GEOSPATIAL ANALYSIS USING REMOTE SENSING IMAGES: CASE STUDIES OF ZONGULDAK TEST FIELD

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ABSTRACT:

Inclined topographies are one of the most challenging problems for geospatial analysis of air-borne and space-borne imageries. However, flat areas are mostly misleading to exhibit the real performance. For this reason, researchers generally require a study area which includes mountainous topography and various land cover and land use types. Zonguldak and its vicinity is a very suitable test site for performance investigation of remote sensing systems due to the fact that it contains different land use types such as dense forest, river, sea, urban area; different structures such as open pit mining operations, thermal power plant; and its mountainous structure. In this paper, we reviewed more than 120 proceeding papers and journal articles about geospatial analysis that are performed on the test field of Zonguldak and its surroundings. Geospatial analysis performed with imageries include elimination of systematic geometric errors, 2/3D georeferencing accuracy assessment, DEM and DSM generation and validation, ortho-image production, evaluation of information content, image classification, automatic feature extraction and object recognition, pan-sharpening, land use and land cover change analysis and deformation monitoring. In these applications many optical satellite images are used i.e. ASTER, Bilsat-1, IKONOS, IRS-1C, KOMPSAT-1, KVR-1000, Landsat-3-5-7, Orbview-3, QuickBird, Pleiades, SPOT-5, TK-350, RADARSAT-1, WorldView-1-2; as well as radar data i.e. JERS-1, Envisat ASAR, TerraSAR-X, ALOS PALSAR and SRTM. These studies are performed by Departments of Geomatics Engineering at Bülent Ecevit University, at İstanbul Technical University, at Yıldız Technical University, and Institute of Photogrammetry and GeoInformation at Leibniz University Hannover. These studies are financially supported by TÜBİTAK (Turkey), the Universities, ESA, Airbus DS, ERSDAC (Japan) and Jülich Research Centre (Germany).

1. INTRODUCTION

Remote sensing technology was firstly introduced in the 1960's to collect intelligence from spy satellites. Since the 1970's Landsat series, which was developed by the United States, has been used for civilian satellites. Landsat-1 was that the first civilian Earth observation satellite was launched in 1972. Following years, seven satellites of Landsat series were launched also. It was actually first named Earth Resources Technology Satellite (ERTS). While data for visible and near-infrared (VNIR) 4 bands with 60m spatial resolution was obtained with Multispectral Scanner System (MSS) sensors in the 1970's, data for 7 bands with 30m spatial resolution was obtained with Thematic Mapper (TM) sensors in the 1980's. The Landsat Enhanced Thematic Mapper (ETM) was introduced with Landsat 7. Images consist of eight spectral bands with a spatial resolution of 30m for Bands 1 to 7 (thermal is one of them). Band 8 (panchromatic) with a spatial resolution of 30m was added. Especially since the early 1990's, several satellite programs developed by many countries such as SPOT was developed by France, Belgium and Sweden; IRS was developed by India; TK-350 and KVR-1000 were developed by Russia; RADARSAT was developed by Canada; Bilsat, RASAT and GÖKTÜRK-2 missions were developed by Turkey. There are also private companies and organizations that provide satellite imagery, as well as governments. Quickbird (Pan: 65cm, MS: 2.62m) and WorldView-1 (Pan: 50cm, MS: 2m) are managed by Digital Globe; IKONOS (Pan: 0.41m, MS: 1.65m) and GeoEye-1 (Pan: 1m, MS: 4m) are managed by Space Imaging Pleiades (Pan: 0.7m, MS: 2.8m) is a joint project being carried out under Optical and Radar Federated Earth Observation (ORFEO) between France and Italy.

