Detecting Spatial-Temporal Changes in Land Use Using Satellite Data in Haraz Basin
Naser Ahmadi Sani a*, Karim Solaimani b, Lida Razaghnia c

a Assistant Professor, Faculty of Agriculture and Natural Resources, Mahabad Branch, Islamic Azad University, Mahabad, Iran.

b Professor, Department of Watershed Management, Sari University, Iran.
c MSc. of Watershed Management, Department of Watershed Management, Haraz University, Iran.

Received 6 April 2018; revised 18 May 2018; accepted 13 June 2018

Abstract

In recent decades, rapid and incorrect changes in land use have been associated with consequences such as natural resources degradation and environmental pollution. Detecting land use changes is a suitable technique for natural resources management. The goal of this research is to study the land use change in Haraz Basin with an area of 677000 hectares in 15 years (1996-2011) using Landsat data. After making the necessary corrections and preparing the indices, images were categorized into nine classes via supervised classification and Maximum Likelihood Algorithm. Finally, the changes were extracted by post-classification comparison. The results showed that there has been a 27.5% change in land use of the area during the 15 years. These changes are related to conversion of rangelands to bare lands and dry farming ones, and conversion of dense forests to sparse forests, horticulture, farming lands, and residential areas. These changes can be due to an increase in population and human activities, which result in increasing demands for natural resources and converting them into farming lands, horticulture, residential and industrial areas. These land use changes along with climate changes raise the alarm for the Haraz Basin status in the future.

Keywords: Change Detection, Haraz Basin, Land Use, Remote Sensing.

* Corresponding author. Tel: +98-9142960545.
E-mail address: n.ahmadisani@gmail.com.
1. Introduction

With the growing population, lands under cultivation can no longer provide the needs of people. Therefore, more lands are needed to be cultivated which in long terms will result in a decrease in quality and quantity of natural resources (Kamkar and Mahdavi-Damghani, 2012). Today, unplanned land use change is a major problem. Natural processes are affected by the characteristics of land use of the basin (Sreenivasulu and Bhaskar, 2010). In a time period spatial distribution of changes is an important issue in studies related to natural resource (Baboo and Devi, 2010). Land use change is one of the most important indicators in understanding the interactions between human and the environment (Li et al., 2017). Both human-induced and natural land cover changes can influence the global change because of its interaction with the terrestrial ecosystem, biodiversity, and landscape ecology. In addition, it reflects the human impacts on the environment at various temporal and spatial scales. Therefore, accurate and up-to-date land use information is essential for environmental planning as well to achieve sustainable development (Haque and Basak, 2017).

Change detection is the measure of the thematic change information that can guide tangible insights into an underlying process involving land cover, land use and environmental changes (Lal and Anouncia, 2015). Change detection plays a pivotal role in sustainable development of human society. Change detection methods find the changes in a geographical area with the use of bi-temporal images of the area (Singh and Singh, 2018).

There are two broad methods for Change Detection techniques; pre-classification and post classification method. Pre-classification method analyses the change without classifying the image value. The NDVI is most common and widely used pre-classification method. Post classification evaluates the change in land cover based on detail classification of land cover. Post classification comparison is the most common change detection approach. Post classification analysis is quite flexible and easy to quantify the statistics of change class (Haque and Basak, 2017).

Many studies in recent years point out that, there is a rapid change in land cover in many parts of the world, particularly in areas with high population density. Traditionally land use and land cover is a core information layer for a variety of scientific activities and administrative tasks such as hydrological modeling, climate models and land use planning (Gadrani et al., 2018). The sustainable management of watersheds needs monitoring, understanding the dynamics of changes, ecosystem response to social and natural pressures, the information providing on planning for natural resource conservation (Nowroozi et al., 2012).

Nowadays, natural hazards such as flood, landslide, and erosion in many areas of Iran are noticed (Hosseinzade et al., 2009). Haraz Basin has a high potential for such phenomena (Mohammadi et al., 2009). In order to tackle such problems, there is a need to study the land use changes of the basin in recent years to have a close and timely glance for changing, adjusting and planning of water resources, natural resource protection and
decrease the soil erosion in accordance with basin correct management and achieving sustainable development. On the other hand, providing a land-use map using fieldwork method is expensive and time-consuming. Therefore, methods like remote sensing in a short period of time and with less cost, can provide maps with reasonable accuracy.

