

# Geomatics for Rehabilitation of Mining Area in Mahis, Jordan

Rami Al-Ruzouq<sup>1</sup>, Samih Al Rawashdeh<sup>2</sup>

<sup>1</sup>Department of Civil and Environmental Engineering, University of Sharjah, Sharjah, UAE

<sup>2</sup>Department of Surveying and Geomatics Engineering, Al-Balqa Applied University, Al-Salt, Jordan

Email: [ralruzouq@sharjah.ac.ae](mailto:ralruzouq@sharjah.ac.ae)

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## Abstract

Mining activities often cause dramatic changes in landscapes, particularly in the dump sites and its surrounding environment. Land rehabilitation is the process of renovating damaged land to some extent of its original shape and aims to minimize and mitigate the environmental effects to allow new land uses. The success of different rehabilitation strategy and newly suggested urban and architecture modeling depends on the landscape characterization (topography of the study area and its derivatives such as slope and aspects, geological and geomorphologic nature of the study area). The aim of this study is to demonstrate the utility of different methodologies based on geomatics techniques (Photogrammetry, Remote Sensing, Global Positioning System (GPS) and three dimensional Geographic Information System (GIS)) for highlighting landscape characterization which is needed for rehabilitation of Mahis area. Photogrammetric adjustment procedures were used to create digital elevation model and Orth-Photo model for the study area using aerial images. Remote sensing data were used for land classification to provide vital information for rehabilitation planning. GPS field observations were used to build spatial network for the study area based on ground control point collections. Finally, realistic representation of the study area with three dimensional GIS was prepared for the study area considering ease and flexible updating of the geo-spatial database.

## Keywords

Land Rehabilitation, Mining, Photogrammetry, Remote Sensing, GIS

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## 1. Introduction

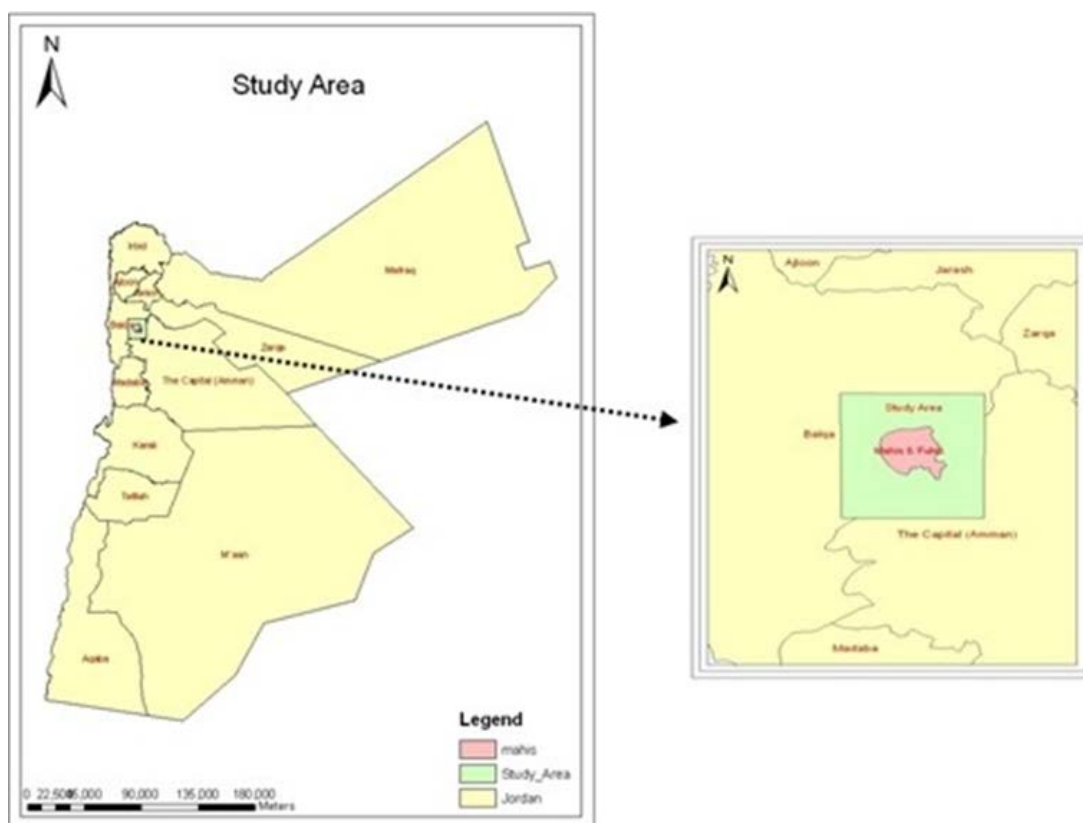
Rehabilitation is the process of returning the land in a given area to some degree of its former self, after some

process (business, industry, natural disaster etc.) has damaged it [1]. Many projects and developments will result in the land becoming degraded, for example mining, farming and forestry. Different Geomatics techniques were used to prepare the comprehensive knowledge base needed for the rehabilitation process; first we started with collecting the Ground Control Points by using GPS, second, remote sensing techniques were applied such as image classification and Band Fusion. Photogrammetric techniques were used to produce DTM and Ortho-photo for the study area. Moreover, 3D modeling using AutoCAD was used to add different modules to the Ortho-photo. Finally by using GIS, different layers like (contour lines and Faults) were added.

