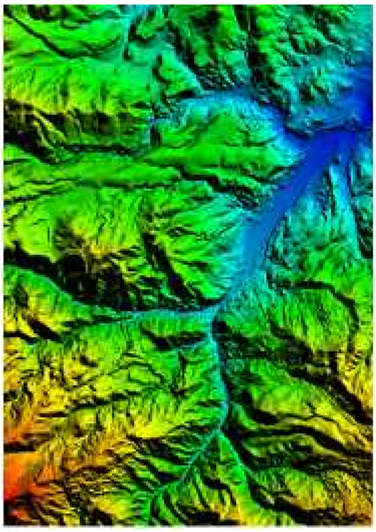

Figure 9. J51-a1 Digital Surface Model

124 three-dimensional control points from stereo models are read precisely for the accuracy assessment of DEMs. The horizontal accuracy that can be obtained from the stereo models after standard photogrammetric triangulation applied to the used photos is ±0.5 m and the vertical accuracy is ±1.5 m.

First, the existing DTED-2 and SRTM-1 data of the study area were tested with three-dimensional coordinates read through the stereo models and the results are given in Table 8.

Table 8. J51-a1 DTED-2 and SRTM-1 accuracy assessment

Data	#of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
DTED-2	3	-2.19	4.36	8.03
SRTM-1	2	1.20	4.84	8.20

Point cloud was collected as DTM using Inpho Match-T software in J51-a1 map sheet area and the automatically unfiltered terrain details were edited in stereo editing software. Resulting DTM was sampled as 5 m, 10 m, 15 m and 20 m in 32 bit Geotiff and accuracy assessment was carried out. The results obtained from the accuracy assessment are given in Table 9. When Table 9 is examined, there are no differences in accuracy levels at different grid spacing. Only the number of points exceeding 3σ is increasing. Selecting a grid spacing of 20 m will result in no height differences in details that are smaller than 20 m and will not be expressed in DTM, especially in creek cliffs and rocky regions.

Table 9. J51-a1 accuracy assessment of different grid spacing for edited DTMs

Grid Spacing (m)	# of points over 3σ (22 m)	Mean Error (m)	RMSE (± m) (68% C.I.)	Accuracy (± m) (90% C.I.)
5	1	-0.64	0.46	1.30
10	1	-0.67	0.48	1.36
15	3	-0.67	0.48	1.35
20	4	-0.67	0.53	1.41

4. RESULTS

When the accuracy assessments on the three different regions are examined, it can be seen that DTM, automatically generated from aerial photographs, has higher accuracy than other existing DTM data, namely DTED-2 and SRTM-1. The accuracy of the automatically generated DTMs, DTED-2 and SRTM-1 data available is given in Table 10 at 90% confidence interval.

Table 10. DTM accuracy assessment summary

Area	Height difference (m)	DTED-2 accuracy (± m)	SRTM-1 accuracy (± m)	DEM5m accuracy (± m)
L23-b3	800-1800	11.95	11.18	2.51
L30-b1	900-1000	3.63	2.93	1.38
J51-a1	1930-3300	8.03	8.20	1.30

When Table 10 is examined, DSM and DTM accuracies produced by automatic matching from aerial photos appear to be below ± 3 m when operator error and aerial photo orientation errors are summoned up. In areas with very flat, low vegetation coverage, accuracy is close to orientation of aerial photos.

Automatic DSM and DTM production from aerial photos takes about 40 minutes for a 1: 25,000 scale map sheet area, with a 4-core Xeon Dual processor workstation. For each map sheet area evaluated in the study, the time spent for editing from DSM to DTM and DTM to contours is given in Table 11.

Table 11. DTM accuracy assessment summary

Area	DSM to DTM (hours)	Editing automatic contours (hours)	Total time (hours)
L23-b3	43	19	62
L30-b1	6	8	14
J51-a1	13	17	30

When Table 11 is examined; it is seen that the most time spent on Usak L23-b3. The reasons for this are; the difference in altitude, the fact that 1/3 of the area is covered with dense forests, the presence of tree communities and bushes in the non-forested areas of area and the settlements. Aksaray L30-b1 map sheet has a height difference of about 100 m, with virtually no plant cover. Although the height differences are great in J51-a1 map sheet, the vegetation and the settlement are rare.

Are the whole country are taken into consideration; large town areas and fully forested areas where the DTM and the time of the final production can approach 10 days, besides the large flats and the plant cover is very rare; On average, it is estimated that DTM and contour production of a 1:25,000 scale map sheet area can last for five days.

5. CONCLUSION

In this study, the accuracy of the DEM produced by dense image matching compared with DTED-2 and SRTM-1 data in the same region of three different types of terrain and different topographic structures in Turkey with 1: 25,000 scale map sheet area. After the accuracy of automatically generated DEMs has been determined, the most appropriate DEM grid spacing has been determined according to the INSPIRE criteria.

When the existing countrywide DEM, namely DTED-2, is taken into consideration, newly proposed DEM5m improves the accuracy approximately five times. Also 5 m grid spacing means that DEM5m represent 36 times denser elevation points and better modelling of the terrain.

National mapping agencies in some other countries produce and present elevation data from a large number of elevation data producers (public and private sectors). These data are merged into a common pond. The elevation data requirements of all the institutions are met from the elevation warehouses. By only producing missing data are multiple efforts avoided for the same regions. In Turkey, especially public institutions produce large scale maps in urban areas and projects areas. In some limited areas they are getting DSM/DTM by laser scanning. If the data can be combined under the same roof, time and costs can be saved.

It is also important to determine the accuracy of the elevation data. For this purpose, geodetic points, leveling points within TUTGA and TUSAGA and the ground control points for aerial photography can be used. Every ground control point to be built by public institutions should be included in this control.

Last but not least, it is proposed that all efforts to produce elevation data should be integrated to generate a countrywide elevation database with different grid spacing and accuracies. But only the metadata of the elevation products should be supplied with central elevation database. By this central elevation database; repetitive efforts to produce elevation data can be avoided, time and resources can be saved.

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POSSIBLE CONTRIBUTIONS OF SPATIAL SEMANTIC METHODS AND TECHNOLOGIES TO MULTI-REPRESENTATION SPATIAL DATABASE PARADIGM

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ABSTRACT: Today, the amount and variety of spatial data have increased dramatically. In addition, the web has made it easier to disseminate and share this kind of data. Therefore, spatial data integration and interoperability have gained more importance. Spatial data are collected from different sources and often heterogeneous in terms of the levels of detail and the points of view. To able to meet the demands of different spatial applications, multi-source and heterogeneous spatial datasets need to be integrated as well as the consistency of these datasets needs to be maintained. In this context, multi-representation spatial database (MRSDB) paradigm has been suggested by researchers. However, the heterogeneity constitutes a significant barrier in this respect and hence the implementations have so far been remained within a rather narrow scope. In this article, it is mainly discussed about the possible contributions of basic methods and technologies of spatial semantics such as ontologies, semantic web and linked data to the data integration for creating a MRSBD. Some examples are also given to illustrate the concept.

Keywords: *Spatial Semantics, Multi-Representation Spatial Databases, Semantic Interoperability, Spatial Ontologies, Linked Spatial Data*

1. INTRODUCTION

In recent years, along with the progress in spatial data acquisition technologies such as sensors and global navigation satellite systems, large amounts of spatial data have been produced. This has led to the emergence of many forms of the same spatial phenomenon in different spatial datasets. A spatial phenomenon can be represented in various ways from semantic, geometric and/or graphic aspects depending on specific application requirements (Friis-Christensen et al., 2005; Basaraner, 2012). In this context, multi-representation spatial database (MRSDB) has emerged as an important paradigm that allows spatial data about the same real world phenomenon coming from various sources to be kept at different levels of detail integrally. For this purpose, spatial data integration problem needs to be solved so that heterogeneous spatial data belonging to a same region or same real world phenomena can be linked and used together. The integration problem is more than a syntactic one. Therefore, it is not only be solved by adherence to one standard file format such as Geography Markup Language (GML) but also involves understanding the meaning of data. Applying semantic web technologies can be a promising approach for reducing the cost and improving the accuracy of the integration by making semantic differences among spatial datasets explicit in ontologies (Hart et al., 2013). Therefore, when used in conjunction with semantic web technologies, the MRSDB paradigm can be used for analysis and visualization at multiple levels of detail and, when necessary, for automatic transfer of updates from finer to coarser levels of detail. Automatic updates between levels of detail are also important for ensuring consistency between datasets of different resolutions (Wang et al., 2009).

