4th INTERNATIONAL CONFERENCE on CARTOGRAPHY & GIS

2012, June 18 - 22 Albena, BULGARIA

UNDER THE PATRONAGE OF MS. KRISTALINA GEORGIEVA
MEMBER OF THE EUROPEAN COMMISSION

EDITORS: Temenoujka Bandrova, Milan Konecny, Georgi Zhelezov
GEOGRAPHIC INFORMATION SYSTEM FOR KONYA CLOSED BASIN PROJECT

Aydin Ustun, I. Öztug Bildirici, Taner Ustuntas, Ekrem Tusat, İhsan Ozkan, Yasar Eren, Adnan Ozdemir

Aydin Ustun, I. Öztug Bildirici, Taner Ustuntas, Ekrem Tusat
Department of Geomatics Engineering,
Selcuk University, Turkey, austun@selcuk.edu.tr, bildirici@selcuk.edu.tr,
tustuntas@gmail.com, etusat@selcuk.edu.tr
İhsan Ozkan
Department of Mining Engineering, Selcuk University, Turkey,
ozkan@selcuk.edu.tr
Yasar Eren
Faculty of Technology, Batman University, Turkey,
yasar.eren@batman.edu.tr
Adnan Ozdemir
Department of Geology Engineering, Selcuk University, Turkey,
aozdemir@selcuk.edu.tr

Abstract
The main goal of the Konya Closed Basin Project is to investigate land subsidence within the basin. The vertical changes have been investigated through GPS measurements and InSAR images taken at different dates. In order to decide whether the land subsidence is significant for land use in residential and agricultural areas within the basin, a GIS system is necessary. For this purpose GoogleEarth, MapInfo and Generic Mapping Tools (GMT) were chosen as GIS software packages. At first, a preliminary study has been performed using 1: 100 000 and 1: 250 000 topographic maps which are scanned and registered. A continuous mosaic of map sheets created from them is overlaid on the terrain in the Google Earth. GPS deformation network was designed over the mosaic map considering land use and hydrogeological properties of the KCB. Other data that the system contains are GPS points, wells, at which water depth is measured, InSAR images, geologic layers created from geological maps, and land use maps created by using NVDI method. The geology maps are digitized in MapInfo. After the completion of data collection, GIS analyses will be undertaken in order to evaluate land subsidence potential of the basin.

INTRODUCTION

Konya Closed Basin (KCB) with an area of 7% of the Turkish territory is located in the central Anatolia. Its surface water bodies do not reach the sea. Fig. 1 displays the KCB border with the black line and topographical and hydrological properties can be seen in. The basin, which has a population of nearly 5 million people, meets the approximately 10% of agricultural and industrial production of Turkey. The water needed for agricultural activities and daily use of people living in the basin area has mostly been supplied from groundwater sources. A study performed by The State Hydraulic Works reveals that there has been about 100 000 deep wells in KCB and only 27 000 of them are legal (İscioglu, 2008). The observations of 24 wells that have been observed since 1960s show an average withdrawal 77 cm per year in the groundwater table (Ustun et al., 2007).

Considering the leveling height changes up to 50 cm at some benchmarks of Turkish Vertical Reference Network in the period of 1973-2005, an initial study on the monitoring of land subsidence effects in the KCB was started. A GPS network of 6 control stations has been monitored in terms of vertical deformations. After 6 GPS campaigns that are undertaken from
2006 to 2009 land subsidence reaching up 5 cm has been determined in the areas where underground water has been heavily used (Ustun et al., 2010). By means of correlation analysis, it has been seen that there is a significant correlation between the magnitude of land subsidence and the use of groundwater.

Figure 1: Konya Closed Basin and the project area (green border)

In 2010, with the aim of monitoring and detecting of effects of land subsidence in the KCB, a project proposal was submitted to The Scientific and Technological Research Council of Turkey (TUBITAK). The part of Konya Closed Basin covering Konya city center and plains of Cumra has been selected for a case study (see Fig. 1). In the same year, the studies of the project were started with the new GNSS network design for a broader research area including Konya city center. Besides the GNSS technique for measurement of surface deformations, geodetic (e.g., InSAR and leveling), geotechnical (magnetic settlement observations in the boreholes near the GNSS stations) and hydrological observations of groundwater levels will also be performed. All vector and raster data compiled, collected and processed from different sources over the duration of project will be analyzed to assess the subsidence effects on the infrastructure systems and the residential areas by means of Geographic Information Systems (GIS). In this context, data management, modeling and risk assessment for detecting and monitoring of land subsidence in the KCB require to built a three dimensional and time dependent (3D/4D) geoinfomation system (Breunig, 2001).

