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# Establishing a Basic GIS Database for Madarsoo Watershed in Golestan (Iran)

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## Abstract
Remote-sensing and Geographic Information System (GIS) techniques have been utilized in this study to establish a GIS database for Madarsoo watershed in Golestan Province. Among the major constituents of this database we can refer to are: composite multicolor images from LANDSAT TM (30 m resolution); Indian IRS 1C/1D (23.5 and 5.8 m resolution) and Quick Bird (60 cm resolution) satellites and land-use/land-cover maps derived from these images; road networks; soil information; Digital Terrain Model (DTM); slope and aspect information derived from Digital Elevation Model; and meteorological and hydrological data. A 'project office' was established with trained personnel at a provincial centre effectively to use the resultant GIS in planning, monitoring and in applications for flood management, as well as to update it regularly. The approach of geographical data base has the potential to store and manage different data with different formats seamlessly. On the other hand it prevents repeating data, decrease errors, and saves the time and expens.
The estaldished data base was applied in mike 11 software to hydrological and hydrolical analysis of flood in the studying area.

*Keywords:* GIS, data base, flood management, Madarsoo watershed

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## ایجاد پایگاه داده جغرافیایی پایه برای حوزه آبریز مادرسو در استان گلستان-ایران

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### چکیده
در این مطالعه، تکنیک‌های سنجش از دور و سیستم‌های اطلاعات جغرافیایی به‌صورت توأم برای پایه ریزی یک پایگاه داده جغرافیایی در حوزه آبریز مادرسو در استان گلستان مورد استفاده قرار گرفتند. تصاویر چند طیفی ماهواره‌های لندست با قدرت تفکیک ۳۰ متر، IRS هندوستان با قدرت تفکیک ۵/۸ و ۲۳/۵ متر و Quick-Bird با قدرت تفکیک ۶۰ سانتی‌متر، نقشه‌های کاربری و پوشش اراضی استخراج شده از این تصاویر، شبکه راه‌ها، اطلاعات خاک، مدل رقومی ارتفاعی، اطلاعات شیب و جهت شیب استخراج شده از داده‌های رقومی ارتفاعی، داده‌های هواشناسی و هیدرولوژی در سطح حوزه آبریز، بخش‌های مهم این پایگاه داده را تشکیل می‌دهند. همچنین یک بخش دفتری با پرسنل آموزش دیده در مرکز استان مستقر گردید تا به‌صورت مناسب از اطلاعات حاصل از GIS در برنامه ریزی، پایش و کاربردهای موردنیاز برای مدیریت سیلاب و در بروزرسانی اطلاعات فعالبت نمایند. رویکرد پایگاه داده جغرافیایی، امکان ذخیره و مدیریت داده‌های متنوع و با فرمتهای متفاوت را بصورت یکپارچه، همچنین پرهیز از تکرار داده‌ها و کاهش خطا و صرفه‌جویی در زمان و هزینه موجب می گردد پایگاه داده ایجاد شده جهت انجام آنالیزهای هیدرولوژیکی بررسی جریان سیلاب در محدودهٔ مورد مطالعه در نرم‌افزار MIKE 11 بکار گرفته شد.

*کلیدواژه‌ها:* GIS، پایگاه داده، مدیریت سیلاب، حوزه آبریز مادرسو.

## Introduction

The increase in population and destruction of natural resources have disturbed the balance of nature and caused several natural disasters such as flooding, land slides and erosion.As the statistics and published reports from different organizations show, during past 50 years more than 3700 floods occurred in Iran. Of these, 53% occurred in just the last decade for which the major reasons were the changes in land use and the destruction of ground cover. The destruction of natural systems and ecosystems has caused an increase in flooding over the past 20 years. Madarsoo watershed left two destructive floods behind on 10 August 2001 and in 2002. During these two disasters, more than 300 people were killed and there were huge financial damages (Ministry of Agricultural Jihad).