National Mapping Agencies (NMAs) such as the Ordnance Survey (OS) of Great Britain and the United States Geological Survey (USGS), which are responsible for production, management and dissemination of spatial data in order to meet the various needs of the relevant institutions and organizations, are working for publishing their data as linked data with semantic web technologies. In this context, taxonomies and geographical (geo-) ontologies for various domains have been produced by these NMAs (Goodwin et al., 2008; Varanka, 2009; Varanka et al., 2015). Ontology is the conceptualization and modeling of classes, entities, and relations of a specific domain with the help of logic systems (Guarino, 1998; Uitermark, 1998; Thomson, 2009; Memduhoglu et al. 2017). On the other hand, a geo-ontology does not consist of only semantic relations such as synonymy, similarity, mereonomy and hyponymy, but also spatial relations such as adjacency, containment and connectedness (Fonseca et al., 2009).

The development and maintenance of ontologies are important to utilize existing data for different purposes. In this regard, ontology integration is a crucial issue for reuse and share information among different communities and to create a knowledge base about a domain (Kavouras et al., 2007). Although there are different classifications in the literature, three levels of ontology can be mentioned in the most general sense: high-level (global) ontologies, domain (task) ontologies and application ontologies (Guarino, 1997). Micro-ontologies have been added to this classification at the bottom level by Hart et al. (2013). Recently, ontology design pattern approach, which comprises special design steps for various applications, is also used as application ontologies (Carral et al., 2013; Hu, 2017). Ontology design pattern is defined by Sinha et al. (2014) as small ontologies capturing essential and reusable characteristics of a certain domain. Geo-ontologies or ontologies that belong to the spatial domain usually are domain ontologies.

A MRSDB stores various connected spatial datasets at different levels of detail (resolution/scale) about a geographic space in order to create a more sophisticated and flexible environment not only for multi-purpose geographic data and map production but also for multi-level spatial analysis and visualization. In other words, MRSDB paradigm simplifies the costly and time consuming tasks of production, management and maintenance of datasets and eliminates inconsistencies among associated datasets.

From a broader perspective, a MRSDB include interlinked topographic and thematic geographic and cartographic datasets at different levels of detail (Basaraner, 2012, 2016). The same real world phenomenon is represented in different feature classes and/or with different semantic, geometric and/or graphic definitions in these datasets because spatial datasets are set up to serve different purposes (Figure 1). To be specific, this heterogeneity mainly results from different semantic, geometric and/or graphic resolutions and different themes such as topography, navigation and tourism about which spatial datasets are created. There are two main methods for creating a MRSDB: (1) generalization and (2) integration. In the first approach, spatial data is generated in highest resolution or at largest scale and then transferred to lower resolutions or smaller scales through generalization. During generalization process, the links between spatial features at different levels of detail are stored. In the second approach, spatial features in separate but associated datasets are interlinked based on semantic and geometric matching rules. Since, generalization is beyond the scope of this paper, creating MRSDBs through integration is discussed here.

Despite the advantages mentioned above, it is not so easy to handle the inconsistencies between multiple spatial datasets . Due to the lack of sophisticated tools that can find and link corresponding spatial features at those datasets, building a MRSDB is a challenging task.

This study aims at investigating possible contributions of spatial semantic methods and technologies to the creation of MRSDBs. To this end, first heterogeneity issues in spatial data are explained. Then, approaches and challenges about the integration of heterogeneous spatial data in MRDBs as well as the potential role that semantic web methods and technologies play within this scope are addressed.

The rest of the paper is organized as follows: Section 2 discusses heterogeneity problems of spatial data and possible solutions to them. Section 3 goes through the data integration and interoperability in terms of spatial semantics. Section 4 introduces semantic methods and technologies within the context of spatial domain. Section 5 describes the potential use of spatial semantic methods for MRSDBs and gives a short overview on current approaches as well as presents simple ontologies as a conceptual use case. Finally, Section 6 concludes the paper.

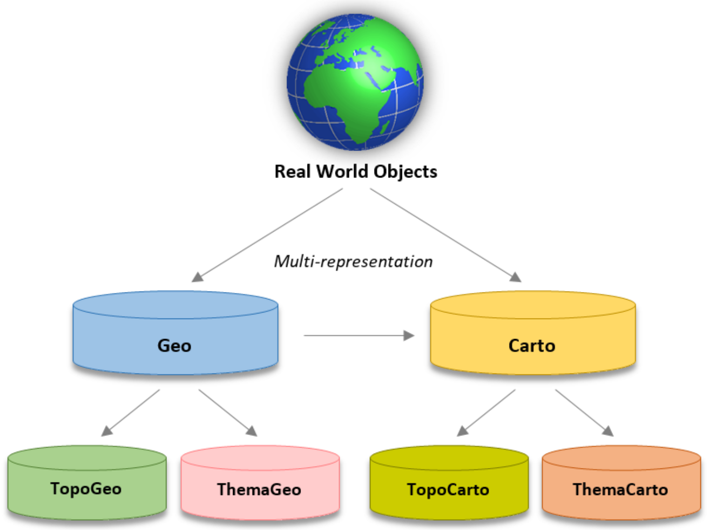

Figure 1. From real world objects to topographic and thematic geographic and cartographic datasets in MRSDB (adapted from Basaraner, 2016)

2. SPATIAL DATA HETEROGENEITY

By its nature as an interdisciplinary area, geographic information science deals with spatial heterogeneity problems. In this section, this kind of heterogeneity problems are investigated and possible solutions to them are discussed along with the literature review.

One of the first categorization about the spatial heterogeneity is provided by Bishr et al. (1999). They divides the heterogeneity into three categories: semantic, schematic and syntactic. Hakimpour (2003), Euzenat et al. (2007) and Khatami et al. (2010) also mention about spatial heterogeneity problems and make similar categorizations to the those proposed by Bishr et al. (1999). Brodeur (2012) and Brodaric (2017) add another level called system to this categorization which specifies heterogeneity between systems. Delgado et al. (2013) makes a classification about spatial heterogeneity types which can occur during ontology integration. These categories are: terminological, syntactic and conceptual heterogeneities. Volz (2005) divides database integration into two steps: schema integration and object (or data) integration. Hess et al. (2007) also categorize heterogeneities as concept-level and instance-level similar to the those proposed by Volz (2005).

Syntactic and structural heterogeneity can occur between two datasets at the technical level. Syntactic heterogeneity concerns the physical representation of data while structural heterogeneity refers to differences in data modeling (Brodeur, 2012). For instance, syntactic heterogeneity can occur when two datasets defined in different spatial formats or encodings while structural heterogeneity can occur when data defined with two different geometry type or concept. On the other hand, semantic heterogeneity can occur at the conceptual level (e.g. two different representations of the same object at different levels of detail or at different points of view).