Mahis mining study area is about 250 m<sup>2</sup> and located at Latitude: 31°58'60N, Longitude: 35°46'0E and 810 meters above mean sea level, **Figure 1**. It is between Mahis and Al-Fuhays towns, which are connected with Al-Salt, and the capital Amman about 30 km away. It is also about 35 km from the Dead Sea which is lowest spot located on the earth. For the past 30 years, this mine has been producing some of the highest grade Kaolins in the area where the output capacity reaches more than 70,000 tons annually. **Figure 2** shows actual situation of the Mahis quarry.

Literature shows that many projects that dealing with rehabilitation of opencast mining area using Geomatics. Most of these projects deal with Photogrammetry Global positioning system (GPS), remote sensing, geophysics and GIS to prepare and organize the geo-base knowledge of rehabilitation process. The legacy of an estimated twenty-seven thousand abandoned mines pose environmental, health, safety and economic problems to communities, the mining industry and governments across Canada [2]. Information gathering for these sites is necessary to enable sound decision-making, cost-efficient planning and sustainable rehabilitation. The sustainable management and rehabilitation of mine sites for decision support project is working collaboratively with federal departments, provincial governments and industry to develop new techniques for information collection and integration to support mine reclamation and policy decisions surrounding mine rehabilitation.

In support of the Ontario Ministry of Mines and Northern Development (OMND)'s Abandoned Mine Rehabilitation Program, scientists are providing a case study using new techniques at the KamKotia mine in northern Ontario. Copper and zinc were mined at KamKotia from 1942-1972, before it was abandoned and left under



**Figure 1.** Location of the study area.



**Figure 2.** Actual situation of the mahis quarry.

government stewardship. During this period, three million tons of tailings were discharged in the area around the mine, before an impoundment was built in 1967. This produced a “kill zone” of approximately 170 hectares [3].

In 2001, the OMND began a multi-year project to rehabilitate the site. To date, a water-treatment plant and a new tailings impoundment have been built, and the exposed tailings areas are being dredged and deposited in the new impoundment. Baseline map of the site was developed using information extraction techniques for remote sensing data, developed in collaboration with the Geo-research Centre (GFZ) in Germany. The map was derived from airborne “hyper-spectral” remote sensing data collected in 2001, with a five-meter spatial resolution. Hyper-spectral sensors collect reflected radiation from the earth’s surface in a large number of narrow spectral bands. In 1991 and 1998, the International Aluminum Institute (IAI) commissioned surveys regarding bauxite mine rehabilitation programs that had been undertaken by operations around the world. The aim in both cases was to provide data on the environmental impacts of bauxite mines and their rehabilitation programs. In 2003, a third survey was carried out to follow up and extend the first two. The survey shows that bauxite miners are making substantial efforts towards the sustainable development of the industry. Moreover, this project includes items that are not founded in the previous rehabilitation projects such as: different layers cover the area (contour lines, faults, hospitals...), bands combinations, DTM and Orthophoto generation, and 3D modeling [4] [5].

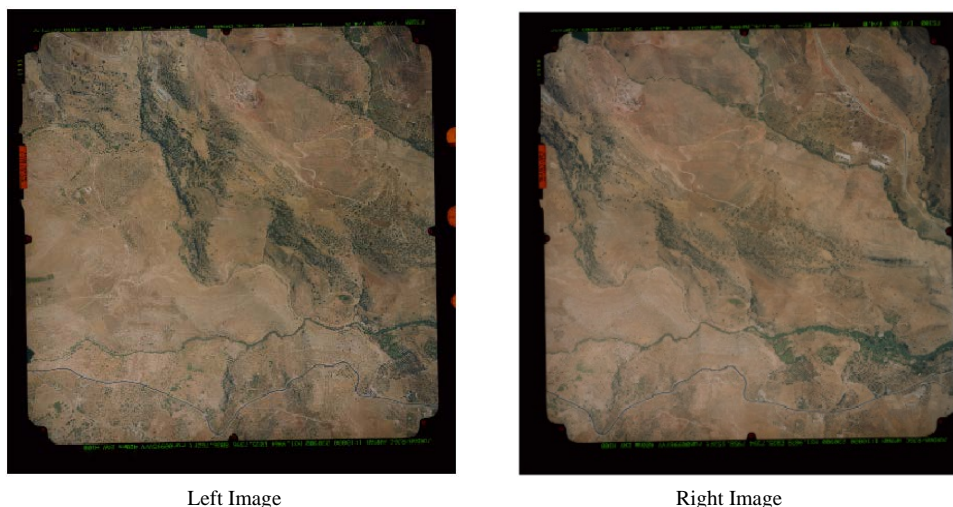
The objectives of this project can be summarized by two main points: first, create geo-database of the study area (Mahis, Jordan). To evaluate the rehabilitation process for the opencast mining area. The Geodatabase include: Digital Terrain Model DTM from different sources such as SPOT, Contour lines and aerial photos, Ortho-photo, Land use map, Ground Control Points and Structural map and finally Produce a three-dimensional Modeling GIS for the study area; second, improvement of the ecological, economic, and social situation of the region, to satisfy the needs of today’s generation without threatening the quality of life of the coming generations.