Applying remote sensing (RS) and GIS to create an accurate and up-to-date information system for large scale areas such as provinces or watersheds is a common economic solution for handling the planning, monitoring and implementation of activities related sustainable development. With regard to what has been mentioned above, the present study is intended to establish a geographical information database for Madarsoo watershed, especially in the flood plain of Madarsoo River. This database is related to flood management and the destructive effects of flooding which is considered to be a natural disaster, and dealing with the financial and human costs imposed on local residents. In this way, an accurate information basis will be established for other studies related to different issues such as: preparing flood warning systems, estimating financial damages, land-use and land cover changes. To this purpose, the following items were applied effectively: satellite images with different resolution powers, aerial photos and other data such as maps, reports, station data, descriptive plans and data obtained from different offices and sources.

## Location of Madarsoo Watershed

Madarsoo watershed is located between E $53'$-$51^0$ to E $56'$-$19^0$ longitude and N $36'$-$30^0$ to N $38'$-$08^0$ latitude. It covers a 2400 km$^2$ area and stretches into three other provinces, to northern Khorassan, Semnan and Golestan. Golestan forest is one of the tourist attractions in the world and it occupies 35% of the area in the middle of this watershed.

## Methodology: RS and GIS Utilized to Create a 'Watershed Geographic Information System'

To study the flood plain of the area and establish crisis management after flooding, the information was collected in twenty different layers (Table 4-1). After preparing the information, the database was employed in flood studies of the area. The procedure and methodologies followed in building the database have already been mentioned. During the next step, the layers, their preparation and the references were introduced. (Figure 3)

**Figure 1- Damage to built-up construction.**

**Figure 2- Damage to a transportation vehicle**

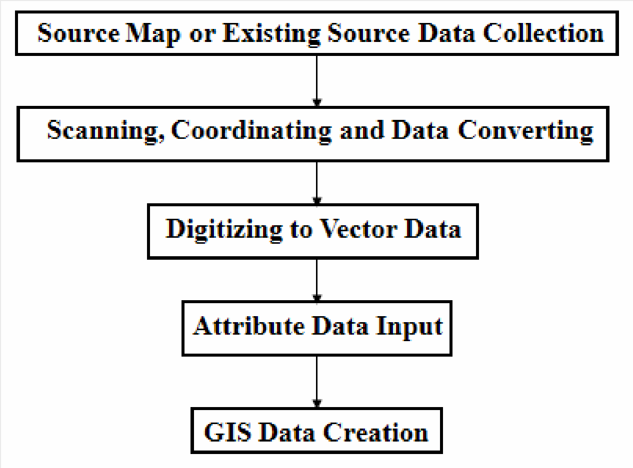



**Figure 3- Flow chart for Establishing the GIS Database.**

The database has been prepared according to two general area scales:

a) A scale of 1:50,000 in the macro area of Madarsoo watershed.

b) A scale of 1:10.000 in the district of the flood basin.