Syntactic and structural heterogeneity problems can be eliminated with standards and specifications. By using XML (eXtensible Markup Languge), GML (Geography Markup Language), RDF (Resource Description Framework), and OWL (Web Ontology Language) these two types of problems can be solved. Communication between different systems can be ensured by protocols such as Ethernet, Transmission Control Protocol/ Internet Protocol (TCP/IP) and Hypertext Transfer Protocol (HTTP). The use of these protocols also removes heterogeneity problems of systems at the same time (Brodeur, 2012; Varol et al., 2017). But semantic heterogeneity problem needs more complex solutions. Using ontologies at modelling of spatial data and matching these ontologies with either manual or more ideally with automatic techniques is the most promising approach for solution of semantic heterogeneity problem.

One of the factors that complicate the harmonization of spatial datasets is the problem of multilingualism (Annoni et al., 2008). Looking at projects such as Infrastructure for Spatial Information in Europe (INSPIRE), one of the major problems that the responsible parties are confronted is that the multilingual inconsistencies result from a multinational structure. Ontology matching can be a potential solution for that problem too. For example, Figure 2 illustrates the land use classifications of Austria and European Coordination of Information on the Environment (CORINE). In the classifications, the corresponding classes at the higher level can be matched easily because there is not a big conflict (naming conflict) but the situation becomes complicated when shifting to a lower level, and matching becomes difficult. This difficulty can be solved by matching techniques and algorithms which will be discussed at the following sections. As taxonomies are seen as the first step in creating ontology, it is possible to match large ontological spatial data such as national spatial data infrastructures in a similar way (Cömert et al., 2008; Ulutas et al., 2016). The matching process can also eliminate the multilingual problem as the classification used in semantic definitions or ontology is done partly independently from the language.

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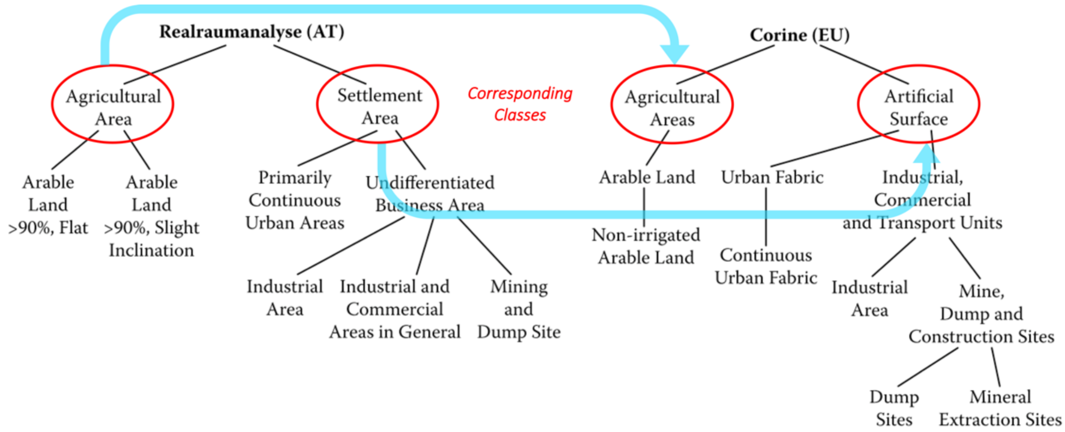


Figure 2. Example of land use classification systems of the Austrian Realraumanalyse (left) and the European CORINE (Annoni et al., 2008)

3. SPATIAL DATA INTEGRATION AND INTEROPERABILITY

The fusion and integration of spatial data is one of the hot topics that are still being discussed in the geographic information community (Yi, 2013). In order to be able to use, analyze or visualize the data of the same real world object from different sources, produced at different levels of detail and/or from different points of view, it is necessary to integrate the datasets by eliminating heterogeneity problems (Figure 3). Semantic web and related technologies have the potential for a solution to the existing integration problem.

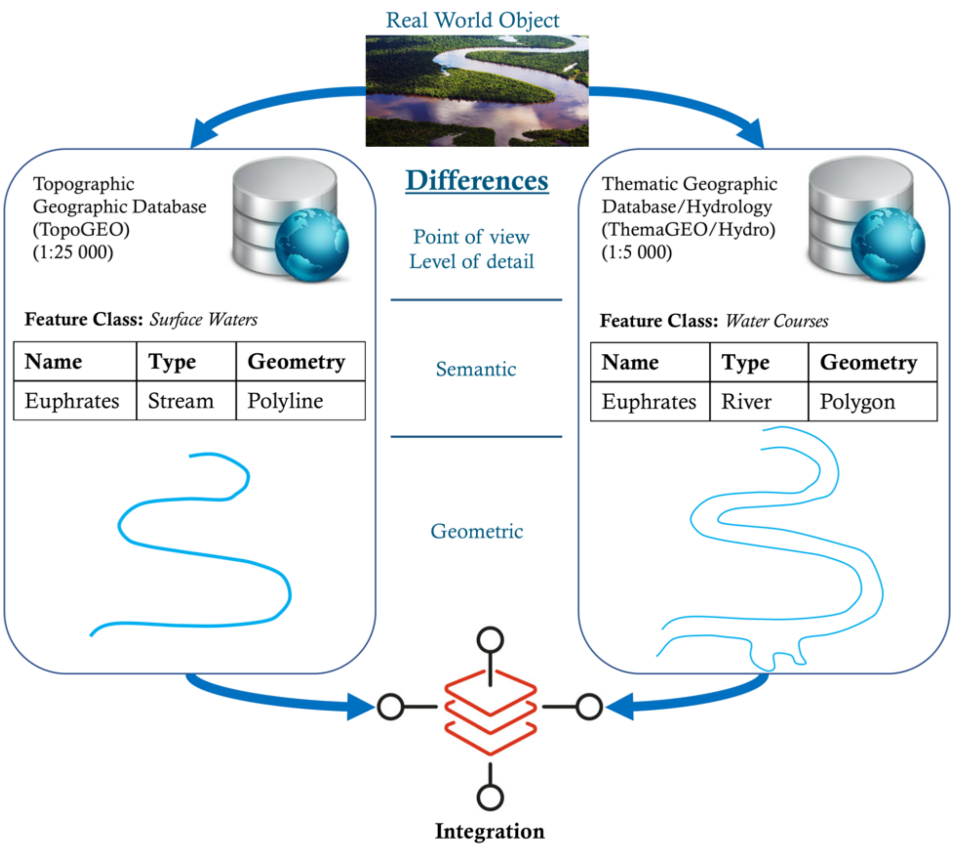


Figure 3. Heterogeneous real world objects in terms of point of view and level of detail which affect their semantic and geometric definitions.

The ontology that provides the conceptualization of the application domain and the knowledge representation provides a potential and support for the integration of heterogeneous information coming from multiple sources and the matching of entities (Rodríguez et al., 2003; Stoter et al., 2006). Since it is not possible to use a single ontology for multiple themes, different level of details or different languages, more than one ontologies needed in most cases. Using these multiple ontologies together and relating them to one another can support heterogeneous information systems (Kieler, 2008; Stock et al., 2011). With the integration, it is possible to obtain a third stronger dataset by combining two datasets that have strong sides on different parts. For example, a dataset obtained from the integration of two datasets with more detailed attributes and more detailed geometry will be able to respond to more complex questions within better accuracy (Uitermark et al., 2005). A benefit of obtaining stronger datasets by aligning different sources of information is to unveil knowledge with automatic machine inference that cannot be discovered easily by humans (Hahmann et al., 2010). Currently there are two main methods to relate ontologies with each other: first one is ontology merging which is creation of global vocabulary/ontology by merging ontologies to map local terms in each dataset and the other one is ontology alignment defined as computation of similarity between local entities and create relations between them (Stock et al., 2011; Wiegand et al. 2015).