The range of wavelengths commonly used for radar remote sensing covers from approximately 1cm to 1m in wavelength. Synthetic aperture radar (SAR) is a form of radar which is used to create images of objects. These images can be either two or three dimensional projections of the object. One of the most important SAR systems is ERS satellites. ERS-1 was launched in 1991 and it completed its lifetime in 2000. ERS-2 which acquired images in C-band was launched in 1995. ERS-2 images are used in studies such as interferometry applications, agriculture, forestry, digital elevation model generation, deformation measurements and soil moisture mapping. JERS-1 satellite was launched in 1992 and its applications focus on: geological survey, land use–land cover observation of coastal regions, environment, disaster monitoring, etc. Radarsat-1 which was launched in 1995 is Canada's first SAR mission. RADARSAT-2 is the second Earth observation satellite of RADARSAT series that was successfully launched in 2007. RADARSAT-1 and RADARSAT-2 are used for ice monitoring and oil pollution detection. While RADARSAT-1 have only C-band and HH polarization data, RADARSAT-2 have dual-channel C-band and HH, HV, VV, VH polarizations. ASAR (Advanced Synthetic Aperture Radar) was an active radar sensor mounted on Envisat satellite, which was launched in 2002. ASAR is a continuation of Radarsat-1. ALOS was launched in 2006 and PALSAR (Phased Array type L-band

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Synthetic Aperture Radar) has three imaging modes that are SpotLight (SL): 1-3m, StripMap (SM): 3-10m and ScanSAR (SS): 60-100m., was launched in 2007. And it is a joint mission being carried out by a public-private-partnership. TerraSAR-X acquires data in three main imaging modes: SL: 1m, SM: 3m and SS: 10m.

Nowadays there is a huge assortment of satellite technologies recording information about the Earth. These technologies can be used for all remote sensing applications such as environment, forestry, agriculture, geology, meteorology, marine and ocean sciences.

2. GENERATION OF GEOSPATIAL INFORMATION FROM SATELLITE IMAGES

Equations used in photogrammetry form the basis of generation of geospatial information from satellite images. Realizing these applications with satellite images is called "space photogrammetry". The aim is basic principles of photogrammetry adapted to motion and image acquisition techniques of the satellite.

Generation of geospatial information from satellite image includes the following topics:

- Elimination of systematic geometric distortions,
- Determination of georeferencing accuracy and validation,
- DSM and DEM generation and validation,
- Ortho-image production and validation,
- Pan-sharpening and quality investigation,
- Evaluation of information content,
- Determination of the actual spatial resolution of the image,
- Automatic feature extraction and object recognition,
- Combination with imagery and geographically-referenced non-image data;

The researchers estimate potential of generation of geospatial information. They need numerous points with high-accuracy, uniformly distributed along vertical and horizontal planes. Additionally, they need higher quality data such as maps and ortho-images in order to validate quality of DEM, The fact of having different land cover and landforms of study area is extremely important to reveal the true geospatial potential of images.

3. ZONGULDAK TEST FIELD AND IMAGES INVESTIGATED

3.1 Zonguldak Test Field

Since 2000s, various kind of aerial and space borne remote sensed optical and microwave images are evaluated over Zonguldak (Turkey) test site. Zonguldak test field is located in Western Black Sea region of Turkey. It is famous with being one of the main coal mining areas in Turkey. The main characteristics of Zonguldak test area:

- Mountainous and undulating topography,
- Dense settlement on rough topography,
- Dense forest,
- Agricultural areas,
- Various water bodies such as rivers, sea, and dams,
- Open and underground mining areas,
- Thermal power stations,
- Iron and steel plants etc.

Zonguldak city centre was also constructed on this undulating mountainous topography (Figure 1).

As known, one of the most significant problems for space-borne imagery is the inclined topographies that are why fully flat areas are always misleading to exhibit the performance of proposed techniques. To demonstrate the contribution of techniques in this paper, the researcher consciously preferred a study area that includes rough terrain Zonguldak and its surroundings is a very suitable test site for the study due to different land use types and its mountainous structure.

