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# Land use and land cover classification over a large area in Iran based on single date analysis of satellite imagery

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ABSTRACT

Accelerated soil erosion, high sediment yields, floods and debris flow are serious problems in many areas of Iran, and in particular in the Golestan dam watershed, which is the area that was investigated in this study. Accurate land use and land cover (LULC) maps can be effective tools to help soil erosion control efforts. The principal objective of this research was to propose a new protocol for LULC classification for large areas based on readily available ancillary information and analysis of three single date Landsat ETM+ images, and to demonstrate that successful mapping depends on more than just analysis of reflectance values. In this research, it was found that incorporating climatic and topographic conditions helped delineate what was otherwise overlapping information. This study determined that a late summer Landsat ETM+ image yields the best results with an overall accuracy of 95%, while a spring image yields the poorest accuracy (82%). A summer image yields an intermediate accuracy of 92%. In future studies where funding is limited to obtaining one image, late summer images would be most suitable for LULC mapping. The analysis as presented in this paper could also be done with satellite images taken at different times of the season. It may be, particularly for other climatic zones, that there is a better time of season for image acquisition that would present more information.



## 1. Introduction

Since land use and land cover (LULC) attributes in a watershed directly influence water driven erosion, knowledge of these parameters plays an important role in ranking erosion potential and in prioritizing and developing sustainable watershed and agricultural management practices (Renard et al., 1997). In many areas of Iran and in particular in the Golestan dam watershed, which is the area that was studied in this research, significant overgrazing and inappropriate land uses (LU) such as farming on steep hillsides and up-down tillage are the main contributors to soil erosion, land degradation and flooding (Japan International Cooperation Agency, 2005; Lar Consulting Engineering, 2007). These problems have significant economic ramifications through their negative impacts on available land resources, land productivity, infrastructure and water quality (Sharifi et al., 2002). Accurate LULC maps can be effective tools in aiding soil erosion control efforts. Such maps can play an important role in watershed management as a whole and help in deciding what sort of lands are capable of sustaining agriculture and which are not (Cihlar, 2000; Renschler and Harbor, 2002). Large amounts of data are required for developing such LULC maps and remote sensing can be a source of accurate, detailed information over large areas. Remotely sensed data and the potential to distinguish between different characteristics of land features from this data provides great potential for rapidly creating accurate LULC maps (Homer et al., 2004).

LULC classification is one of the most widely used applications in remote sensing. There are many approaches that have been used to correlate image data with vegetation characteristics. Over the last few decades, numerous studies have shown the efficacy of satellite imagery in characterizing vegetation types (Joshi et al., 2006; de Asis and Omasa, 2007; Focardi et al., 2008), forests (Labrecque et al., 2006; Sivanpillai et al., 2007), and crops (Cohen and Shoshany, 2002; Wardlow et al., 2007). Chust et al. (2004) evaluated the ability of morphological indices and landscape analysis to test the improvement of land cover (LC) classification reliability in a mountainous area. They were able to define 12 LC categories using an image segmentation method (based on edge detection originated by abrupt changes in the intensity of neighboring pixels) and a supervised classification (maximum likelihood classi-

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fication) of a Landsat Thematic Mapper (TM) satellite image. In addition, Hagner and Reese (2007) calibrated the maximum likelihood method for classification of nine primary forest types in the CORINE land cover mapping project.

Several vegetation indices that combine reflectance of two or more wavelengths in different ways have been developed and used in characterizing vegetation growth and development (Jackson and Huete, 1991; Zheng et al., 2004). Some widely used indices are the Normalized Difference Vegetation Index (NDVI), Difference Vegetation Index (DVI), Ratio Vegetation Index (RVI), Greenness Index (GI), Soil Adjusted Vegetation Index (SAVI), Transformed SAVI (TSAVI), Modified SAVI (MSAVI), and Perpendicular Vegetation Index (PVI). The basis of most vegetation indices is the estimation of photosynthetically active radiation (Joel et al., 1997).

There are several distinct growth periods during a growing season and classification of vegetation characteristics depends on the presence or absence of vegetative cover and the condition of that vegetation at the time of the acquired image. Many researchers have mentioned that a significant correlation exists between spectral data and different vegetation growth parameters (Tucker, 1979; Thenkabail et al., 2004; Tian et al., 2007; Houborg and Boegh, 2008). Guerschman et al. (2003) recommended that, when possible, three images (spring, early-summer, late-summer) be used in the identification of summer crops, winter crops and rangelands. Using five Landsat TM image dates from a single year, Oetter et al. (2000) were able to create a map of 20 LULC classes. Lucas et al. (2007), comparing single and multi-date Landsat Enhanced Thematic Mapper (ETM+) images for vegetation classification, found that multi-date imagery allowed for a more accurate classification of different vegetation types. In another study, Maxwell et al. (2004) were able to identify four major LU types (bare soil/sparse vegetation, rangeland, urban, and riparian) and three crop types (corn, sorghum, and soybeans) using only bands 2 and 4 of a single late summer Landsat Multi-spectral Scanner (MSS) image.