In the field of ontology matching, there are some close terminologies that can lead to misuse. These are: mapping, integration, alignment, merging and matching. They are all applied to heterogeneous ontologies, but they have some differences. Clarifying them will prevent their misuse. Ontology mapping is finding relations between similar instances or concepts based on statistics. It maintains a link between two ontologies. Ontology integration takes two ontologies as input and gives an adjusted ontology. Ontology alignment is set of corresponding concepts between ontologies and also it shows degree of similarity. It keeps consistency of original ontology. Ontology merging is developing a new sophisticated ontology based on two or more ontologies. Lastly the ontology matching is a set of correspondences itself. Ontology matching is similar to the ontology alignment approach but difference is that matching involves correspondences rather than concepts (Kipngenoh, 2010).

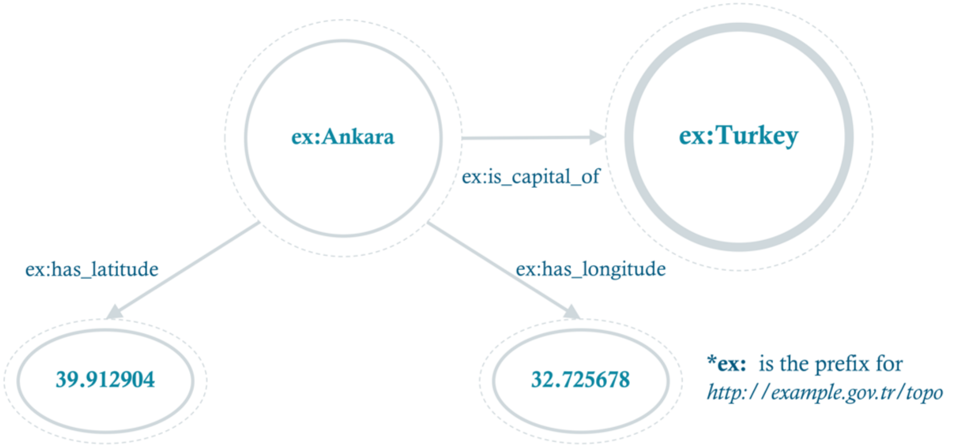
Despite the advantages mentioned above, the use of ontologies for integration has some drawbacks as well. These are: (1) expensiveness of time, complexity and quality of building ontologies and (2) difficulty of proper formalisms to support by reasoning systems (Hakimpour, 2003).

4. SPATIAL SEMANTIC METHODS AND TECHNOLOGIES

The semantic web concept was first introduced by Tim Berners-Lee in 2001, which is known as the founder of the web (Berners-Lee et al., 2001). Semantic web emerged as an extension of the existing web that allows people and machines to work together provided with a well-defined meaning of information, allows web to exist not only for the understanding of humans but also for machines (Lassila et al., 1999). With logic systems (description logic, first order logic etc.), this concept provides a potential for making meaningful information from big data concept which is the collection of divergent data from everywhere.

Resource Description Framework (RDF), which is a building block at the heart of the semantic web and its applications, allows the definition of any web resource to be interpreted by the relevant machine (Beckett et al., 2004; Sikos, 2015). RDF is a semantic data modeling language in which data is held in the form of subject, object and predicate. For example, when said "Ankara is the capital of Turkey, Ankara is the subject, Turkey is the object and capital is the predicate which expressing the relationship between the subject and the object (Figure 4). When these expressions are defined with semantic web technologies together with specific vocabularies and rules, the machines can infer meaningful information from these expressions. When looking at the example mentioned above, machines can infer that Ankara is a city, Turkey is a country and every country has only one capital so Istanbul is not the capital of Turkey (van Harmelen, 2008). When these RDFs get related or connected with each other, they become linked data (Hahmann et al., 2010). The semantic web approach, where linked data is embedded, can transform the classical web phenomenon that exists only in the form of documents which only people can understand and interpret into a case where also machines can automatically inference and make Berners-Lee's vision possible (Hu et al., 2016). The LinkedGeoData initiative, which transforms OpenStreetMap to the RDF knowledge base with linked data rules and links this data to other knowledge bases such as DBpedia and Geo Names, contributing to the geospatial part of the semantic web (Auer et al., 2009).

As an extension of RDF, Web Ontology Language (OWL) can be employed for defining the advanced relationships between concepts. Although OWL is based on RDF, more advanced class definitions and restrictions can be made with OWL. For example, we can express Ankara is the only capital of Turkey and no other city can be capital with OWL's inverseFunctionalProperty feature. OWL uses description logic (DL) and makes decisions based on this mathematical model. The documents created with the OWL are also known as ontologies that can be published over the Web. OWL has three sublanguages: OWL Lite, OWL DL, and OWL Full. OWL Lite provides language constructs for a classification hierarchy and simple constraints. OWL DL supports the maximum expressiveness while retaining computational completeness and decidability. OWL Full provides the maximum expressiveness and more syntactic freedom for RDF with no computational guarantees. As understood from the definition, OWL DL is the most common sublanguage for the creation of ontologies. The simplest form of the language can be defined as the concepts such as classes, properties, and individuals (Figure 5).



Subject	Predicate	Object
http://example.gov.tr/topo/Ankara	http://example.gov.tr/topo/is_capital_of	ex:Turkey
http://example.gov.tr/topo/Ankara	http://example.gov.tr/topo/has_latitude	39.912904
http://example.gov.tr/topo/Ankara	http://example.gov.tr/topo/has_longitude	32.725678

Figure 4. The RDF structure in the form of triples (adapted from Memduhoglu et al., 2017)

Class is a set of individuals that share common properties. Properties define relationships between individuals or data values. Individuals are instances of classes and properties. For instance, as seen in the Figure 5, England, Turkey and USA are instances of country class and livesInCountry corresponds to the property that expresses relationship. OWL is a declarative language which represents knowledge rather than programming language. The set of classes and statements about classes is known as the Terminological Box or Tbox. The set of Individuals and facts about them is known as the Assertion Box or Abox. It is possible to define and automate the use of the ontologies in data integration through OWL, which are made up of a large number of systems with their own semantic meanings. Using these diverse systems together in a common ontology, OWL supports spatial information interoperability at the semantic level. The query language of semantic web is SPARQL (SPARQL Protocol and RDF Query Language) developed by the World Wide Web Consortium (W3C). However, SPARQL does not support spatial queries and analysis. To query semantically defined data and perform basic spatial analysis, GeoSPARQL standard has been developed by OGC as an extension to the SPARQL standard (McGuinness et al., 2004; Prud'hommeaux et al., 2008; Perry et al., 2012; Hart et al., 2013; Zhang et al., 2015).

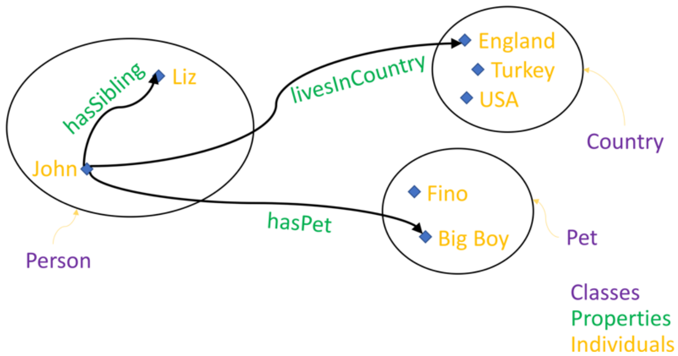


Figure 5. The components of OWL which consist of Classes, Properties and Individuals (adapted from Horridge et al., 2013)

Protégé is a commonly used open source software for building and using ontologies. Protégé supports OWL and RDF ontologies to be loaded, edited and visualized. It also allows importing Semantic Web Rule Language (SWRL) files. Protégé contains various plugins and reasoners like HermiT, FaCT++ and Pellet. With these reasoners the knowledge can be inferred from data which exist in the form of ontologies. Protégé has also a web version called WebProtege. Projects can be loaded into the WebProtege and used ubiquitously. There is a commercial alternative to the Protégé called TopBraid Composer which is also an ontology editor and a visual modeling environment for creating and managing ontologies in the semantic web standards RDF and OWL. In addition to the ontology editors there are plenty of tools, libraries and software packages to support semantic web. For instance, Jena is a free and open source Java development platform for the semantic web applications. Jena contains the following components: Fuseki which is SPARQL server and TDB which is triple store that stores

RDFs. Since aforementioned software are all open source, they have strong community support and well-structured documents that can be found freely on the web.