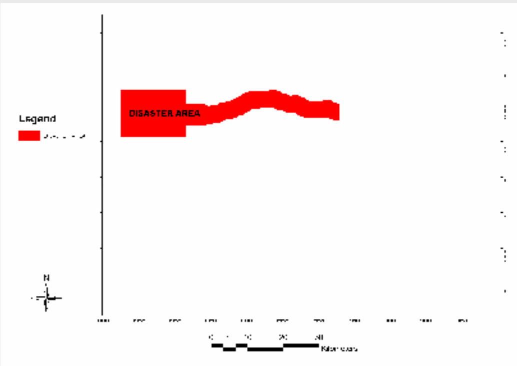



**Figure 4- The study area on a 1:10.000 scale**

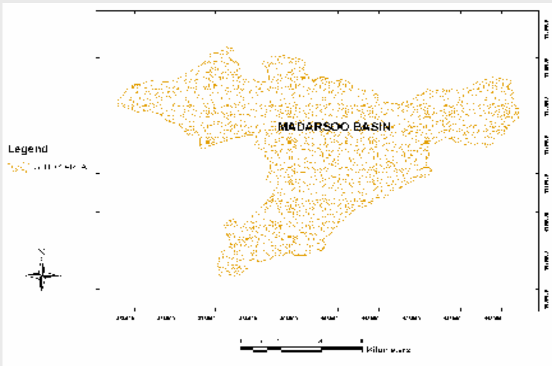



**Figure 5- The study area on a 1:50.000 scale**

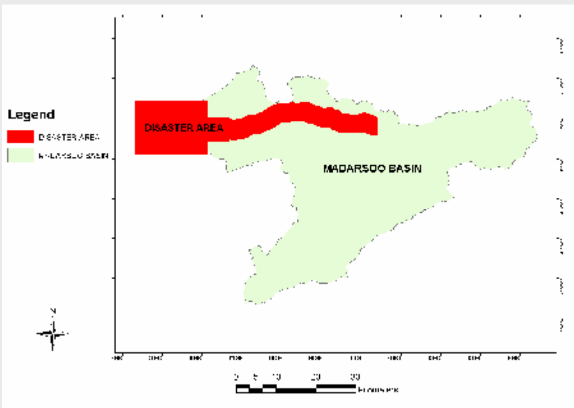



**Figure 6- The overlap of the two areas**

Remote Sensing technology, with its high-resolution, multi-spectral images of large areas, is an important source of contemporary data and knowledge for the Madarsoo watershed database. Through such images, various information layers can be prepared and updated easily. In present study, LANDSAT TM (30 m resolution) and Indian IRS 1C/1D (5.8 m resolution) which have provided full coverage of the watershed are used for visual inspection and also for the natural-looking basic layer. These images have also been processed for various thematic purposes, including a land-cover/land-use map of the watershed through image classification and vegetation-index analysis. On the other hand, Indian IRS images (with 5.8 m resolution) have been utilized to enhance the LANDSAT-TM coarser resolution (but which is richer in color information) through well known 'image-fusion' techniques. This way, we can obtain fused images that are rich in color and high (5.8 m) in resolution that can be used for various purposes. Also, Quick Bird images – with a resolution of 60 cm – have been prepared for Madarsoo flood plain and for margins 5 Km far from the river in Madarsoo valley. This image was also used for separation of different land uses with high accuracy, true identification of residential and industrial areas to examine the destructive potential of floods with different returning periods, providing an information link of field checks to related features and other purposes. Furthermore, a number of other layers for Madarsoo have been created using data and maps from various local- and national-level public sources.

## Data Sources and Layers for GIS database in Madarsoo watershed

Table 1 presents prepared layers in the Madarsoo data base of which the data sources and some layers are explained later. As mentioned in table, data can be divided into 6 groups. These groups are satellite images, basic data, topographic data, environmental and social data, and crisis data.

Also, the geometric features of each layout have been presented in this table. It is worth mentioning that in most layouts the scale is also presented. In most cases, the studies have been done with a higher degree of accuracy and have been collected using a better scale.

**Table 1- The required layers sit scale.**

| Data | | Data Type | Data source | Attributions |
|---|---|---|---|---|
| Basic Data | Administration boundaries | Polygon, line | Topographic Map (1:50,000) | Statistics data |
| | Basin Boundaries | Polygon, line | Topographic DEM (1:50,000) | |
| Topographical Data | Road Network | Line | Topographic Map (1:25,000) | Road name and Payment Condition Code |
| | River network | Line | Topographic Map (1:25,000) | River name, river Class Code |
| | Water body | Polygon | Topographic Map (1:25,000) | Name |
| | Build up area | polygon | Topographic Map (1:25,000) | Name and Type |
| | Village | point | Topographic Map (1:50,000;1:25,000) | Named , Type and Statistic Data |
| | Major Building in Disaster Area | polygon | Arial photo | Name and Type |
| | Contours | Line | Topographic Map (1:25,000) | Evaluation |
| | Land cover and Land classification | Polygon | Topographic Map (1:50,000) | Type, Class Code |

## Satellite Data

LANDSAT-TM images, as a source data, have been collected between 1997 and 1998 during the spring and summer months. After geo-referencing these images with a root-mean-square (RMS), positional error of < 1 pixel size (30 x 30 m2), a joint mosaic of all frames and the physical watershed area were created (Figure 7). Furthermore, a mosaic of IRS-Liss3 has been prepared which, being more recent and not having any clouds, TM data makes it possible to process the present phenomenon more accurately. In those parts of study area for which IRS-Pan images were prepared, the phenomenon could be processed accurately due to the high resolution power of these images.