Remote sensing is an appropriate tool for providing information. Remote sensing is now providing an effective tool for the advanced ecosystem and socioeconomic management (Haque and Basak, 2017). Remote sensing is a powerful and cost-effective data source for assessing the spatial and temporal dynamics of land use/land cover (Li et al., 2017). Over the past ten years, remotely sensed data used for studying the land use changes of (Gadrani et al., 2018). Remote sensing change detection quantifies the effects of humans on a landscape scale without creating further disturbances to ecologically sensitive areas; the results of which can be used for effective conservation management into the future (Willis, 2015). Satellite images are being widely used for change detection applications like urban planning, vegetation monitoring, forest cover management, disaster management (Singh, and Singh, 2018).

Remote sensing and GIS are useful in analyzing the land cover changes in basins. In fact, multi-temporal data obtained from remote sensing are effective in mapping and detecting changes of the landscape (Yin and He, 2012). By mixing the data obtained from remote sensing and GIS, the land cover changes pattern during the time period can be analyzed and detect the changes (Fichera et al., 2012). Various researchers of inside and outside the country have been done about the land-use change detection using satellite data and different analyzing methods (Matkan et al., 2010; Babykalpana and Thanushkodi, 2011; Vafaei et al., 2013).

Many stakeholders worldwide have acknowledged the advantages of remote sensing. Satellite imagery is the most useful tool employed while studying the land use change. On the other hand, Landsat imagery is practically free with oldest records in the archive date back to the 1970s (Gadrani et al., 2018). The utilization of remote sensing data allows getting spatial data in relatively short and vast areas with high accuracy and low cost compared with the conventional way. Remote sensing also can be multi-temporal which allows analysis of land use changes for few years efficiently. Moreover, understanding the proportion of land use changes over time is essential for planning and development of control measures. According to the study hypotheses, many changes have occurred in the Haraz basin from 1996 to 2011. The Landsat imagery has a high potential for spatiotemporal change detection in land use. Therefore, detecting the comprehensive spatial and temporal changes of the entire basin of Haraz with the use of accessible and low-cost data for both periods, as well as the use of convenient and accurate analysis methods considered as the research innovation. Based on the above ideas, this study aim to quantitative assessment, land use mapping and detect changes during the period using the Landsat imagery in Haraz Basin.
2. Study area

The study area is Haraz Basin, which covers 677000 ha in Mazandaran Province (Figure 1). This area is mostly for range, forest, farming and horticulture land uses.

![Figure 1. Location of study area in Mazandaran province, Iran](image)

3. Materials and Methods

3.1. Data and Corrections

Landsat satellite images have been used for land use mapping in the beginning and end of the analyzed 15-years period (1996 & 2011). Before using satellite data, the radiometric and geometric errors correction was carried out using Ortho-rectification method with rivers, roads and DEM maps in PCI Geomatica software. In this study, observing of all the bands and different color composites showed the striped error and cloudy areas. Therefore, the classes of cloud and shadow were included in the classification.

3.2. Indices preparation

According to the results of some similar studies, and for better extraction of information, PCA and rationing analysis (SAVI & NDVI indices) were used for indices preparation. Since in PCA analysis, visible bands (1-3) and infra-red bands (4-7) have a high
correlation, it was used separately on these bands set. Then the resulted first components were used as artificial bands in classification. Also, a color composite (RGB432) was used for a better recognition of the area and making of training samples.

3.3. Classification

In this study, supervised classification method and Maximum Likelihood algorithm has been used to classify images. The Supervised Maximum Likelihood classification is the most common method in remote sensing image data analysis. It identifies and locates land cover types known prior through a combination of personal experience, interpretation of aerial photography, map analysis, and fieldwork. It uses the means and variances of the training data to estimate the probability that a pixel is a member of a class. The pixel placed in the class with the highest probability of membership (Haque and Basak, 2017).

The land use classes were: 1 bare land, 2 irrigated farming, 3 dense forests, 4 sparse forests and horticulture, 5 range-dry farming, 6 first-grade range, 7 second-grade range, 8 residential lands and 9 water. Before selecting the best band combination, training samples chosen separately for each image. RGB color composites, field control points, and aerial photos were used in the selection of training samples.

3.4. Accuracy assessment

To remove isolated pixels and to smooth the classified images, a 3×3 window mode filter was used. Then the accuracy of classifications was assessed using a point ground truth map including 130 points.