There are also semantic matching/alignment tools and algorithms worth to mention. Ontology Alignment Evaluation Initiative (OAEI) has the goal for evaluation of the increasing number of methods available for schema or ontology matching. For this goal, the initiative also organizes an annual evaluation event and publishes the tests and results of the event for further analysis. One of these tools is S-Match, which is an open source semantic matching framework that provides several semantic matching algorithms and facilities for developing new ones. The other tools are Alignment API, AROMA, BLOOMS and RIMOM. (Delgado et al., 2013; OAEI, 2018)

GML is an Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) encoding standard for the representation, storage and exchange of geographical features to ensure interoperability. In general, GML is a XML implementation to describe generic geographic data sets that contains points, lines and polygons. Since GML does not define geographic objects, it can be extended to define core reference ontologies or schemas like CityGML. Although current version (2.0) of CityGML does not support multi representation of features, the upcoming version (3.0) will support the multi representation framework. In this context, Löwner et al. (2016) discuss alternative profiles for new version of CityGML to support multi representation framework (Cömert et al., 2010; Roussey et al., 2011; CityGML, 2018)

GML can help to resolve structural and syntactic heterogeneity problems but cannot resolve semantic heterogeneity problems directly. Instead of this, as a standard representation of geographic features, GML can support the translation of geographic features into machine understandable forms like RDF or OWL. Since, GML is widely adopted by geospatial community and it is commonly used in spatial data infrastructures, the web of linked data could profit from this effort, as large amounts of standardized spatial information could be made available as linked data. (van den Brink et al., 2014; Zhang et al., 2015)

Although, RDF and OWL are good alternatives for GI community to adopt the modern methods and techniques that suit to information age, they have a significant limitation in terms of spatial indexing and performing advanced GIS operations (Goodwin et al, 2008).

5. USE OF SPATIAL SEMANTIC METHODS AND TECHNOLOGIES FOR MRSDB

MRSDB provides an efficient environment for multi-purpose spatial data modeling, processing, analysis, visualization and dissemination. On the other hand, semantic web methods and technologies are promising for automatic integration and inference. In this sense, combining two approaches will provide the best of both worlds.

In the literature, a few approaches are proposed toward MRSDB. Among them, some approaches are potentially more pertinent. The first one is the VUEL approach, which is described by the author as "a unique combination of visible elements (geometry and graphic symbols) with a particular semantics". The VUEL uses Unified Modelling Language (UML) notation to present table linking three dimensions: geometric, semantic and graphic (Bedard et al., 2002).

Another approach is the stamping technique which can be considered more relevant to semantic web technologies (Vangenot et al., 2002). The stamping technique takes the form of binaries to represent object from two perspectives. From these two perspectives, the first one stands for the point of view and the latter represents the level of detail or resolution. Each of these binary representations is called a stamp, for instance ("cartography", 1 meter) and stamps characterize different representation of real world objects. In this regard, two approaches are proposed for multi representation: the integrated approach where the stamping technique is used to define customized data structures and the inter-relationship approach where representations are linked through correspondence links.

Benslimane et al. (2003) take the stamping technique one step further and merged the stamping technique with the description logic to create a DL-based ontology language for multi-representation. They create set of constructors based on DL and stamping technique and present a contextual ontology language to support multi representation ontologies called MuRO (MultiRepresentation Ontologies). MuRO is an ontology which expresses a specific domain by a variable set of properties or attributes in several contexts.

Friis-Christensen et al. (2005) develop a Multi Representation Management System (MRMS) to manage and model multiple representations. They present a Multiple Representation Schema Language (MRSL) which is a conceptual schema language used to describe consistency requirements in a multiple representation context within spatial data. The basic elements of the MRSL are matching, consistency and restoration rules. The graphical notation of MRSL is based on an extension to UML and the Object Constraint Language (OCL). They use stereotypes which provide a way of defining a virtual subclass of a UML metaclass with additional semantics.

A more recent study about this topic has been realized by Stoter et al. (2011). They present an information model for a multi-scale topographic database containing rich semantics both on multi-scale data content and on scale transitions. Information Model Topography (IMTOP) model has been expressed using the UML and complemented with OCL. The IMTOP uses inheritance, derivation relationships and derived attributes to model a class at specific scales. The advantage of this approach is its simplicity at reading and deriving a model per map scale by showing the relevant classes for that map scale only and the disadvantage is that it is expressed with UML and OCL instead of RDF or OWL. The authors also state that transferring IMTOP into an ontology language such as RDF or OWL will make more semantics known at machine level required for wide reuse of the data.

The aforementioned studies, methodologies and tools about the MRSDB have not gained mainstream adoption owing to the complexity of the process of creating MRSBDs. The lack of software tools that can provide the definition of OCL expressions and the use of confusing schemas involving very long OCL expressions make it difficult to use widely. Using these techniques with OWL or RDF will provide them a powerful background of standards and ease of the adoption from geographic information community. Furthermore, the application of a description logic language like OWL will allow inferences from datasets in a MRSDB.

Creating taxonomies is an important step to build ontologies and provide interoperability of spatial information. As an example, three groups of simple ontologies created from taxonomies at three different levels of detail (LoD) were presented in Figure 6a, 6b and 6c. Following ontologies were created: (1) topographic geographic ontology (TopoGEO) which corresponds to topographic point of view for a group of feature classes such as hotels, shops and restaurants (Figure 6a), (2) thematic geographic ontology for tourists (ThemaGEO/Tourist) which is created for the use of tourists (Figure 6b), and (3) thematic geographic ontology for cities (ThemaGEO/City) which corresponds to city managers' point of view (Figure 6c). The heterogeneity problems occur due to the ontologies have different points of view and levels of detail (LoD). For instance, hotel is in: LoD 3 and under *Building and Construction > Social Facility* class in TopoGEO, LoD 2 and under *Accommodation* class in ThemaGEO/Tourist, LoD 3 and under *Tourism > Accommodation* class in ThemaGEO/City. It can be seen that Hotel class is different both in LoDs and classifications. In order to eliminate this heterogeneity problem, matching techniques and algorithms can be applied to the ontologies either manually or automatically. After the matching step an appropriate MRSDB method can be used to achieve the goal. After this last stage, an MRSDB powered with semantics can be established to analyze spatial data through levels of detail and new knowledge can be inferred automatically by machines from existing datasets

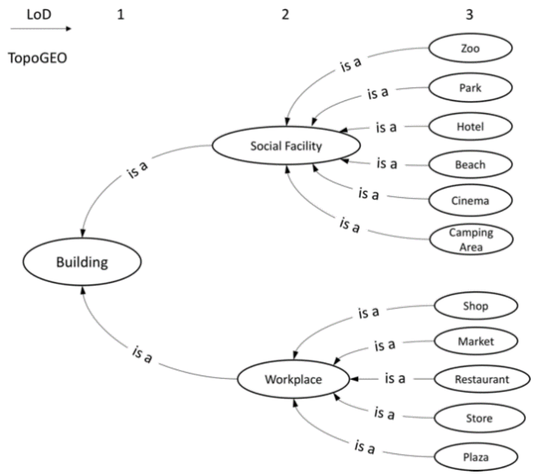


Figure 6a. Topographic geographic ontology (TopoGEO)