In this paper, we will discuss the various steps for spatial data collection and processing in the Mahis area to establish the geographic information system. This includes, photogrammetry processing based on aerial and satellite discussed in Section 2. Section 3 illustrates the output of remote sensing based on Landsat satellite image. Section 4 describes various elements of Geographic Information System (GIS). Three dimensional modelling of produced geospatial element were depicted in Section 5 for better visualization and interpretation capabilities. Rehabilitation process and requirements needed for the suggested modeling were discussed in Section 6. Finally, conclusion and future work are discussed in Section 7.

## 2. Photogrammetric Processing

Photogrammetry was the main source of spatial data in our project, two main photogrammetric products generated; ortho-photo, and digital elevation model (DEM). As shown in **Figure 3**, stereo aerial photos were used in this project and have the following properties:

- Aerial photos scanned from hard-copy images and one strip directed (North-South).
- 60% overlap between two adjacent photos.
- 1:25,000 photos scale and 23 cm<sup>2</sup> film format.
- Spatial resolution is about 50 cm<sup>2</sup> with 5.7 km<sup>2</sup> coverage per photo.



**Figure 3.** Aerial photos for Mahis area (Jordan).

### 2.1. Digital Terrain Model (DTM) Extraction

The concept of creating digital models of the terrain is relatively recent development. DTM is simply a statistical representation of the continuous surface of the ground by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field. The choice of data sources and terrain data sampling techniques is critical for the quality of the resulting DTM. At present, most DTM data are derived from three alternatives source: Ground surveys, Photogrammetric data capture (which is the data source of the DTM in this project), and Digitized cartographic data sources. **Figure 4** shows the resultant DTM after aerial triangulation process for the aerial photos using ground control points described in the next Section. **Figure 4** shows the variation in elevation from 396 - 736 m above mean sea level where white color shows highest elevation [5] [6].

### 2.2. Ortho-Photo Generation

An ortho-photo is photo that has the same characteristics of a map. Thus, ortho-photo can be used as maps to make measurements and establish accurate geographic location of features. Ortho-photos are generated from aerial photographs and satellite images through a process known as ortho-rectification. A normal (uncertified) aerial photograph and satellite images does not show features in their correct locations due to displacements caused by the tilt of the sensor and terrain. Ortho-rectification transforms the central projection of the photograph into an orthogonal view of the ground. Therefore it is removing the distorting effects of tilt and terrain [7].

Generation of an ortho-photo map from aerial photograph requires information on the location of the camera and its orientation in space as well as a model of the terrain elevation. In this project, ortho-photo was generated for the study area using information obtained from the photogrammetric processing and the DTM. **Figure 5** shows the three dimensional result of the Ortho-photo and DTM.

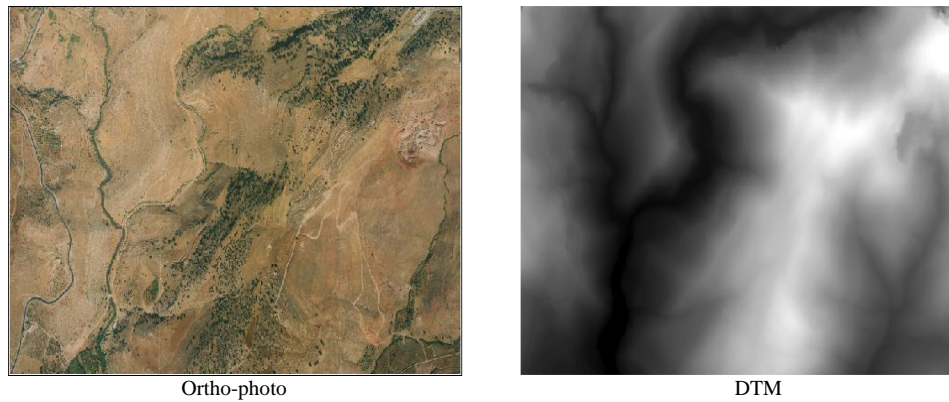
### 2.3. Ground Control Points (GCPs)

Photogrammetric control consists of any points whose positions are known in an object-space reference coordinate system and whose images can be positively identified in the photographs. In aerial photogrammetry, the object space is the ground surface, and various reference ground coordinate systems are used to describe control point positions. Photogrammetric control, or ground control as it is commonly called in aerial photogrammetry, provides the means for orienting or relating aerial photographs to the ground [8].