## Digital Elevation Data

In order to prepare a digital elevation model for the study area – as a source data – the area was fully covered by standard topographic map sheets which had been prepared by the National Cartographic Center of Iran on a 1:25,000 scale (Figure 10). After creating GIS layer of elevation points and contour lines (separated by 10 m, vertical) from the raw elevation data, a digital elevation model (DEM) for each sheet was produced. This data is prepared as a mosaic of map sheets for the study area (Figure 11). Draping satellite images of proper color bands over the DEM, resulted in three-dimensional, realistic-looking virtual images from every part of the project area (Figure 13).

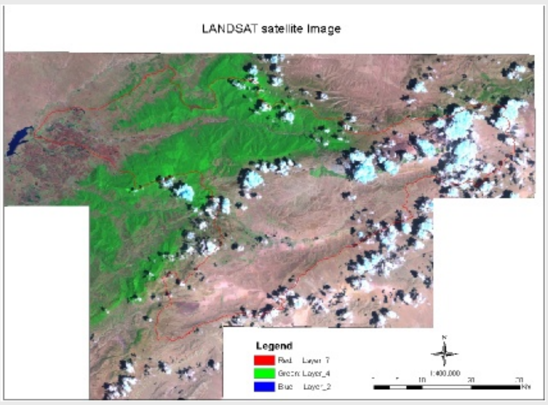



**Figure 7- Landsat image of study area**

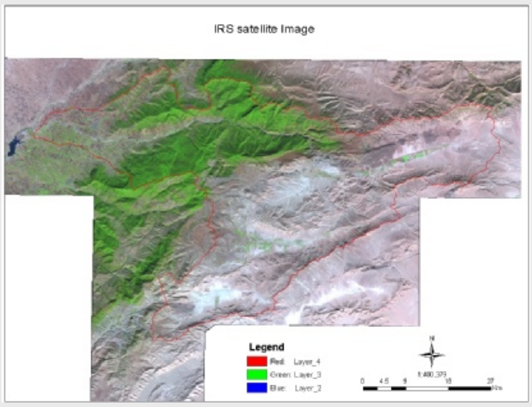



**Figure 8- IRS-Liss3 image of study area**

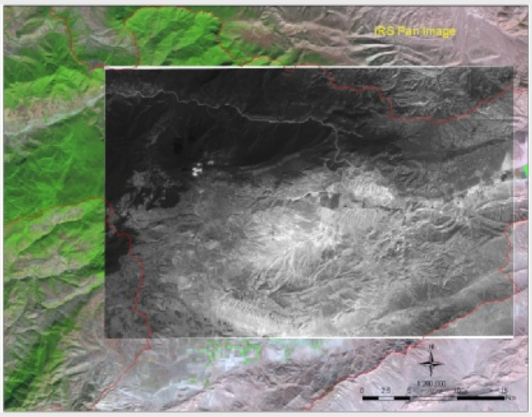



**Figure 9- IRS-Pan image of study area**

One can choose the points of view and elevations of observation, with natural or artificial colors. The terrain slope, its slope length and aspect angle at any location, as well as the drainage network layer for a selected part within the study area and a hill shade image for 3D-appearances for visual evaluation are derivable from the DEM for further analysis, if the need arises (Figure 12).

## Administrative boundaries

This layer includes the boundary information for provinces, their suburbs and contains two types of geometry: polygonal and line. To prepare this layer, the following items were considered very important: expert knowledge, geographical features, topography and local surveys. The scale for borders of these layers is based on 1:50,000 maps; for some parts, 1:25,000 maps are available. Therefore, country division is based on that scale and it is clear that the preparation of this layer is based on 1:50,000 maps. This layer is in simple vector form, and is important for administrative purposes. Provincial boundaries also offer an important means for percentage-area analysis statistics of temporal changes and comparison.