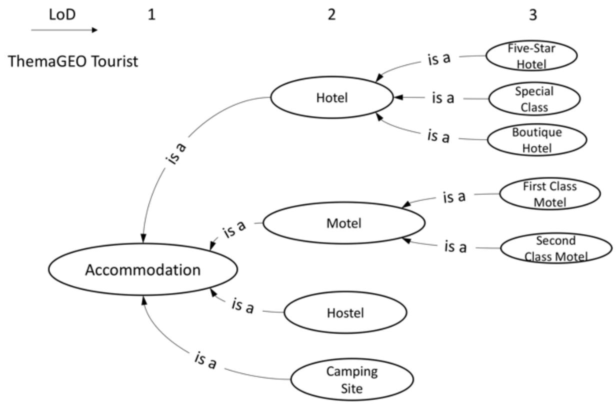


Figure 6b. Thematic geographic ontology for tourists (ThemaGEO/Tourist)

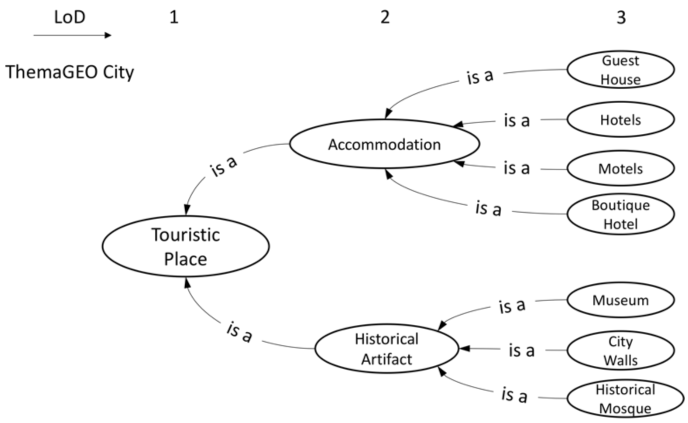


Figure 6c. Thematic geographic ontology for cities (ThemaGEO/City)

6. CONCLUSION

In this study, the problems about the integration of spatial data have been identified and it has been investigated whether the methods and technologies about spatial semantics, which appear to be a potential contributor to the solution of these problems, can be utilized for creating MRSDBs. Simple ontologies from three different points of view and three different levels of detail are also created as an example of integration challenge that a MRSDB has to cope with. Incorporating multiple ontologies into MRSDBs as multi-representations of spatial objects can provide a new insight into the solution of heterogeneity problems and the integration of heterogeneous spatial datasets. With such an approach, a MRSDB can be created by means of multiple ontologies, the inconsistencies in the data between different levels of detail can be detected, the semantic integration of various spatial data and multilingual datasets can be ensured and new knowledge inferences can be made (Tanasescu, 2007; Varanka, 2009; Basaraner, 2013; Ulutaş et al., 2016; Hu, 2017; Memduhoglu et al., 2017). Future work will focus on creating ontologies based on RDF/OWL within the scope of MRSDBs.

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DETECTION OF PARAGLIDING FIELDS BY GIS

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ABSTRACT: Nowadays, people living in the city tend to get away from the city and integrate with nature as they find the opportunity to keep away from stress in terms of current living conditions and their effects. This situation is increasing the interest in nature tourism and orientation to nature sports with each passing day. One of nature sports is also paragliding.
In this study, alternative flying fields suitable for paragliding which is one of nature sports within the boundaries of Sivas province, Turkey were automatically determined by Geographical Information Systems (GIS) analyses and the developed user interface program by taking into account the international technical conditions required for flying. The suitability of these fields determined was checked with the flight tests performed in company with the experienced paragliding pilot, and they were proposed as nature tourism areas. With this study carried out, it was ensured that the paragliding fields, which are mainly determined by observational and experimental methods, were scientifically determined in accordance with the international technical specification criteria. Furthermore, a new method has been developed to be able to automatically determine alternative paragliding fields in any city with the help of the introduced GIS-based system and user interface program.

Keywords: *GIS; Ecotourism; Paragliding; Spatial analysis; Nature-based tourism*

1. INTRODUCTION

Nowadays, urban people who are trying to maintain their life in limited recreation and sports areas in cities in the face of increasing urbanization are taking up going to nature by getting away from these artificial spaces (Koçak, 2010; Kienast et al., 2012). People want to integrate with nature to keep away from stress and to be healthy (Kaplan and Ardahan, 2012; Ardahan and Yerlisu Lapa, 2011). Along with this orientation, a quick/easy accessibility expectation brings appropriate areas near the city to the forefront as a need brought about by the fast and intense urban life. However, in the face of this demand, a very limited number of functional rural recreation areas with natural quality in city surroundings and the gradual decrease in existing areas make it compulsory for people to go to recreational tourism areas in further remote areas for recreational purposes to the extent of their economic opportunities and time (Ardahan and Yerlisu Lapa, 2011). This situation, which requires time together with the financial burden, decreases the practicability of nature sports by everyone and causes them to appeal to a certain population (Ekinci et al., 2012).

Natural environment offers recreational opportunities that can be associated with tourism development. Tourism revives in rural areas where nature sports such as trekking, mountain climbing, rafting, paragliding, birdwatching, scuba diving, spelaeology, etc. are done and provides significant economic inputs to the region (Özer and Çavuşoğlu, 2014). According to the definition made by the International Ecotourism Society, ecotourism is the travel made to natural areas in the responsibility of protecting the environment and improving the welfare of local people. Ecotourism includes very different forms such as passive (drawing pictures accompanied by landscape), active (paragliding, mountain bike, etc.), consumption (hunting, fishing) and out-of-consumption (walking, birdwatching, etc.) (Bell et al., 2007). The main purpose of this alternative tourism type, which is different from traditional tourism, is to increase the economic welfare of local people by preserving the natural and cultural resources of the region in a sustainable way (Kiper, 2011). On the other hand, these kinds of sports activities and the increased demand for ecotourism also increase the pressure on nature, which has a delicate balance within itself (Sezgin and Gümüş, 2016). In this respect, the adoption of a sustainability approach in natural areas and the protection of the natural environment require comprehensive planning and the proper management of the resources in the area planned (Koçak, 2010; Bunruamkaew and Murayama, 2011). The symbiotic relationship between human and nature necessitates a rational planning approach (Fung and Wong, 2007).

The ability of GIS to associate information with geographical location provides significant contributions to the development and management of tourism (Hai-ling et al., 2011). The fact that the economic, social and environmental demands of sustainable development are evaluated together makes the decision-making process difficult in tourism planning (Bahaire and Elliott-White, 1999). Butler (1993) mentions the need for the effective use of GIS to ensure the sustainability of a natural area in the presence of tourism while determining new tourism areas (Hai-ling et al., 2011). In this respect, GIS makes a great contribution to the development of sustainable tourism. GIS plays a role in the supervision of environmental conditions, the examination of the suitability of places, the evaluation of conflicting interests and the modeling of relationships (Bahaire and Elliott-White, 1999). A strong database infrastructure is needed to create the map of the potential resources that can be used in a large area or the scenarios for the use of resources (Kliskey et al., 1999). The current provider of this infrastructure is GIS. The development of GIS-based inventories brings objectivity, flexibility, and efficiency to the management of recreational resources (Chhetri and Arrowsmith, 2008).

In particular, there are many studies on the use of GIS in the management of recreational resources. Issues such as tourism transport capacity, sustainable tourism infrastructure planning (Boers and Cottrell, 2007), sustainable land-use planning (Bunruamkaew and Murayama, 2012), determination of areas with potential for ecotourism (Bishop and Hulse, 1994; Boyd et al., 1995; Miler et al., 1998; Tseng et al., 2013; Parladır, 2013), nature-based tourism modeling, recreational use potential modeling (Kliskey, 2000) come to the forefront in these studies. This problem is also related to geographical site selection. In the literature, different studies were performed related to site selection by GIS (Şentürk and Erener, 2017; Rutherford et al., 2015).