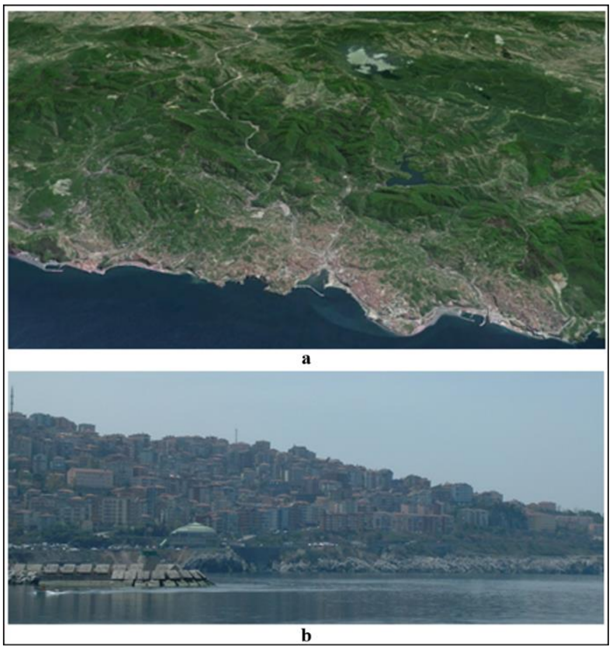

Figure 1. Zonguldak and its surrounding from Google Earth (a), and an example of Zonguldak topography (b).

3.2 Images Investigated

The investigated images were originated from various countries within various research projects. Figure 2 illustrates the countries with respect to the number of sensors investigated. The ESA missions were ignored since this is an international organization.

Some images such as Bilsat-1 and TK-350 were evaluated in a limited number of studies worldwide. The diversity of images provides the comprehensive comparison each other, covering such extreme topography.

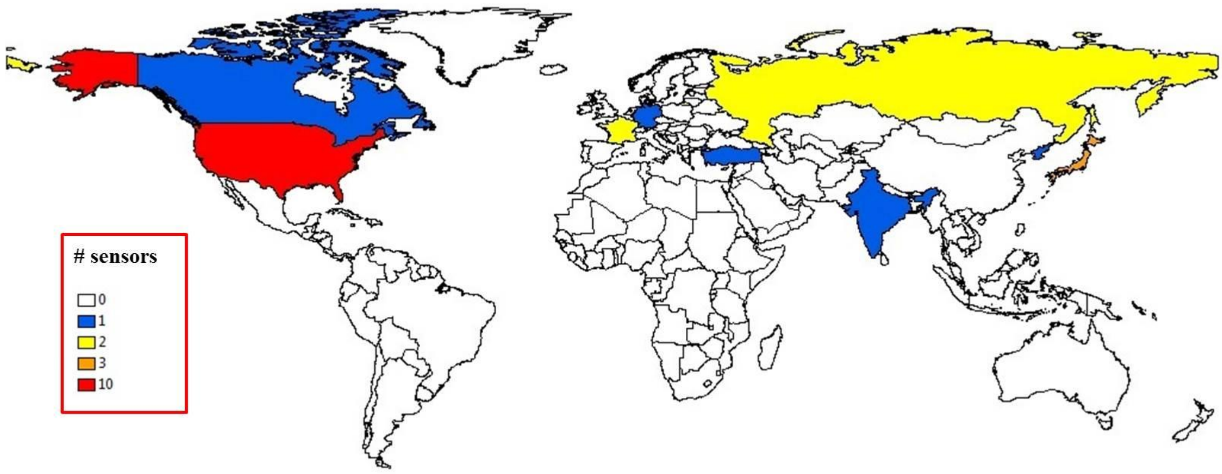

Figure 2. Developer countries of investigated sensors.

4. GEOSPATIAL ANALYSIS

4.1 2/3D Georeferencing Accuracy Assessment

Mountainous and rough areas are suitable to find out real geometric potential of optical and SAR images. Mathematical models may generate unsatisfactory results for these areas that are expected to be successful. So that, Zonguldak is an ideal test field for 2/3D georeferencing accuracy assessment. Researchers have been estimated with an accuracy of under 1 pixel for all images using the sensor dependent, sensor independent and figure condition methods, and adjustment method was preferred in these researches with ranging between 23 to 163 GCPs distributed in horizontal and vertical planes. It is certain that the accuracy may increase in the future with some developments, for example, using a collocation model which considers constraints among the parameters or different models other than the second-order polynomial for modelling the parameters can be used. TK-350, Spot-5, ASTER, Kompsat-1, KVR-1000, IRS-1C, OrbView-3, Bilsat-1, IKONOS, QuickBird and Pleiades have been investigated for 2/3D georeferencing accuracy in the Zonguldak test field (Figure 3). These studies were carried out by developing academic software BLUH system and GeoEtrim, and a commercial one, PCI Geomatica.