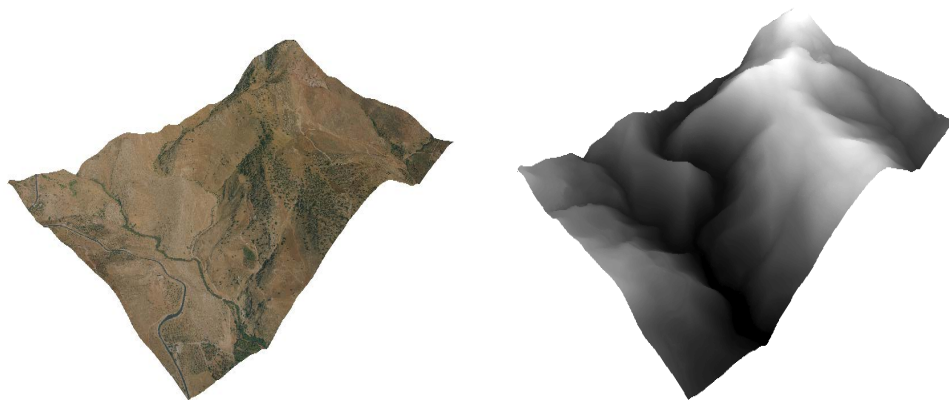
After collecting the project aerial-photos, GCPs is needed. Thus, planning and distribution of the GCPs on the photos (Planning Stage) is necessary in order to make the suitable selection of GCP which covered study area, as in the following **Figure 6**.

Difficulties during GCP collection due to the steep and high mountains topography of the study area is where only very few interest and sharp features appearing in the aerial and it was not easy to be distinguished.

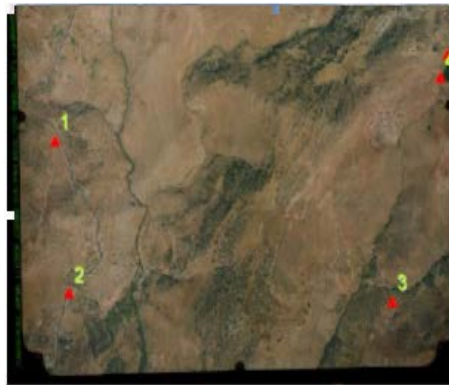




**Figure 4.** Ortho-Photo and DTM generated after aerial triangulation process.



**Figure 5.** The Ortho-photo and the DTM in 3D view.



**Figure 6.** GCPs distribution in the overlap region.

### 3. Remote Sensing

Remote sensing is concerned with acquiring spatial information from a range of sensors, including satellite imagery, airborne scanners and radar satellites. Remote sensing provides important coverage, mapping and classification of land cover features, such as vegetation, soil, water and forests. In this project, remote sensing focuses on Band-Combination and classification. The data used for this purpose was Landsat Scenes covering Jordan and some of the nearby countries. The Landsat scenes were in the 6 TM bands (bands 1, 2, 3, 4, 5, and 7), **Figure 7**. The scenes are geo-referenced images in the UTM36N WGS84 coordinate system. The spatial resolution of these scenes is 30 m and captured in year 2000.

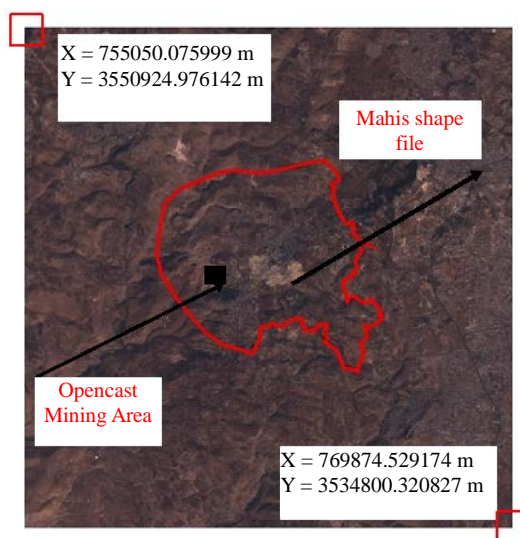
### 3.1. Supervised Classifications

Supervised classification is more closely controlled by you than unsupervised classification it requires more input and experience by the analyst but it can produce more accurate and useful results than unsupervised classification. In this process, you select recognizable regions within an image, with help from other sources, to create sample areas called training sites. Your training sites are then used to train the computer system to identify pixels with similar characteristics. Knowledge of the data, the classes desired, and the algorithm to be used, is required before you begin selecting your training sites. By setting priorities to your classes, you supervise the classification of pixels as they are assigned to a class value [9] [10].