Paragliding which is one of the alternative nature sports appealing to adrenaline junkies carries a risk by the way it is done. It is necessary for athletes to receive a license to fly on their own. Apart from the pilot experience, the flying field should meet the technical requirements to ensure safe flying. First of all, appropriate hills are required for paragliding. The land structure of the front of the hill and the climatic conditions should be investigated very well, and their analyses in terms of suitability and risks should be performed by experienced pilots. Appropriate weather conditions (fog, wind, snow, rain, etc.) are important in areas considered for paragliding. The predominant wind direction, slope, and altitude of the take-off field are the most important features that should be primarily evaluated for the safety of the take-off field. Another feature that is essential for the safety of the take-off field is that there should be no barriers in areas within a distance that can endanger the take-off, flight and landing safety on the hills to paraglide. Landing areas should be a flat area away from anything that can cause turbulence (Topay, 2003). It is certain that these scientific determinations will provide convenience in far better elevations during flying and going away for kilometers. Although the determination of flying hills and landing areas with appropriate conditions in large geographies is difficult, the examination of all fields by pilots is also impossible. At this stage, GIS-based studies are crucial for determining potential flying fields.

When the studies carried out on paragliding and seeking a correct answer to the questions of when and where for safe flying are examined, appropriate field selection analyses and the examination of wind potential come to the forefront. One of the major constraints of paragliding sport is meteorological conditions. Weather conditions should be taken into consideration for the completion of the activity in a pleasant, safe and comfortable way (Falavarjini, 2015). In the study carried out by Krüger-Franke et al. (1991) on paragliding accidents, they determined that accidents mainly occur due to heavy landing taking place depending on the sudden fluctuations in the wind and thermal pattern and hitting rocky, woody and similar areas. Furthermore, the land structure of the take-off field can also cause accidents (Fasching et al., 1997). In their study, Ceyhan et al. (2014) investigated the suitability of the wind potential of the selected regions for paragliding. It is mentioned that the wind speed and direction along with the geographical characteristics of take-off and landing fields should be taken into account for flight safety in paragliding and that continuity in wind is required so that paragliding can be done. For the reduction of paragliding accidents, the importance given to pilot training needs to be increased and also aerodynamics, suitable thermal and weather conditions should be taught well (Fasching et al., 1997; Schulze et al., 2002).

To perform an appropriate location analysis by including the specific criteria of nature sports types into the scope of evaluation requires multiple data management. In this context, GIS techniques play an important role in managing complex relationships such as the storage, processing, and analysis of a wide variety of spatial data (Chen, 2007; Fung and Wong, 2007; Carreta et al., 2016; Zhang, 2012). The rapid development of technology and the facilitation of information flow have also expanded the areas of usage of GIS. GIS applications are also needed to obtain more useful and productive results in ecotourism studies that require multiple data analysis. However, the fact that it is impossible for anyone, who does not know GIS, to perform all these analyses restricts the usability of GIS. Furthermore, the analysis of so many parameters in a manner associated with each other also brings along the management difficulty of a rather complex and long process. Therefore, a problem that may occur in any of the steps of the procedure in the process of associating all data with each other can affect the whole process and cause time loss by requiring everything to be done from the very beginning. At this point, ensuring that anyone who does not know GIS can use these analyses and facilitating the traceability of this complex process require the development of the user interface program.

In the literature, there are not many studies on the determination of paragliding fields. A study was carried out by Pirselimoğlu Batman and Demirel (2015). In this study, the practicability of paragliding activity on the Altındere Valley Meryemana Stream route was investigated. However, GIS was not used in this application. First, flight points were determined with observational and experimental information, then, whether these points met the technical requirements was checked. However, this method provides the control of the availability of observationally determined paragliding fields in a known region rather than suggesting alternative paragliding fields in a region that is not known. The fact that GIS was not used in the study restricted the project objective and weakened it in terms of the technical infrastructure by suggesting a limited number of flying fields in a restricted area. Furthermore, the fact that only the target area was studied also restricted the widespread effect of the application.

Turkey is a very rich country in terms of geographical and climatic conditions allowing many nature sports to be done with its natural resources and historical texture (Kaplan and Ardahan, 2012). However, this geographical potential, which is still not used sufficiently, needs to be uncovered. Based on this need, in the present study, it was aimed to determine the alternative flying fields suitable for paragliding, which is one of nature sports in Sivas province.

In the determination of the fields for paragliding which is a risky sports branch, attention should be paid to criteria such as the take-off direction, slope and altitude of the hill to paraglide, determination of the required field widths to be able to continue flying for a long time and the fact that landing areas allow for secure landing. With this study, a model has been created for a short-term, low-cost and scientific determination of potential flying fields in accordance with the criteria specified in a wide area such as the provincial border. In accordance with the results obtained, an attempt to contribute to tourism in the region was made by recommending new flying fields to paragliding lovers. Furthermore, a new method has been developed to be able to automatically determine alternative paragliding fields in any city with the help of the introduced GIS-based system and user interface program.

2. THE STUDY AREA

Sivas provincial border (Turkey) was selected as the study area (Fig. 1). The provincial area, which starts on the high plateaus of Central Anatolia and rises to the east, ends with a mountainous and steep section in the north, east, and south-east. The average altitude is above 1000 meters. The region with a rugged structure is also open to northern winds. The winds blowing in Sivas region consist of the northwest wind blowing from the northwest by 19.3%, the north-east wind blowing from the north-east by 16.8%, the north wind blowing from the north by 18.1%, and the remaining part consists of various winds (Governorship of Sivas, 2017).

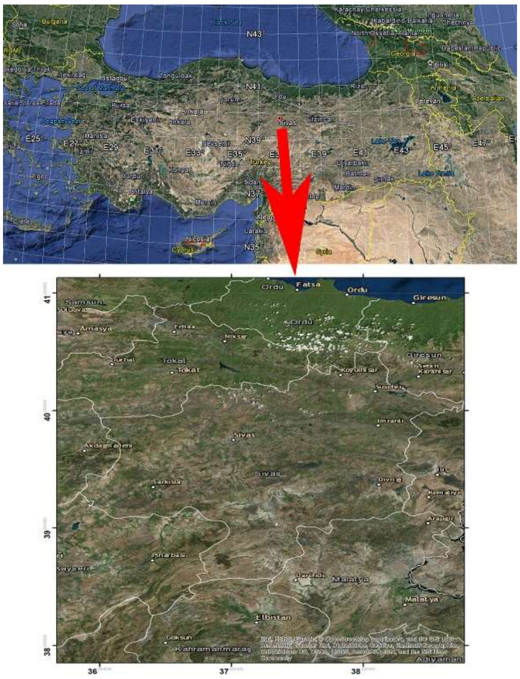

Figure 1. Study Area

When the tourism structure of Sivas province is examined, it is observed that thermal tourism along with cultural tourism mainly comes to the forefront. Mountaineering and trekking attract attention when the nature sports done in the region, which is not known sufficiently in terms of nature sports, are examined (Governorship of Sivas, 2011). However, the city has enough wind potential for paragliding, and it is necessary to determine suitable flying fields in the city to evaluate this feature.

3. MATERIALS AND METHODS

This study was carried out in 3 stages. They are given in Fig. 2.

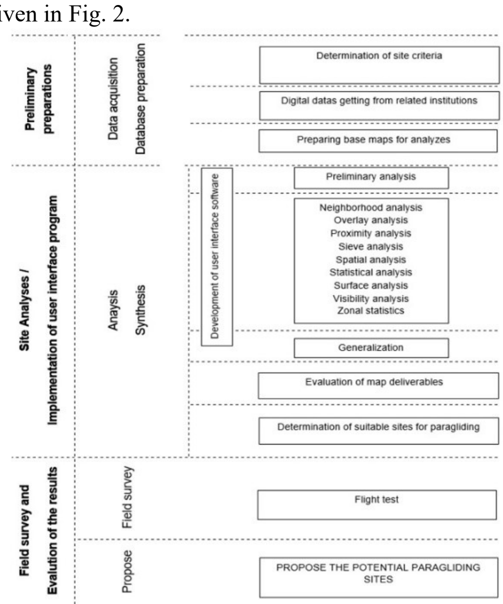

Figure 2. Stages applied in the study

The data presented below were used within the scope of this study.