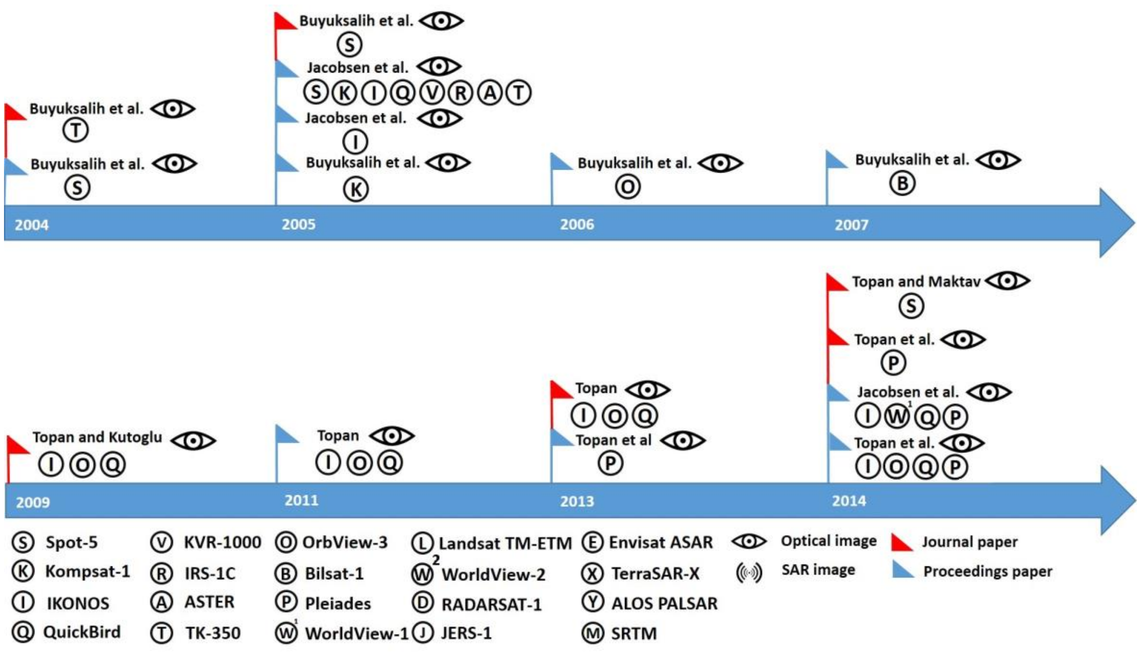

Figure 3. Summary of previous studies of 2/3D georeferencing accuracy assessment.

4.2 DEM Generation and Validation

Digital Elevation Model (DEM) is the simplest form of 3D representation of a terrain's surface. DEMs provide significant information for commercial and public applications such as generation of orthoimages, navigation, hydrology, disaster management, environmental analysis, contour lines generation, cartography, civil applications, geographical information system (GIS), urban planning, disaster management agriculture, land cover classification and many more. There are many techniques for DEM generation in remote sensing such as traditional photogrammetry based on aerial photos, stereo-optical satellite imagery, air-borne laser scanning (LiDAR) and interferometric synthetic aperture radar (InSAR). Other methods except LiDAR have been used in Zonguldak test field. By this time, many SAR and optical sensors such as TK-350, ASTER, Kompsat-1, Spot-5, IKONOS, QuickBird, Pleiades, TerraSAR-X, COSMO-SkyMed and SRTM have been used for DEM generation and validation in the Zonguldak test field (Figure 4). The existing DEM from the topographic map could be used, but has to be checked for changes and also correctness which is not guaranteed in case of Zonguldak test field. DEM generation studies in Zonguldak with SAR and optical images demonstrate the effectiveness of the approach covering a mountainous, rough and forest areas. Where DSMs were generated by PCI Geomatica and BLUH system, the filtering DSM to DEM and validation were carried out by BLUH system.