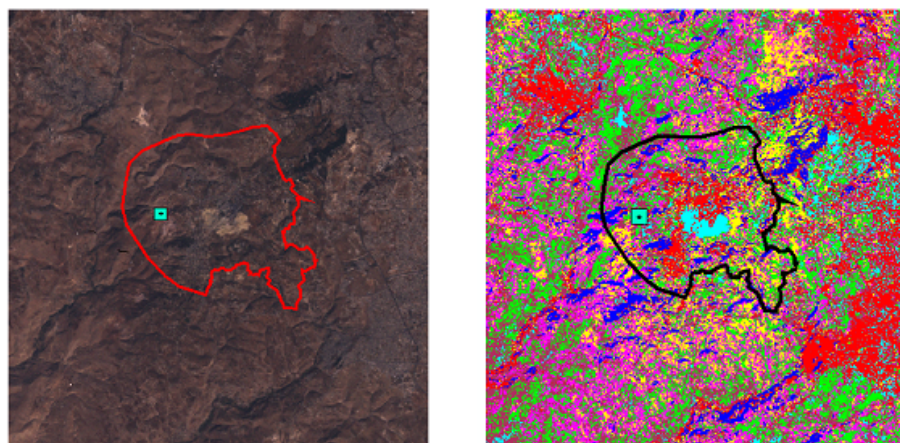
Maximum likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability. The maximum likelihood classifier is considered to give more accurate results than parallelepiped classification however it is much slower due to extra computations, **Figure 8**.

### 3.2. Unsupervised Classification

An unsupervised classification organizes image information into discrete classes of spectrally similar pixel values [9]. This is a highly computer-automated procedure. In an unsupervised classification the software automatically divides the range of spectral values, contained in an image file, into classes. A classification report can



**Figure 7.** Land-sat subset image for the study area.



**Figure 8.** Maximum likelihood classification.

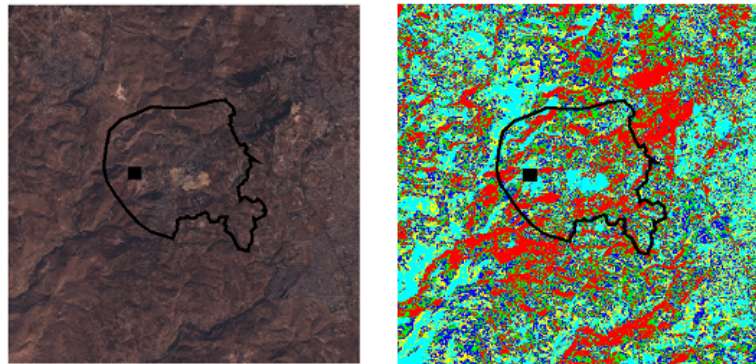
indicate the presence of a specific ground cover because a proportion of the classified pixels fall within its known spectral signature.

In such a case, you need to know what the spectral signature of the target ground cover is in order to identify its presence. Unsupervised learning or clustering is a way to form “natural groupings” or clusters of patterns. K-Means method works by choosing random seeds, which can be thought of as points with random DN values. After the seeds have been chosen lines are formed to separate the classes. Next, the points lying within the delineated areas are analyzed, and their means are noted. The means then form the new seeds, and a new series of lines are formed to separate the classes. This process is then repeated several times, **Figure 9**. Assuming that the number of clusters is known and well defined, k-means algorithm has been adopted rather than the ISODATA algorithm.

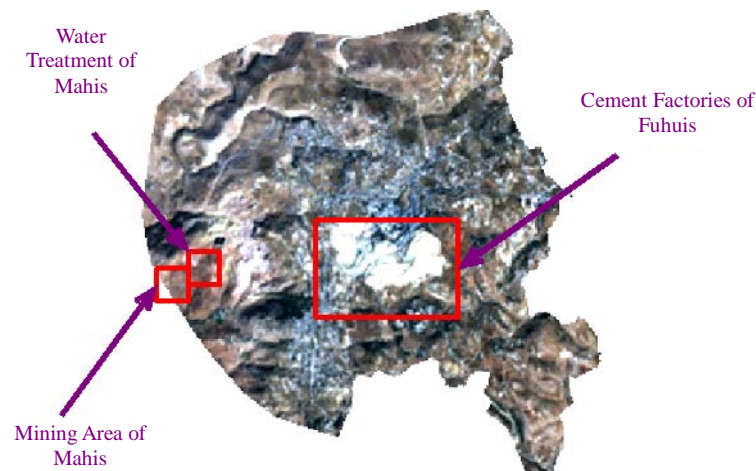
### 3.3. Bands Combination

Satellites acquire images in black and white, and it is possible to create the beautiful color images. Images created using different bands (or wavelengths) have different contrast (light and dark areas) [9] [11]. Computers make it possible to assign “false color” to these black and white images. The three primary colors of light are red, green, and blue; computer screens can display an image in three different bands at a time, by using a different primary color for each band. Different combination for these three images we get a “false color image”.

Combination 3, 2, 1: the “natural color” band combination, **Figure 10**. The visible bands are used in this combination, ground features appear in colors similar to their appearance to the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are gray, and shorelines are white. This band combination provides the most water penetration and superior sediment and bathymetric information. It is also used for urban studies.