3.5. Change detection

After ensuring the accuracy of the classification, post classification change detection analysis was executed. For this purpose, each year land use map was converted to vector format. The polygon of the cloudy and striped area processed in GIS environment and converted to correct classes. By overlaying both period land use maps and using Dissolve function, the area percentage of different land uses; and the changed and unchanged areas for a period of 15 years were identified.

4. Results and Discussion

4.1. Data corrections

Geometric correction of images with remove topographic error was done using Ortho-rectification method with RMS error less than one pixel. Figure 2 shows high accuracy geometry correction.
4.2. Indices

The different indices and color composites were generated to decrease the negative effect of inappropriate factor that exist in almost every band (with different quantities), increases the separation capability of the phenomena, and select the training samples. The images color composite (RGB432) and some indices have been shown in Figures 3-6. As that color composites indicate, the most land uses of the area consist range, dry farming, forest, and horticulture.
Figure 4. RGB<sub>432</sub> of 2011

Figure 5. SAVI index of 1996
4.3. Land use maps

Land use maps of 1996 and 2011 have shown in Figures 7-8, and Tables 1-2. These Tables and Figures indicates the study area land uses such as residential, farming, water resource, horticulture, forest, range, and bare lands. In 1996, the area percentage of different land uses including residential, farming, water bodies, horticulture and sparse forest, dense forest, first-grade range, second-grade range, dry farming, and bare lands are 0.87, 20.8, 0.38, 1.68, 20.46, 9.86, 8.5, 35.3, and 2.1 respectively. In 2011, the values are 5.04, 16.5, 0.76, 7, 14.4, 1, 7.5, 39, and 8.6. The main land uses were rangelands and range-dry farming in 1996. In 2011 there was an increase in the bare land and range-dry farming area. But, the area of dense forest decreased slightly, and rangelands area decreased significantly. Figure 9 shows the area of different land use classes for each period.
Figure 7. Land use map of 1996

Figure 8. Land use map of 2011
### Table 1. Land use area of 1996

<table>
<thead>
<tr>
<th>Class</th>
<th>Land use 1996</th>
<th>Area (Ha)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
<td>5895.931028</td>
<td>0.870386</td>
</tr>
<tr>
<td>2</td>
<td>Farming Lands</td>
<td>140991.441</td>
<td>20.813843</td>
</tr>
<tr>
<td>3</td>
<td>Water Resource</td>
<td>2575.294254</td>
<td>0.380177</td>
</tr>
<tr>
<td>4</td>
<td>Horticulture &amp; Low Density Forest</td>
<td>11443.45214</td>
<td>1.689338</td>
</tr>
<tr>
<td>5</td>
<td>Dense Forest</td>
<td>138636.3678</td>
<td>20.466175</td>
</tr>
<tr>
<td>6</td>
<td>First Grade Range</td>
<td>66807.17997</td>
<td>9.862401</td>
</tr>
<tr>
<td>7</td>
<td>Second Grade Range</td>
<td>57480.99581</td>
<td>8.485624</td>
</tr>
<tr>
<td>8</td>
<td>Range-Dry Farming</td>
<td>239283.772</td>
<td>35.324235</td>
</tr>
<tr>
<td>9</td>
<td>Bare Lands</td>
<td>14278.19849</td>
<td>2.107817</td>
</tr>
</tbody>
</table>

### Table 2. Land use area of 2011

<table>
<thead>
<tr>
<th>Class</th>
<th>Land use 2011</th>
<th>Area (Ha)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
<td>34192.2555</td>
<td>5.047627</td>
</tr>
<tr>
<td>2</td>
<td>Farming Lands</td>
<td>111564.8884</td>
<td>16.469752</td>
</tr>
<tr>
<td>3</td>
<td>Water Resource</td>
<td>5176.763136</td>
<td>0.764218</td>
</tr>
<tr>
<td>4</td>
<td>Horticulture &amp; Low-Density Forest</td>
<td>47746.27049</td>
<td>7.048537</td>
</tr>
<tr>
<td>5</td>
<td>Dense Forest</td>
<td>97501.7859</td>
<td>14.393688</td>
</tr>
<tr>
<td>6</td>
<td>First Grade Range</td>
<td>7202.241924</td>
<td>1.06323</td>
</tr>
<tr>
<td>7</td>
<td>Second Grade Range</td>
<td>51109.25297</td>
<td>7.544996</td>
</tr>
<tr>
<td>8</td>
<td>Range-Dry Farming</td>
<td>263999.2077</td>
<td>38.972848</td>
</tr>
<tr>
<td>9</td>
<td>Bare Lands</td>
<td>58899.96656</td>
<td>8.695099</td>
</tr>
</tbody>
</table>