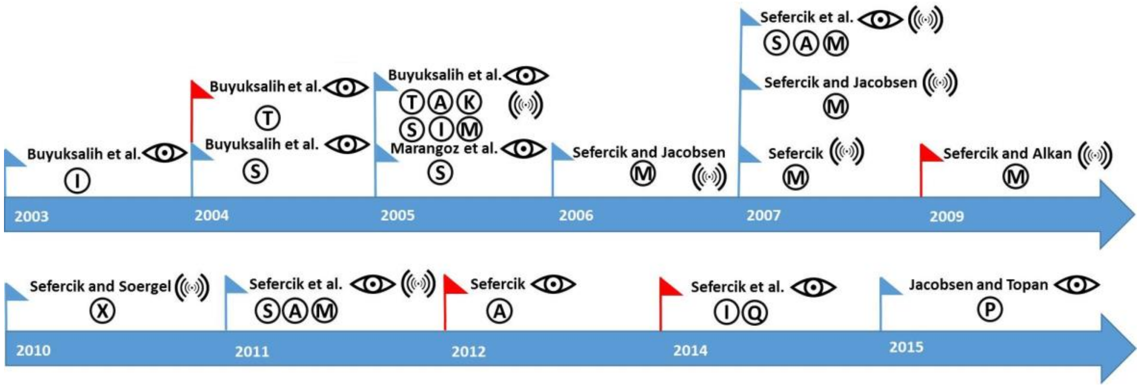

Figure 4. Summary of previous studies of DEM generation and validation.

4.3 Information Content

The extraction of object has become easier and more accurate with enhanced geometric resolution. The grey value range and spectral resolution are very important for recognition and classification of objects. The nominal ground sampling distance (GSD) may not be equivalent of effective GSD corresponding to the information content. Object recognition is affected by the topographic conditions, object contrast, sun elevation and azimuth and atmospheric conditions. The information content of panchromatic and multispectral satellite images (Landsat 7 ETM+, ASTER, OrbView-3, TK-350, KVR-1000, SPOT-5, IRS-1C, Kompsat-1, Bilsat-1, IKONOS, QuickBird and Pleiades) are available for the Zonguldak test field (Figure 5). As a rule of thumb, the measurement precision of visual interpretation is 0.25 mm, and one object (i.e. an edge) can be recognized by 3×3 or 5×5 pixels. Considering these cases, the following formula can be valid for the printed maps.

$$GSD = \left(\frac{1}{3} \sim \frac{1}{5}\right) \times 0.25mm \times scale \qquad (1)$$

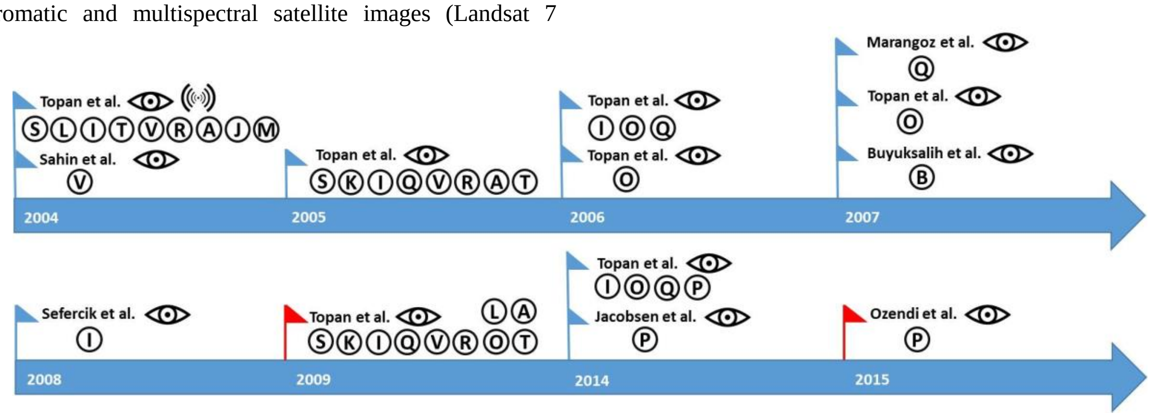

Figure 5. Summary of previous studies of information content.