**Figure 9.** K-means classification.



**Figure 10.** Mahis and fuhuis from space (321 ETM+).



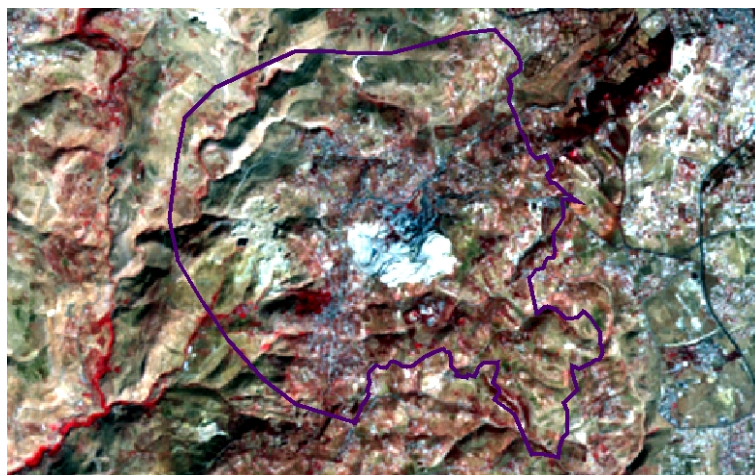
Combination 4, 3, 2: the standard “false color” composite. Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns. Ice, snow and clouds are white or light cyan. Coniferous trees will appear darker red than hardwoods. This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth. Generally, deep red hues indicate broad leaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas. Densely populated urban areas are shown in light blue. This TM band combination gives results similar to traditional color infrared aerial photography, **Figure 11**.

## 4. Geographic Information System (GIS)

In general, data entry can be very time consuming, but it is the most important task of the GIS process. This Section discusses the basic organization of entering data, scanning, layers designing, digitizing, geo-referencing and projection, (3D) applications in GIS, creating a layout for study area [12]. In this paper, “ArcGIS” program was used in the GIS processing that include scanning, geo-referencing and digitizing,

### 4.1. Maps Scanning and Geo-Referencing

A Map can be defined as extremely accurate sketch which simulate the reality with two fundamentals special effects. The first is the map scale which is the ratio between distances on the map to the same distance on ground. The second is the map projection and the coordinate system which is defined as systematic transformation of the spheroidal shape of the earth so that the curved, three-dimensional shape of a geographic area on the earth can be represented in two dimensions, as x, y coordinates. Projection formulas are mathematical expressions that convert data from a geographical location on a sphere or spheroid to a representative location on a flat surface. See **Table 1** and **Figure 12** which shows a sample of the processed topographic and geological map.

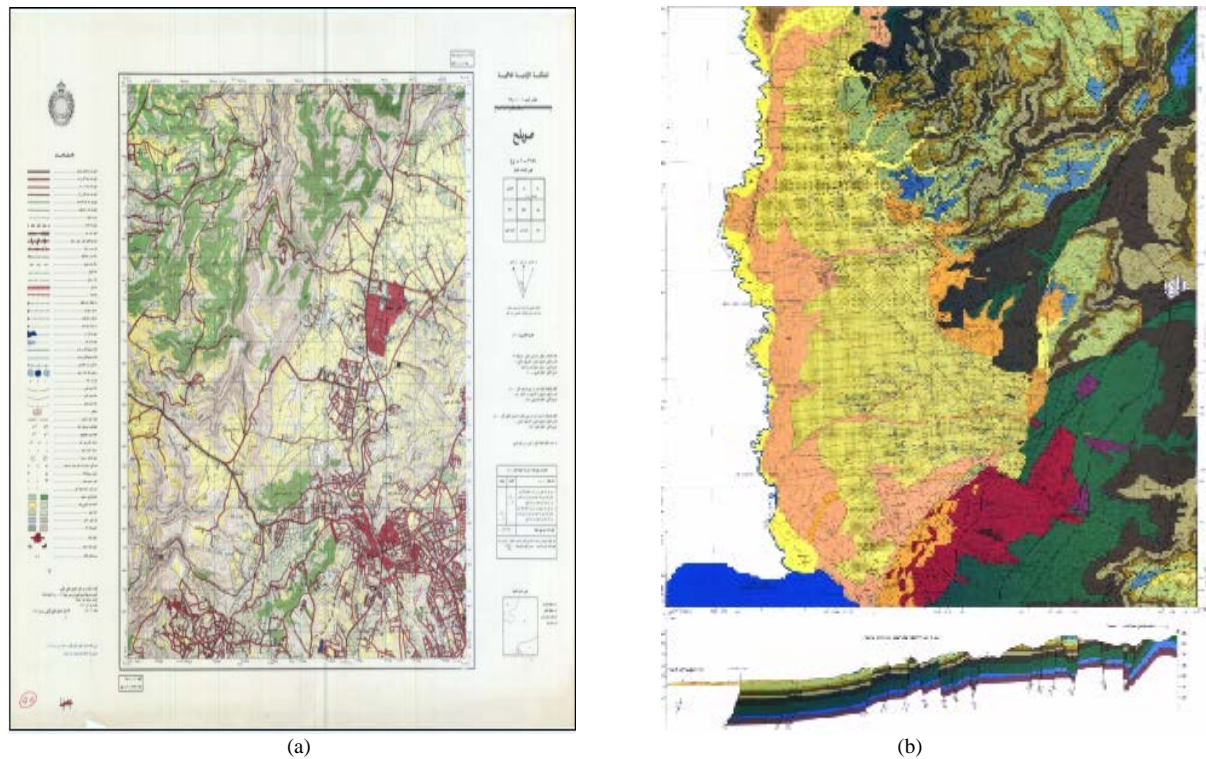


**Figure 11.** 4, 3, 2 band combinations.

**Table 1.** List of the scanned topography and geology maps.

Name	year	Type	Scale
Mahis	1992	Topography	1:10,000
Wadi as ser	1992	Topography	1:10,000
Sweileh	1991	Topography	1:50,000
Dead sea	1997	Topography	1:50,000
Amman	2001	Geology	1:50,000
Salt	1993	Geology	1:50,000
Sweileh	1993	Geology	1:50,000
Dead sea	2001	Geology	1:50,000