The Iranian Forest, Range and Watershed Management Organization has been involved in mapping the LULC for the last 45 years using aerial photographs and topographic maps. Recently, satellite images have been used for such LULC classification, in a manner different from that proposed in this paper. The problems surrounding existing LULC maps are as follows: (i) Agricultural lands (irrigated farming and dry farming) have been mapped with visual interpretation techniques on optical image composites and field investigations. These polygon boundaries have been found to not be accurate and have overlapped with other classes. (ii) Further, on the same maps, an initial field investigation showed that low density forest and different rangeland classes have significantly overlapped. (iii) About 15% of the land area was classed as 'mixed'; separation into individual classes was not possible.

Because of the frequent difficulty in obtaining multi-date images for a single year for all the study areas of interest, the goal of the present study was to develop a new protocol for LULC classification using a large study area (4511.8 $km^2$) based on readily available ancillary information plus analysis of three single date Landsat ETM+ images. The study area chosen was the Golestan dam watershed in Iran.

## 2. Materials and methods

### 2.1. Study area

With an area of 4511.8 $km^2$, Iran's Golestan dam watershed is located between 55°21′ and 56°28′E longitude, and 36 44′ and 37°49′N latitude, in the northeast portion of Golestan Province (Fig. 1a). This sub-watershed of the Gorgan River watershed is composed of a complex combination of mountains, hills, plains and rivers. The highest elevation is 2492 m above mean sea level and the lowest elevation is 47 m. Because of its geographic situation and topography, a wide range of climates prevail across the different portions of the Golestan dam watershed: from semi-arid in the north-west and south to humid in the central portion (Fig. 1b). Mean annual precipitation ranges from 195 to 700 mm and mean annual air temperature from 8.5 to 17 °C. March is the month of greatest rainfall, and June to October are the dry months (Japan International Cooperation Agency, 2005; Lar Consulting Engineering, 2007).

Existing landform maps show roughly half (49.3%) of the Golestan dam watershed to be mountainous, with the remaining landforms being: 30,743.6 ha (6.8% of total area) river alluvial plains; 8,038.7 ha (1.8%) piedmont plains; 8654 ha (1.9%) gravelly fans; 33,664.2 ha (7.5%) upper terraces; 8230 ha (1.8%) river terraces; and 139,630 ha (30.9%) hills (Saadat et al., 2008). Different sedimentary rocks such as limestone, sandstone, shale, dolomite, marl along with conglomerate, loess sediments and alluvium underlay the area (Banaei, 1993). Located in this area, the 920 $km^2$ Golestan Forest National Park has been recognized by UNESCO as part of the international network of Biosphere Reserves (Japan International Cooperation Agency, 2005). Agriculture is also an important sector in the Golestan dam watershed. The main crops are wheat (*Triticum æstivum* L.), barley (*Hordeum vulgare* L.), sunflower (*Helianthus annuus* L.), watermelon (*Citrullus lanatus* (Thunb.)), rice (*Oryza sativa* L.) and cotton (*Gossypium hirsutum* L.) (Banaei, 1993). Accelerated soil erosion, high sediment yields, floods and debris flow are serious problems in the Golestan dam watershed (Sharifi et al., 2002; Japan International Cooperation Agency, 2005).

### 2.2. Materials

The following image and map materials were used in this study:

(i) Growing season Landsat ETM+ images: spring (10 May, 2003), summer (20 July, 2000), and late-summer (09 September, 2001). It should be noted that the images are from different years, but lack of availability necessitated this limitation. As such, for this study it was assumed that the images are representative of their respective seasons.
(ii) 1:25,000 scale digital topographic maps with 10 m contour lines prepared by the National Cartographic Center of Iran and the Forest, Range and Watershed Management Organization (based on 1993 aerial photos). These were mainly used for geo-referencing satellite images and for some ground-truthing.
(iii) Two digital ancillary layers were also collected to assist in the interpretation and classification of the remotely sensed data. These were a 1:25,000 scale landform map prepared by Saadat et al. (2008), and a 1:50,000 scale climatic zone map based upon de Martonne's dryness index, prepared by Lar Consulting Engineering (2007).
(iv) Ground-truthing was collected for the purpose of supervised and NDVI classification and classification accuracy assessment. These data were collected in the same month as each image was acquired (May, July and September), but 4–6 years after the images were taken (details below).
(v) ERDAS Imagine (version 8.7) and ArcInfo (version 9) software were used for image classification and data analyses.

### 2.3. LULC classification and mapping

#### 2.3.1. General description

LULC classification is one of the most widely used applications in remote sensing. The most commonly used approaches include unsupervised classification, supervised classification, image segmentation and NDVI. Each of these methods has their own