This paper presents the studies related the design and establishment of GIS for the KCB. The preliminary studies include the compilation of vector data and topographic, geological and hydrological maps and the registration process of them. The diversity of projection, scale and datum of these maps requires a special concern for the representation of data and the project results within unique reference system. In this study, data compilation, organization, datum transformation and software aspects are dealt with.

GIS COMPONENTS OF KCB PROJECT

In the KCB project, the following data are collected and compiled for the considered GIS study: Topographical base maps of 25K, 100K and 250K, hydro/geologic maps of 100K, 200K and 500K, as well information of active fault lines about the basin, hydrological data including the positions of deep wells, groundwater level monitoring stations and surface water
bodies (e.g., river, lake, and embank), the station coordinates of GNSS and leveling network, InSAR and remotely sensed imagery data. All data are stored and organized using the Mapinfo and Google Earth. In addition, to create some GIS layers, such as terrain relief based on the SRTM (Shuttle Radar Topography Mission) data, GMT (Generic Mapping Tools) software package is also used (Wessel and Smith, 1991). For this study, 3 arc-second resolution of the SRTM data filled with local topographic maps as taken reference for topographic representation of the basin (JPL, 2008; Bildirici et al., 2010).

Maps and vector data obtained from different sources are transformed to WGS84 datum, and latitude longitude coordinate system. Doing so, all data are compatible with Google Earth. In order to interpret the influence of agricultural activities on land subsidence occurrences, land use maps are created by remotely sensed imagery. For this purpose, Erdas software are used to process Landsat TM imagery data.

DATA COLLECTION AND ORGANISATION

Topographic Maps

The topographic maps of 250K and 100K covering the KCB are collected and scanned. The map set consists of 9 and 12 sheets for 250K and 100K maps, respectively. Although these sheets are produced in the UTM (Universal Transversal Mercator) system, their datum systems for coordinates are different: ED50 (European Datum 1950) and WGS84 (for those produced after 2002).

All sheets are registered under Mapinfo GIS environment. The actual map area is a quadrangle in the UTM system. In order to create a seamless mosaic, the actual map area of these sheets must be rectangular; otherwise, there will be gaps on the edges of the sheets. To achieve this, all sheets are transformed into equidistant cylindrical projection, mostly called geographical coordinate (latitude/longitude) system in GIS software. With this process, datum transformation from ED50 to WGS84 is also applied. After performing these operations of projection and datum transformation, the actual map areas are cut and the rectangular image files are created. These files are re-registered in the Mapinfo, and thus, a seamless mosaic has been generated. Same files are also registered in Google Earth, and the images are draped over the terrain using the image overlay function. 250K and 100K mosaics are shown, in oblique view in Google Earth, as seen in Fig. 2. It can be said that the results of spatial matching seems good since there are no gaps and overlays at the edges.

Figure 2: 3D oblique view of topographic mosaic map for 250K (left) and 100K (right)

In terms of colors and contrast, the sheets can be distinguished in the mosaic. The reason is that the production dates of the sheets are different. Although all 100K sheets are produced considering the same regulations, the resulting analog maps are not the same. In Fig. 3, a part of the 100K mosaic map is shown, where 4 sheets meet. The edge matching seems appropriate, however, the changes of the color and contrast between individual sheets is remarkable. Same problem occurs also in the mosaic of 250K maps. Here, one of the sheets is produced according to the old regulations of the manufacturer, General Command Mapping of Turkey, so the symbolization, and datum differs from the other sheets. This situation can also easily be identified in Fig. 2. In this work, all sheets are scanned in the same device with the same resolution. After scanning, no modification, in terms of image processing, is applied. In near future we plan to do some enhancements in the scanned files, in order to minimize the differences between the sheets of same symbolization.
Hydro/Geologic Maps and Data