**Figure 12.** Sample of scanned maps. (a) Topography; (b) Geology.

## 4.2. Structural Map

Structural Map contains many structural elements such as faults, rocks composite, wells to help us lately to select the proper sites for buildings, farming, etc. [13]. The study include four geological maps [Amman, AS-Salt, Suwaylih, Al-Karama]. Digitized Faults from Geology Map with scale 1:50,000 shown in Figure 13.

## 5. Three Dimensional Modelling

A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. A TIN is a vector-based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (x, y, and z) that are arranged in a network of no overlapping triangles. TINs are often derived from the elevation data of a rasterized digital elevation model (DEM) [14].

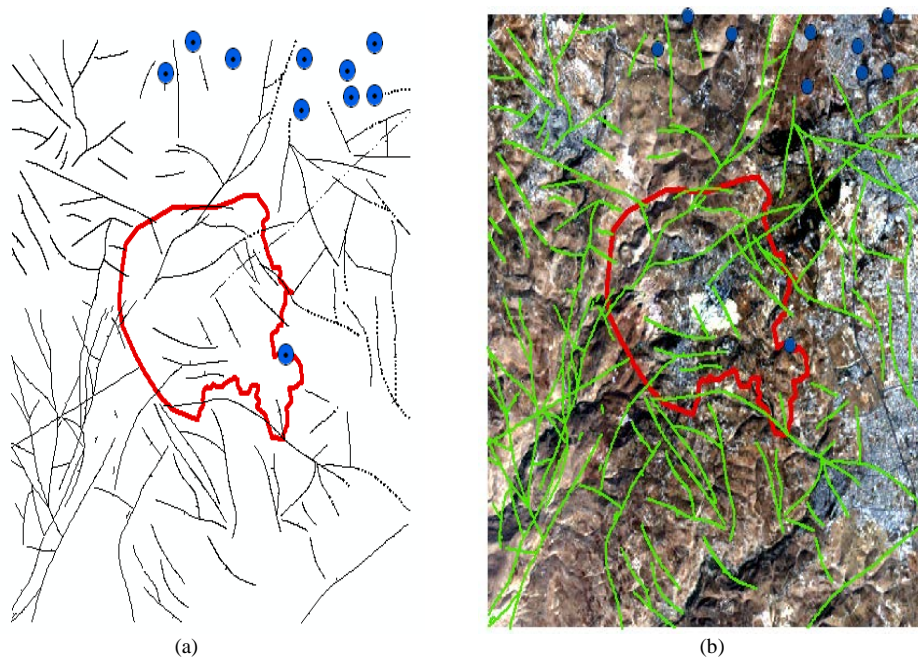
Triangles in a TIN can be oriented in different directions. The orientation of triangles is referred to as triangulation. Figure 14 shows some triangles that are oriented vertically while others are oriented horizontally. Thereafter, the TIN can be converted to raster with 10m resolution. The slope and aspect (direction of slope) has been also derived from TIN. Creating the Slope and Aspect are very important in our rehabilitation process, to know exactly where to build the suggested modules, Figure 14.

## CAD Modeling

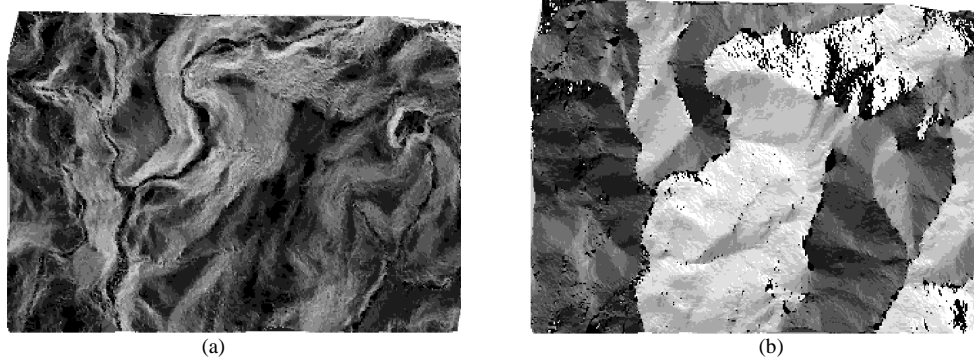
CAD (Computer Aided Design) files, can be displayed in GIS. Many CAD files are created in a local coordinate system, and must be transformed or moved, to align with GIS data in a real-world coordinate system [15]. Figure 15(a) explores the Geo-referencing 3D-Models above ortho-photo while Figure 15(b) shows the rendered 3D-Model after Transformation.