4.4 Object Recognition

Projected pixel size and Ground Sampling Distance (GSD) are very important terms of geometric resolution. The first term is the physical size of the projected pixel, and second one refers the distance of the centres of neighboured pixels projected on the ground. The effective GSD should be determined for object extraction. Object extraction methods like manual and automatic object based image analysis (OBIA) have been widely used in order to detect temporal changes of earth surface including all terrain and non-terrain objects such as buildings, forest, and roads etc. in remote sensing applications. Manual extraction method is performed on screen manual digitizing of images. The automatic extraction method is definitely faster compared to manual extraction method and additionally facilitates the extraction of vector semantic data. Furthermore, automatic extraction data can be easily used with computer aided design (CAD) and geographic information system (GIS) based software. Objects have been recognized and extracted using eCognition. Overall accuracy of object-oriented classification of satellite data generation, such as the Landsat, SPOT, ASTER and KVR-1000 were 70%-85%. IKONOS, QuickBird or OrbView sensors with 1m spatial resolution, overall accuracy was determined as 80%-90%. The object recognition difficulties are decreased and overall accuracy is increased with commercial satellites with resolution of cm (Worldview, GeoEye) in the late 2000's (Figure 6).

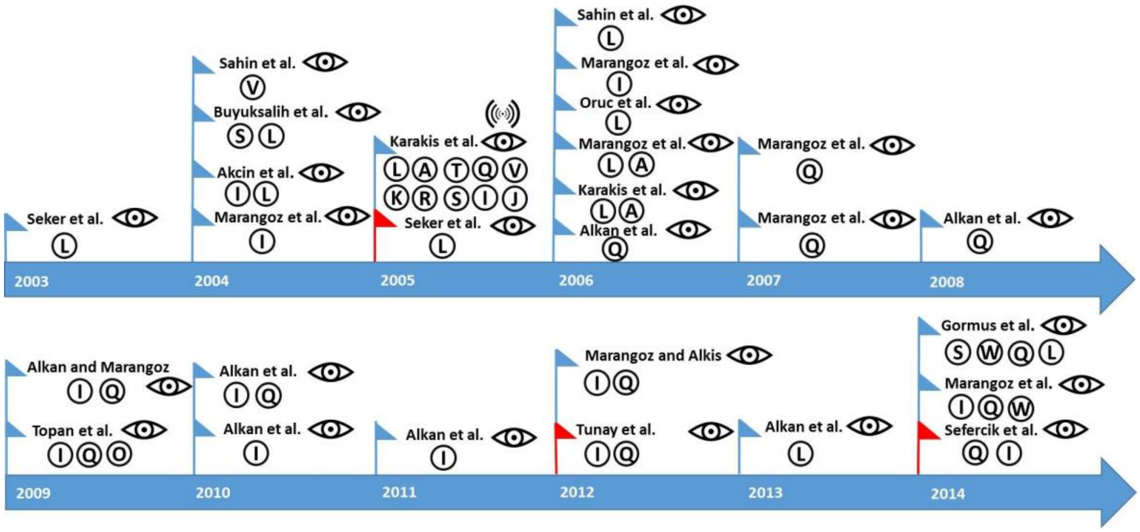

Figure 6. Summary of previous studies of object recognition.