A hydrogeologic map shows hydrologic features as rivers, streams, lakes and according to the mapping purposes other basin characteristics like artificial deep wells. A 200K paper map of the basin had been prepared by State Hydraulic Works of Turkey in 1972. It helps us to recognize hydro/geologic characteristics for designing the GNSS network and drilling boreholes for geotechnical analysis. When selecting the GNSS station places, this map has taken as reference to investigate the interaction between surface deformation and groundwater levels. Most of the GNSS stations are chosen close to the groundwater level monitoring stations which are operated by the State Hydraulic Works. The borders of hydrogeologic areas associated with ground characteristics and the positions of groundwater monitoring wells are included in GIS environment as vector and raster data layers.

In Turkey, geological maps are produced at different scales by General Directorate of Mineral Research and Exploration. The most detailed map set is 100K geologic sheets. 12 sheets including the KCB area are supplied and scanned. The images are registered by MapInfo. Then, geological features are manually digitized. There are 27 different areal features in the maps. A sample view of the geological maps is seen in the left panel on Fig. 4.
Figure 4: A part of the geological 100K map sheet K27 (left), a map showing the active fault systems and seismicity of the project area (right panel, Eren, 2004)

The image files of geological map sheets are arranged like the topographical maps, and defined in Google Earth format as ground overlays. Doing so, the geological sheets are draped over the terrain, and 3D visualizations are obtained.

Tectonic faults located in KCB area are mostly depicted in geological sheets at the scales of 500K. In order to design GNSS and leveling network and to evaluate the land subsidence in KCB area, local tectonic activity should be taken into account. Therefore more precise fault data is necessary. The first study was carried out by using 500K geological maps and then these data are detailed by means of 250K topographic maps (Eren, 2004). The original study on the fault systems and seismicity of the project area is displayed in the right panel on Fig. 3. The vectorized data from geologic maps and the historical records about the seismicity for the study area are imported into the GIS environment by MapInfo tools.

**GNSS Network**

A GNSS network to detect and monitor vertical deformations for Konya city center and surrounding areas was designed and established in basis of topographic, geologic and hydrogeologic properties of thought study area in Fig. 1. Three dimensional displacements at 28 GNSS stations will be observed during the project lifetime of three years. It is expected to collect 10-12 campaign data in this period. The station coordinates and associated station-ground properties are recorded in the database with different layers. The records in the database about these stations as well as InSAR deformation maps are considered 4D geodata in the GIS environment. The stations of GNSS network displaced in Fig. 5 are evaluated in three separate groups according to the nature of the ground.
Figure 5: Topographic map of the project area. Red lines show active fault systems. Black, blue and green symbols denote the GNSS stations to measure the ground displacements.

- The mountainous areas not expected significant point-wise displacements: Spatial deformations and displacements in the lowland plains will be referred to these stations.

- The areas not expected subsidence, left the basin floor (savanna): In the limestone formations, outside the area of agricultural activities and settlements, the ground subsidence is not expected. The stations in these areas are used to estimate the behavior fault systems surrounding the basin.

- The lowland areas expected subsidence: These units consist of the agricultural and residential areas, especially Kenya city center. The intensive use of groundwater are observed in that places. The ground characteristics are identified in terms of geotechnical and hydro geological parameters of soil and rock materials.

SAR Data and Interferograms

For mapping the Earth’s surface topography and its temporal changes, the InSAR (Interferometric Synthetic Aperture Radar) is a state-of-the-art technique that uses the remote sensing radar images taken at different positions and times. It enables to look at certain region on the earth in every 35 days and surface deformations in LOS (Line Of Sight) can be detected using the differences of phase returning to the spacecraft or aircraft sensor (Massonnet, 1998; Burgmann et al., 2000). Spatially and temporarily, in observing ground surface vertical deformations, InSAR has a great potential since presenting a unique pixel density with ~100 pixels/km².