- Energy transmission lines,
- Stand,
- Highways,
- Streams,
- Lakes/ponds,
- Dams,
- Corine land use,
- Protected areas,
- Military areas,
- Airports,
- Digital Elevation Model (DEM),
- Aspect and
- Wind direction.

Different geographical analyses (Statistical analysis, spatial analysis, zonal statistics analysis, surface analysis, proximity analysis, neighborhood analysis, sieve analysis, overlay analysis, visibility analysis) were used to determine the suitable paragliding areas. These analyses, which is included in decision making and planning techniques, is based on the elimination of unfavorable locations within certain criteria starting from the most unfavorable criteria in determining location suitable for the purpose of the study.

Firstly, the grid network to be used as the basis of the study was formed in a way to cover all Sivas provincial border. The grid size was determined to be 250 m x 250 m to ensure the sufficient sensitivity in the analyses to be performed. The analysis criteria to be used in the determination of the fields were determined based on the "Flying Altitudes, Conditions and Hill Features" specified in the Turkish Aeronautical Association Flight Training Directive, supported by the International Aviation Federation (Fig. 3). Furthermore, the criteria applied with experiential knowledge for safe flight were extended with the help of experienced pilots (flight instructors with EP license). The analysis criteria created in this context are presented in Fig. 3. The analyses were performed separately for take-off and landing fields.

In this study, although the criteria given in Fig. 3 were used, the relative criteria that may vary according to the flight pilot's professionalism were presented as the parameters that the user could enter in the developed user interface program depending on his/her preference. Furthermore, the user interface program was developed with the Model Builder in ArcGIS 10.1 GIS software environment (Fig. 5) so that it could be used anywhere in the world, on condition that the data listed above were provided. The variable parameters considering in this user interface program were given in Fig. 4.

Factor	*Analysis Type*	*Analysis Site*	*Suitability criteria*
Slope	*Slope*	*Departure*	*18° - 30°*
		Landing	*0° - 5°*
ΔH= departure-landing	*Surface*		*60 m < - ≤ 350 m (amateur)*
			60 m < - ≤ 600 m (moderate)
			200 m < - ≤ 1400 m (professional)
Viewshed	*Viewshed*	*Departure*	*Horizontal view 225°*
			Horizon Upper / Lower +90° / -90°
			Visibility distance 2000 m
View x Wind			*Headwind or wind from sideways (4*
Flight Distance			*2 km – 8 km*
	Distance		
Stand			*≥ 200 m*
Lake			*≥ 300 m*
Dam – Pond			*≥ 500 m*
Stream			*≥ 300 m*
Power line			*≥ 500 m*
Road			*≤ 200 m*
Airport			*≥ 6 km*
Protected Sites			*> 0 m*
Marsh			*> 0 m*
Naked rocky			*> 0 m*
Thana			*> 0 m*

Figure 3.The criteria applied with experiential knowledge for safe flight

	Variable Criteria	
Grid sizes	Distance from stand	Distance from Mars
Province	Distance from lake	Distance from road
Slope	Distance from dam / pond	Wind direction
ΔH	Distance from power transmission line	
Flight distance	Distance from stream	

Figure 4. Variable criteria

At the end of these processes, grid areas of 250 m x 250 m in size suitable for the flight were determined within the provincial borders of Sivas. Then, the generalization process was performed to eliminate the unfavorable targets determined as individual cells in the entire study area. According to the result obtained, the regions having more targets than a certain field width within the boundary to be decided (1 km x 1 km) were accepted as the regions suitable for flying.

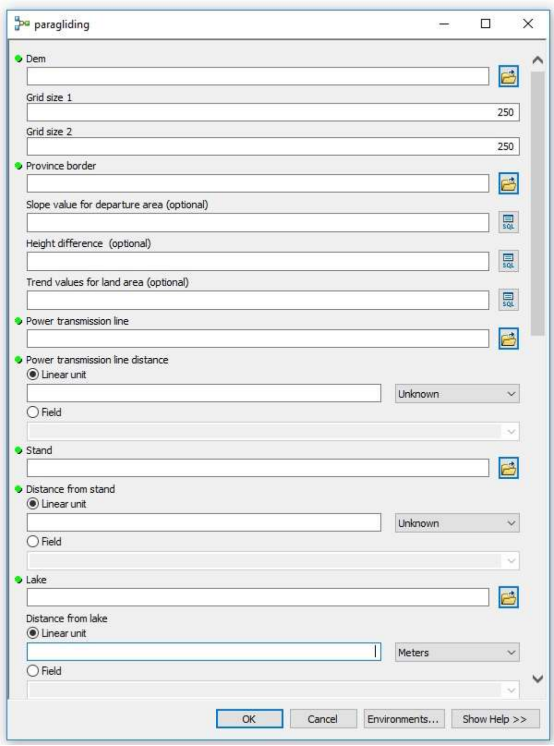

Figure 5. The user interface program developed on ArcGIS software

4. RESULTS AND DISCUSSION

It was proceeded to the final stage of the study after determining automatically the fields suitable for flying in the GIS environment by the user interface program developed. 32 fields were determined as the fields suitable for paragliding (Fig. 6). 8 out of the designated target points were randomly visited (Fig. 6), and the suitability of the region for paragliding was validated. The test flight was performed in the field by the professional paragliding pilot with EP license (Fig. 7), and the acceptability of the field as a paragliding field was decided. According to the results obtained; all fields were determined as flight areas from the point of topography but one of them was not accepted due to the missing data of power transmission lines in the area.

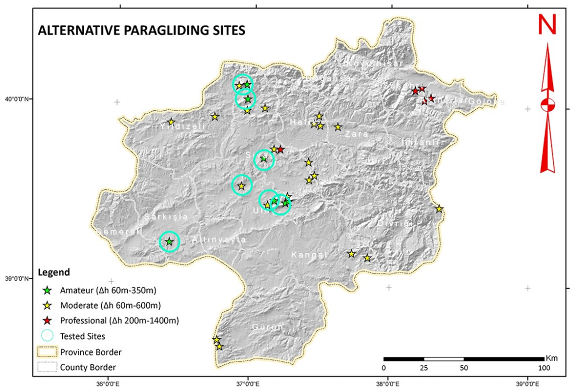

Figure 6. Suitable paragliding fields map

Figure 7. Test flight in some of paragliding fields determined

5. CONCLUSION

GIS is an extremely important tool in geographical analysis and provides a great deal of convenience to its users. It is seen that the large areas which cannot be analyzed via observations, can be analyzed objectively and scientifically by the help of GIS. However, the accurate and up-to-dateness of data is of great importance in such GIS studies.

The outcomes of the study have indicated potential new tourism areas by bringing many fields that have not yet been discovered by paragliders to the agenda. It is thought that these fields that can be transformed into attraction centers with various promotional and demonstration flights over time will make positive contributions to the socio-economic development of the region. On the other hand, the outcomes of the study suggest new alternative flying fields that can be reached more easily and quickly by paragliding lovers. This will provide economic benefits by reducing the time and cost that athletes spend to do paragliding and also allow the sports branch to reach larger masses.

Publishing the potential paragliding fields on web-based GIS is extremely important in terms of reaching more users. As a result of publishing this study on the web, it will be more beneficial for paragliding lovers in the future. Thus, paragliding which is one of nature-based sports will stand out further. Consequently, it will be easier to advertise not only paragliding but also other nature-based sports by GIS for people.

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