4.5 Deformation Monitoring

In these studies, researchers reported the results of long time subsidence monitoring by persistent scatterer interferometry (PSI) analysis with C- and L-band SAR data and GPS measurements over the coal mines, Kozlu, Uzulmez and Karadon. In order to determine deformation of deep forest area, L-band is necessary so researchers use ALOS PALSAR and JERS-1 for periodic observations. The applications of InSAR technique using C-band microwave such as TerraSAR-X, ENVISAT ASAR and RADARSAT-1 have been reported in the determination of subsidence in the urban area. In first studies, deformation was detected by PALSAR approximately 3-4 cm/46 days in 2006. On the other hand, deformation was generally rated as 20–40 mm/year in same study area using ALOS PALSAR data (Figure 7). Studies were performed by various commercial and academic softwares.

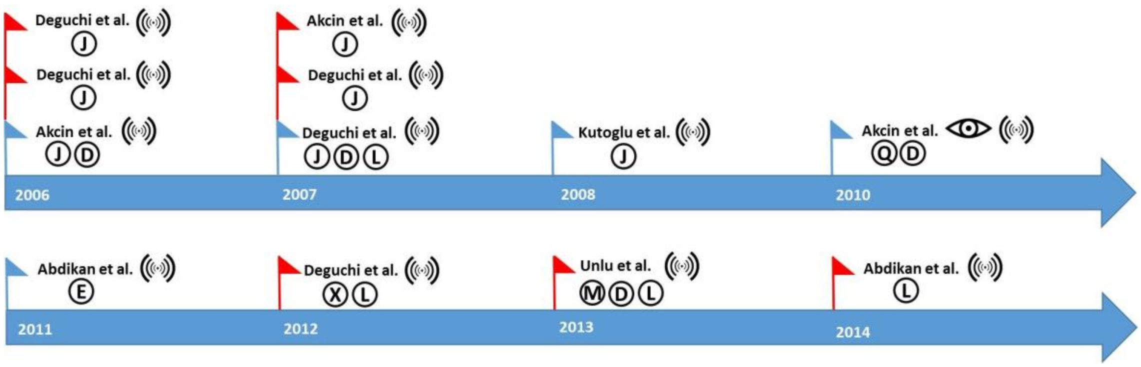

Figure 7. Summary of previous studies of deformation monitoring.

5. CONCLUSION

Combination of mountain and forest areas is complex problem and must be used several algorithms for geospatial analysis. However, the results obtained in flat areas are not satisfactory. Accordingly, researchers prefer area that has mountainous topography and different land use types as like Zonguldak test field. Zonguldak have many different natural land use types such as dense forest, river, sea, urban area and different non-natural structures such as open pit mining operations, thermal power plant. Because of this fact, Zonguldak and its surrounding is suitable to find out real geometric potential of SAR and optical images. In this paper, more than 60 proceeding papers and more than 20 journal papers about geospatial analysis applications that are performed on the test field of Zonguldak and its surroundings were reviewed. In mentioned papers, many geospatial analysis in Zonguldak test field were reviewed by authors. These applications include elimination of systematic geometric errors, 2/3D georeferencing accuracy assessment, DSM and DEM generation and validation, ortho-image production, evaluation of information content, image classification, automatic feature extraction and object recognition, pan-sharpening, land use and land cover change analysis and deformation monitoring. The geospatial analysis applications of panchromatic and multispectral satellite images such as ASTER, Bilsat-1, IKONOS, IRS-1C, KOMPSAT-1, KVR-1000, Landsat-3-5-7, Orbview-3, QuickBird, Pleiades, SPOT-5, TK-350, RADARSAT-1, WorldView-1-2 and radar image such as JERS-1, Envisat ASAR, TerraSAR-X, ALOS PALSAR and SRTM are used for the Zonguldak test field. Geomatics Engineering Departments of Bülent Ecevit University, İstanbul Technical University, Yıldız Technical University, and Institute of Photogrammetry and GeoInformation at Leibniz University Hannover achieved success in their applications. TÜBİTAK (Turkey), the Universities, ESA, Airbus DS, ERSDAC (Japan) and Jülich

Research Centre (Germany) supported these researches. These studies with various scopes make Zonguldak a significant test field.

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