In this project, the ASAR image set of ENVISAT satellite from 2003 to 2009 is used to investigate subsidence and its time-dependent changes in the basin by using differential interferograms. The location of the study area is covered by the track 207 and frame 2853, track 207 and frame 2835, track 436 and frame 2853. The several interferograms having good coherence show significant deformations for the first track and frame, 207 and 2853. Before the interpretation, the
preliminary results will be validated by other geodetic techniques like GNSS. The valuable interferograms can be attached easily as raster images. The InSAR processing softwares, such as DORIS (Kampes and Usai, 1999) and GMTSAR (Sandwell et al., 2011) are capable for geocoding the final interferograms to the Earth fixed coordinate system, e.g. WGS84 or exporting them to the GoogleEarth kmz/kml files.

Land Use Data

When taking into consideration of the land use and agricultural quality, 48% of the KCB has the sustainable agricultural units that would produce quality products. Approximately 10% of total groundwater reserves of Turkey have been abstracted in the KCB, annually (İscioglu and Hamarat 2004). The agricultural demand on this water is increasing every year.

Irrigation is one of the factors that create stress on groundwater sources. In this context, the changes in the agricultural land units and water bodies are investigated by using remote sensed imagery. The results are land use maps as part of layers of KCB-GIS. Landsat TM images taken in 1989, 1998, 2003 and 2010 are used and processed to produce this kind of maps. The classified images with respect to Normalized Difference Vegetation Index (NDVI) can be used to identify different areas (Rouse et al., 1973; Tucker 1979). The identified classes are water, rock, grassland and green area (agricultural usage).

Figure 6 shows the results of classification, while Table 1 summaries the numerical changes of land use. As seen in the table and figure, the increase in green area shows the agricultural activity, therefore increase in irrigation. The water required for irrigation is gained from the ground water. The correlation between land use changes and surface deformation obtained from InSAR techniques will be analyzed spatially using GIS tools. For these purposes, the intermediate results of these works will be registered as independent layers within the frame work.

Table 1: Field classes with respect to the NDVI values and their changes between 1989-2003

<table>
<thead>
<tr>
<th>NDVI Value</th>
<th></th>
<th>1989</th>
<th>1998</th>
<th>2003</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1</td>
<td>39</td>
<td>20</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>Rock &amp; Soil</td>
<td>-0.1–0.1</td>
<td>17437</td>
<td>16859</td>
<td>17045</td>
<td>16396</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.2–0.4</td>
<td>907</td>
<td>1251</td>
<td>1219</td>
<td>1464</td>
</tr>
<tr>
<td>Gcn Area</td>
<td>0.4–1</td>
<td>285</td>
<td>538</td>
<td>368</td>
<td>766</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>18668</td>
<td>18668</td>
<td>18668</td>
<td>18668</td>
</tr>
</tbody>
</table>

CONCLUSION AND SUMMARY

In this study, we introduce the data components of GIS for a project related with detecting and monitoring land subsidence occurrences in the Konya Closed Basin. There are many environmental factors triggering land subsidence. In KCB project, a diversity of data are collected and integrated within a GIS framework. Only, this kind of environment can achieve to combine, manage, and analyze data that comes from different sources. At the current stage of the system, input data have been collected and combined. Because the collected raster and vector data are distinguished from each other by their spatial and temporal references, in some cases a conversation for data integrity has been required throughout the project duration. The integration and representation of spatial data will be presented in basis of the WGS84 coordinate system as default.
Figure 6: NDVI classification at different dates the features. (The classes: water (blue), rock & soil (brown), grassland (light green), green area (green))

With this project, it is aimed to build a component based 3D/4D information system. This environment will help us to spatial and temporal management of geodata and forecasting possible consequences of land subsidence effect in the KCB. To do this, it requires several GIS software tools in storing, analyzing, visualizing and representing geodata. GoogleEarth, MapInfo and GMT are considered main software sources to perform different goals.

ACKNOWLEDGEMENT
This paper supported by the Scientific and Technological Research Council of Turkey under Grant 110Y121 and Selecuk University Scientific Research Projects Coordinatorship under Grant 1207.

REFERENCES


Eren, Y. (2004), The earthquake risk in Konya, Yer Bilimi ve Teknigi Dergisi, 1, 1, 12-16 (in Turkish).