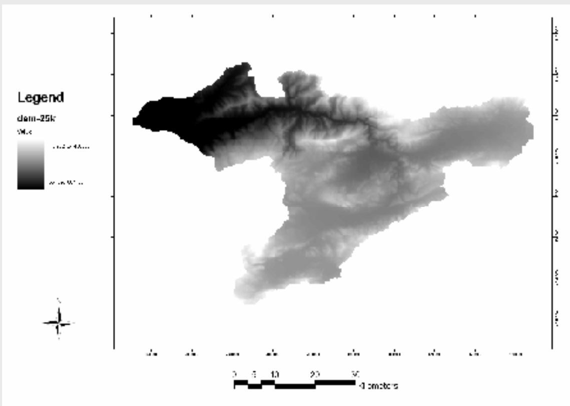



**Figure 11-Digital elevation model of study area**

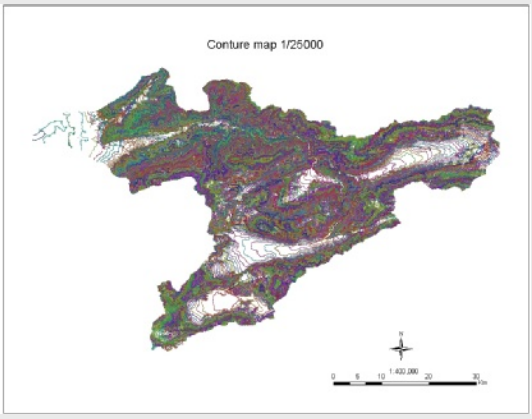



**Figure 10-Topographic map of study area**

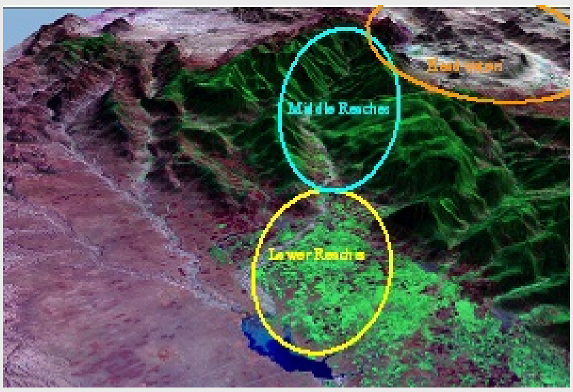



**Figure 13- Draping satellite images over the DEM**

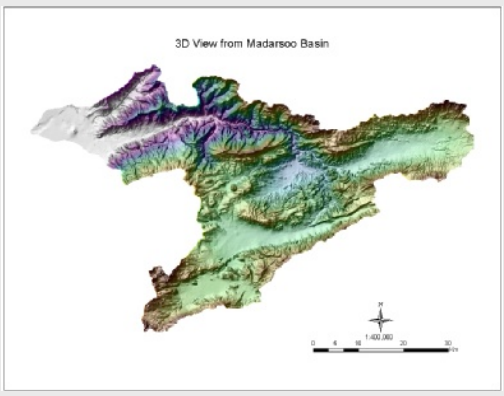



**Figure 12- 3D view from Madarsoo basin**

The map of country division contains information about the province, townships, districts and villages. The definitions are:

1- Province: several townships make up a province
2- Township: several cities or towns make a township
3- District: several villages make up a district
4- Rural district: Several villages and rural areas make up a rural district.

In the database, the administrative boundary is presented up to rural districts (Figure 14).

## Basin boundaries

A basin is a topographic area whose drainage system is through a river network. The geometry of this layer is line and polygonal which is inserted in database as a basin. Since there were no distinctive names for the basins, they are identified by numbers. The boundaries of Madarsoo and its internal sub-basins have been extracted according to 1:50,000 topographic maps (Figure 15).