**Figure 9.** Area of different land use classes in 1996 and 2011
4.4. Land use changes

To understand the spatial changes for 15 years, Figure 10-11 displays the map of change detection for different classes as well changed and unchanged areas. As shown in the earlier studies, many land use changes have occurred in different parts of the world (Gandhi et al., 2015; Haque and Basak, 2017), this study illustrated that during the 15-year period, land uses has changed in 27.5% of the study area. About 16% of the changes the conversion of first- and second-grade rangelands to each other and other land uses.

About 6% of the changes were accounted for the conversion of dense forest to horticulture, sparse forest, farming and water resources and 5% was related to the conversion of farming to a residential, horticulture, and water resources. Also about 0.4% was accounted for the conversion of sparse forest and horticulture to farming land and residential area (Figure 10). In addition, it is noted, that, according to recent droughts, water resources of study area should show a decrease, but in 2011, an increase was observed which is due to the construction of a dam. All the above changes in line with some researchers (Basanna and Wodeyar, 2013; Utomo and Kurniawan, 2016) are positive and negative.
In Figure 11, manmade phenomena such as roads, villages, and cities, as well as the waterway have been shown on the change map. The human-induced phenomena can lead to more destructive human activities. In this study, about one-third number of cities and villages, and about a quarter of the roads and waterway length was located in the changed areas. The presence of further waterway indicates the mountainous condition of the study area and its effects on soil erosion.

As we know, only phenomena located in the changed areas do not affect the land use change, but the phenomena in other areas can affect directly and indirectly the land use changes in adjacent and distant areas. The effects of these point and line phenomena are not limited to their location.

In addition to the impacts of human activities, climate change can also be another reason for land use changes. Moreover, the role of cultural and scientific educations, monitoring, and appropriate management by governmental and non-governmental organizations, as well as employment and poverty status and dependence degree of local communities on natural resources can also affect land use change rate.

This study has used digital remote sensing data as a spatiotemporal approach to detect land use changes. Similar studies have been done and the approach has been deemed suitable for analyzing the land use changes (Baboo and Devi 2010; Babykalpana and Thanushkodi 2011; Fichera et al. 2012; Yin and He 2012). In the current study, the Kappa statistics calculated for the classified Landsat images indicate high accuracy; which
suggests that Landsat imagery have high potential in land use mapping studies (Li et al., 2017).

The changes caused were mainly by human activities, which increased the demand for natural resources and often represented exploitative and unsustainable use (Githui et al., 2010; Sajikumar and Remya, 2015).

In line with some researchers (Haque and Basak, 2017; Singh and Singh, 2018), the results show that the method used has higher accuracy indicating the effectiveness of the method. The results show that remote sensing and geographic information system are providing effective techniques for the advanced ecosystem and socioeconomic management (Haque and Basak, 2017; Valjarević et al., 2018). Also these technologies are useful in acquiring more detailed insight into the condition of different land uses especially forests in the world (Valjarević et al., 2018).

As noted in earlier studies (Babykalpana and Thanushkodi, 2011; Haque and Basak, 2017), accurate and up-to-date land use/cover information is essential for environmental planning, to understand the impact on the terrestrial ecosystem and to achieve sustainable development. The change analysis can be helpful in predicting the unfortunate natural disasters to provide humanitarian aid, damage assessment and furthermore to device new protection strategies (Gandhi et al., 2015).

5. Conclusion

The obtained results are a warning for the future management of the Haraz Basin because 27% of the study area experienced land use change during the 15-year period. These changes can be due to an increase in population and human activities, which results in increasing demands for natural resources and converting them into farming lands, horticulture, residential and industrial areas. In addition, climate changes are effective on these conversions, which is due to human interference in natural ecosystems. The observed trend may continue in the future, leading to increasing environmental damage and loss of rangelands and forests. Therefore, analyses and predictions of future changes and effects on different processes are important for the efficient and sustainable use of resources, to prevent irreversible changes in the future.

References


Yin, J., & He, F. (2012). Researching relationship between the change of vegetation cover and runoff based and RS and GIS. Procedia Environmental Sciences, 12, 1077-1081.