## 6. Rehabilitation

A Rehabilitation Plan for abandoned mine reclamation should contain certain key elements [16]. These elements



**Figure 13.** Geo-referenced structural map with digitized faults.



**Figure 14.** (a) Slope map; (b) Aspect map.



**Figure 15.** (a) 3D-model dropped over ortho-photo; (b) rendered 3D-Model after transformation.

are important whether the concern is mine fire control, mine subsidence prevention, mine hazard removal or mine drainage abatement. The elements are inter-related with information from one element feeding the others. The development of rehabilitation plans is an evolutionary process. Plans begin with a vision and move forward through the initiative, commitment and perseverance of the involved partners. It is not something that can be put together in a week or month. In the beginning, the content of the plan and each element in the plan may be more conceptual than real. As work is completed, the focus will become clearer and the plan will take on some sub-



stance. A Rehabilitation Plan should include the following elements: Goals must be reasonable and achievable. There should be a deadline for achieving the established goals. The time schedule will be used to develop the financing plan. Goals can be short-term and/or long-term. The benefits to be gained by achieving the goals should be thoroughly discussed. Technical alternatives for addressing the problems, including the costs, must be considered. The alternatives should identify both conventional technologies and innovative technologies that reduce the cost of reclamation. The pros and cons of the alternatives should be discussed. The recommended solution should be the one that best achieves the goals at the least cost. A plan for paying for the recommended solution is essential to showing that the goals are achievable. The financing plan should address each project within the plan, its schedule for completion, its capital costs and its annual operation and maintenance costs. A strategy for implementing the rehabilitation plan is essential. It should identify who-will do what-by when. It should address all of the elements listed above and be as detailed as necessary to insure the work will get done. The implementation strategy need not be completed when work begins but it should address each element to some degree. It will evolve as work progresses so that at some point in time, it will be clear as to who-will do what and when. The rehabilitation plan should identify measures for determining if the plan has been successful. Have the goals been achieved? Are partnerships flourishing? Has the funding occurred as proposed? The measures should be monitored during the life of the plan and a periodic status report prepared [15].

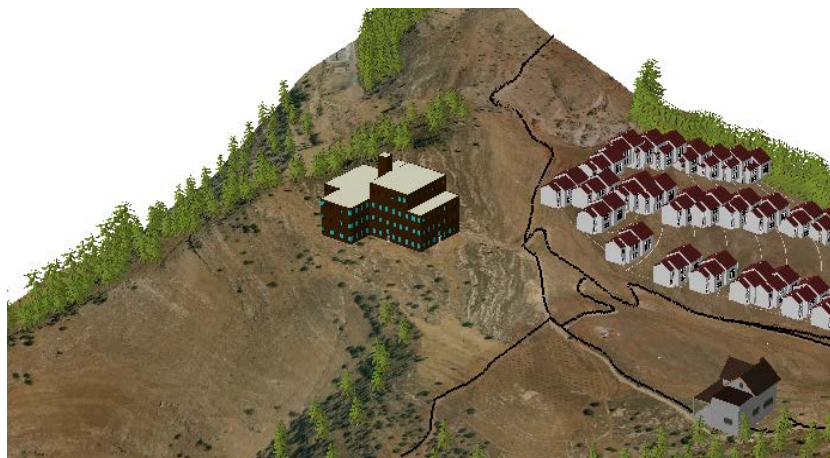
**Figure 16** shows one of the suggested models that have the following considerations:

- Improve the environment, keep the sense of sustainability local species, and increase the quality of life for population of region.
- Increase the attraction of the region due to natural potentials like vertical cuts which allow new kinds of sports like climbing, mountain biking.
- This module contains school, school Garden and small forest. The aim of this module is to enhance educational diversity by teaching outside the classroom. Through a personal contact with natural potentials the visitors can create a further awareness for ecological issues and an understanding. The people should learn to understand the interrelation between the ecological, economic and social or rather cultural activities.
- This model Avoid wild settlements and to lead developmental necessities in to controllable areas.

## 7. Conclusion and Future Recommendation

As mentioned before the main object was to re-develop the mining area in Mahis. To achieve this Photogrammetry, Remote Sensing and GIS, techniques were applied to the study. The topography of the area and the geological effects in terms of faults and structures have been explored. The geomatics tools facilitate the exploration of the area and assessment procedures that required for rehabilitation process. It has been shown that geomatics techniques were necessary and suitable to establish geodatabase needed by the decision-makers.

It has been shown that the distribution of the ground control points is very important in Photogrammetric Process moreover the quality of the Ortho-photo depends on the quality of the DTM. Future recommendations would focus on building a true Ortho-photo for the mining area in Mahis. Make questionnaire to know exactly



**Figure 16.** One of the suggested model.

what people in the study area need to be executed. Building several suggested modules according to local priorities and the financial opportunities. A developmental concept should consider the transportation issues as part of the needed geodatabase.

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