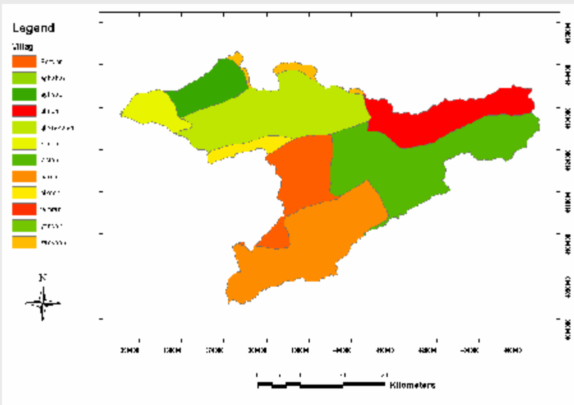



**Figure 14- Country division region in the area according to rural districts.**

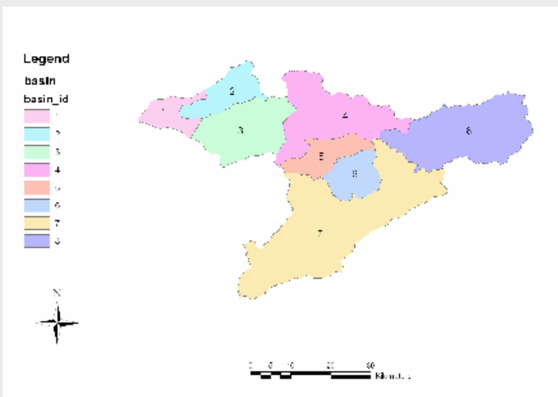



**Figure 15- Madarsoo basin and its internal sub-basins.**

## Road Network

This layer contains all accessible roads with different degrees. The different degrees of the road network have been determined by the database legends. The road network means all accessible ways between dwelling places and all information for this layer has been extracted through 1:25,000 topographic maps. This layer has been inserted in the data base at a scale of 1:25,000 (with no change). The details of the road network from 1:50,000 maps have been prepared in past years and are old. As we know the accessible ways also have changed a lot and they have increased as well. Hence, 1:25,000 maps have been utilized to extract the road network, for they are newer than 1:50,000 maps (Figure 16).

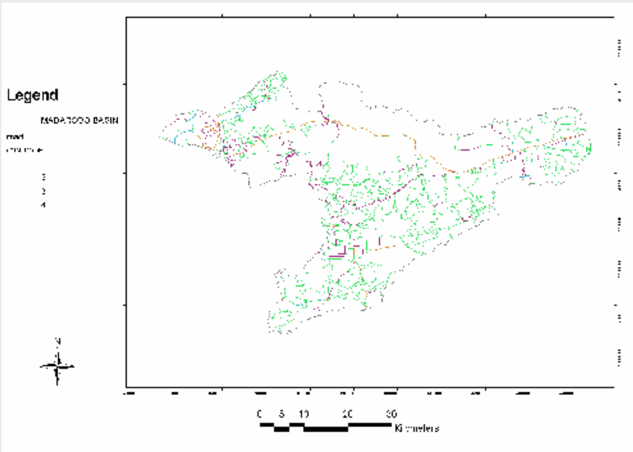



**Figure 16- The accessible road network in the study area**

**Table 2- Information about the road networks.**

| FID | Shape | CON_CODE | DESCRIBE | شرح |
|---|---|---|---|---|
| 39 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 40 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 41 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 42 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 43 | Polyline | 1 | PAVED ROAD | راه آسفالته |
| 44 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 45 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 46 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 47 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 48 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 49 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 50 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 51 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 52 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 53 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 54 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 55 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 56 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 57 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 58 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 59 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 60 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 61 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 62 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 63 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 64 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 65 | Polyline | 3 | JEEP DIRT ROAD | راه خا كي جيپ رو |
| 66 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 67 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 68 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 69 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 70 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |
| 71 | Polyline | 4 | PEDSTRAIN DIRT ROAD | راه خاكي پياده رو |

## River Network

This layer, the same as road network layers, has been extracted and digitized from 1:25,000 topographic maps. Since the river network is crucial in flood studies, the details are also presented in 1:25,000 maps (Figure 17)

## Land Use

Studying land-use and type is among the important tasks of watershed management. In this study, the land-use layer has been prepared using satellite images. The basis of classifying and extracting layers was the legend prepared from USGS (Figure 18).

## Geology and Fault Line

This layer is one of the layers in the data base which has been prepared by digitizing paper based on a 1:100,000 map. (Figure 19).

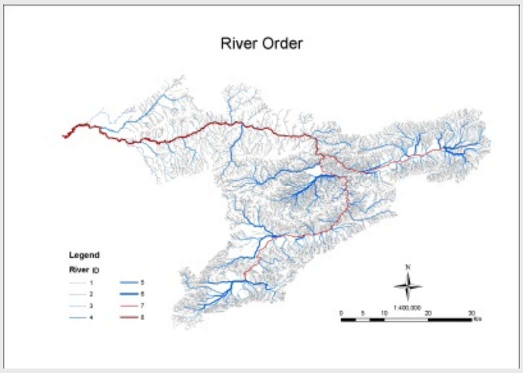



**Figure 17- River network of the study area**

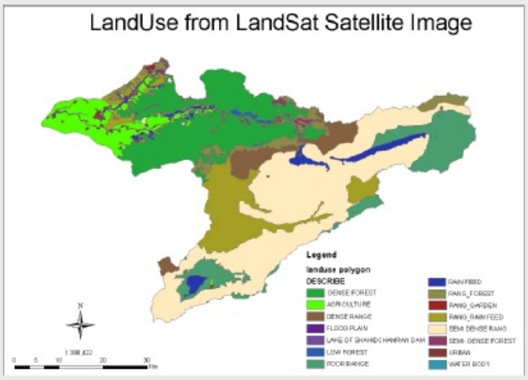



**Figure 18- Land use from satellite image**

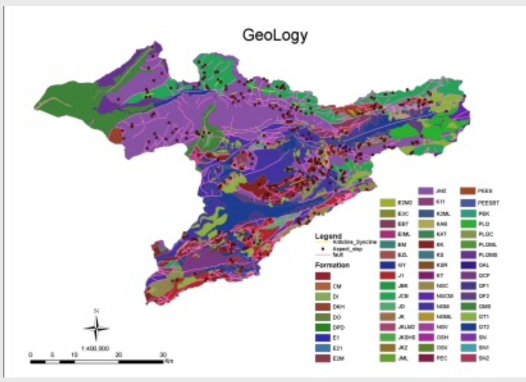



**Figure 19- Geological map of the study area**

## Soil Distribution

Preparing a soil distribution map is one of the important tasks in watershed management studies. Unfortunately, there has been no comprehensive soil map up to now just some information gained during completing data base and is called the "soil region". In the study area, this layer contains two major classes; the origin of this data is from 1:250,000 maps. In order to increase the detail of the maps it is necessary to undertake a project entitled: Preparing Soil Maps. This important task hasn't been included in preparing the data base project. So, in order to show the details of soil in the study area, a file has been set in the data base which is called soil distribution. Soil type layer has also been inserted.

## Rainfall Distribution

This layer has been prepared with help from the Water Resource Development Organization (TAMAB). The information of some climatology stations has been utilized. After adjusting the statistics, their shortcomings have been eliminated. The methods of each climatology station have been interpolated using Ilwis software in order to finalize annual isohyets lines. Since the number of the stations wasn't enough to gain monthly isohyets lines, these lines have been estimated annually. Of course, the aim was to compare two annual rainfall maps. After comparing interpolated rainfall maps with previous rainfall maps, its accuracy has been converted into polygons and each polygon was given the rainfall range.

## Organization of Layers

Since the Madarsoo GIS data base is a system consisting of numerous data layers, some common rules presented as follows have been accepted in creating and organizing the layers:

(a) All the layers were prepared using Universal Transverse Mercator (UTM) co-ordinates. In the UTM system, Madarsoo watershed falls within the internationally accepted Zone 40.

(b) At present, a total of 20 layers exist, and they are grouped under six main divisions:

(1) Satellite images;

(2) Basic data;

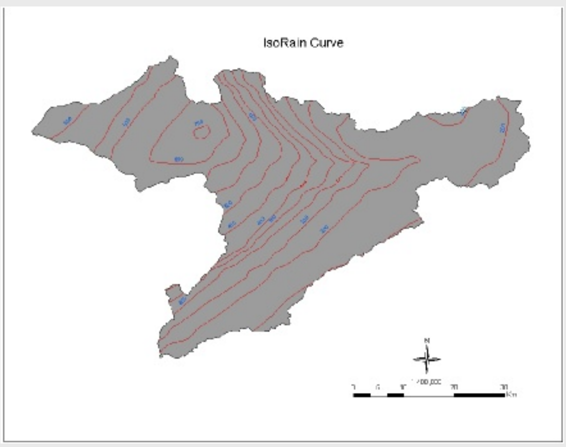
(3) Topographic data;

(4) Natural environmental data;

(5) Social economy data; and

(6) Disaster data.

To make all the data files reachable in the Madarsoo Data Base, some standards such as naming layers, installing them under specific themes and handling the attributes have been accepted.




**Picture 20- Iso-rain curve of the study area**

(c) The formats of data layers had to be defined carefully due to high volumes of physical space required for the files (as vector or raster data).

(d) Madarsoo data base was designed to be used actively by several technical groups of various professionals located at different provincial offices. Hence, it was critically important for the project team to select a user-friendly GIS structure and interface. The interface needed to be understandable and easy to utilize and update. Therefore, the R&D team has prepared a simple and user-friendly form of GIS interface for the PC environment based on Esri-ArcGIS.

## Results

We can note the following:

(i) Madarsoo GIS data base can provide a basis for planning, implementation and monitoring economic decisions, constraints on development programs and, in particular, flood management, flood warning systems and systems to evaluate flood damages in the watershed. Madarsoo GIS aims to provide the solution for ecological, agricultural, flood management and other problems of the area. To this purpose, more than 20 levels of data (most of which re-created and derived from existing layers) have been prepared in order to achieve this goal. The main purpose of this study is to identify the major causes of flooding in the study area, recognizing flood-prone regions with different returning periods within the Madarsoo margins, identifying safe zones, establishing flood warning systems and training local residents. All of these will lead to pre-, on-time and post-flood management. Therefore, using modern systems in information management is inevitable.

Several tasks of this study were completed in a relatively short period of time (several months) using the already existing Madarsoo database.

(ii) As the above description reveals, the scale of the data base layers varies between 1:10,000 and 1:250,000 due to the variety of data sources. Pixel sizes of satellite images also vary. On the one hand, LANDSAT-TM images with 30 m linear resolution correspond roughly to 1:100,000 resolution at their visual optimum; on the other hand, color composite satellite images have been created using data fusion of QB-Pan images with QB-MS images for some parts of the study area. Having a linear solution of 60 cm enables us to produce more detailed GIS layers, down to scales of 1:5,000.

Delineation of the boundaries threatening rapid industrialization areas around main cities, as well as streets and structures in low-level towns, can be easily observed at these scales via satellite images.

**Figure 21- The position of buildings on QB images; the photo was taken during a field check and shows its link to position in the data base**

(iii) It is also important to utilize the most recent possible data in the project. The image used in this study belongs to 2004 and is recent. However, some information layers are rather old. Therefore, by using satellite images, these maps have been updated. Among updated features, we can refer to roads, land-use and water bodies.

This effort is an example of the use of GIS and satellite images to update the existing road network, rivers, land-use and land cover classes and water bodies, and to bring them to map status with all the details correct and up-to-date. However, some of the layers in the Madarsoo data base (for example, soil and geologic information) are much older and may need minor or extensive upgrading with the participation of proper technical personnel. Sometimes the only information available about a particular subject-matter may be quite dated. Such information and thematic maps must be used with care and forewarning. Comparison of such data with contemporary satellite images does help to estimate the current status of the data.

## Conclusions

Modern technologies, including remote sensing, advanced computer hardware and software technologies (such as GIS, which has notable data-handling and querying capabilities) need to be utilized at all levels of administration, planning and monitoring. Since all the applied data are in digital form, they have all the flexibility of easy manipulation, augmenting, updating and reapplication practicalities that is much needed by present problem handlers and solvers. Watershed and/or provincial level GIS's need to be the basic administrative, planning, monitoring and assessment tools used throughout Golestan (Iran). Recognition of the need for using such tools has been especially acute since the 2001 and 2002 floods in Golestan Province. During the construction of the GIS data base, we have seen that many essential layers that are necessary for agricultural, environmental and administrative applications have already been created, in various forms and scales, by various public offices and institutions in Iran. Among the most notable of these are:

1. Soil data for the study area on a 1:250,000 scale by the Soil and Water Conservation Organization.
2. Meteorological data for all the areas at various scales by the leading climatology center of Golestan and related offices.
3. Geological data for Madarsoo watershed on a 1:100,000 scale by the National Geological Organization.
4. (Digital) elevation data for all provinces at 1:25,000 and other scales by the Survey and Geographical Organization of the Ministry of Defense.
5. Satellite data with full coverage for the watershed: single coverage by LANDSAT-TM images, IRS images by the Iranian Space Agency and QB images by a business corporation.

These basic information layers, available for most parts of the country, constitute an important asset for creating a digital information system for the study area, which aims to be part of an information-based society that is integrated with the digital global community.

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