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**A STUDY ON THE ESTIMATION OF POTATO CROP ACREAGE USING
SATELLITE IMAGES AND FUZZY ARTMAP ALGORITHM**

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ABSTRACT

Today, the potato due to its nutrition values is a very important food for nourishment of world's population. The use of remote sensing for estimating the cultivation acreage has been accomplished through different techniques. The current study aimed at comparing some of these techniques in Ardabil area as a center for producing potato. The current study sought to estimate the potato crop cultivated acreage through the Landsat 8 satellite images of 2013 beside using the image processing techniques such as analysis of the principal components, monitored classification, the intensity-based Fuzzy method (ARTMAP), and the Normalized Different Vegetation Index (NDVI) and Tasseled Cap Index (in two directions of greenness and wetness). The results indicated that the combination of the monitored classification and the categorizing intensity-based Fuzzy method algorithm detects the potato's cultivated acreage more accurately. The obtained accuracy for classified image was 80.4 and 0.77 for Kappa Index. The cultivated acreage in the studies area was 15536 hectares using a combination of the above techniques. Also the NDVI is more accurate compared to Tasseled Cap.

Keywords: potato, the cultivated acreage, Landsat 8, Fuzzy method, Ardebil

INTRODUCTION

Land use and land cover and their exact area are valuable information in an area which is always needed by decision-makers and

managers of natural resources and various agricultural sectors. Among these land uses which are so important for supplying the

human food are the agricultural lands and orchards. Remote sensing by the aid of natural and artificial electromagnetic waves is widely used in agricultural planning and investigations. The remote sensing techniques are widely used in the plants analysis due to the frequency of the received image of an area, shooting at different wavelengths at a time, and the possibility of processing and interpretation of acquired data (1). Today, for the most sectors, the satellite images are not only cheap, but also its benefits are so much that the costs of data purchase are trivial regarding the speed of task accomplishment, the accuracy, and the volume of obtained data. Currently, the benefits of remote sensing are well manifested in techniques used for agriculture sector due to the timeliness and the ability to detect rapid changes (2), (3). The estimation and determination of the rate of agricultural products is very important for planning and decision-making. Collection of the data and reports about the agricultural products by the traditional methods is so costly and remote sensing can provide the agriculture experts with beneficial information by detecting the type and cultivated acreage of the products. The basis of correct planning and management in agriculture is the availability of the statistics and precise information on

agricultural capabilities. The use of remote sensing data leads to distinguishing different agricultural conditions, including the level, type and time and location patterns of cultivation due to features such as multi-temporality and being multi-spectral, variable location distinguishing and radiometric functionality, and wide and integrated vision (4). Awareness of the distribution of several agricultural products is a basic need for commercial planning and decision-making and also it is necessary for some sectors of farming such as water stress and yield estimation (5).

In this regard, the satellite data and remote sensing technology is a beneficial and efficient means for estimation of the cultivated crops yield and their acreage. The development of image processing techniques besides satellite data with the ability of locational, spectral, and time distinguishing in the recent years has led to the use of this modern technology as rapid and low-cost means compared to the traditional methods for estimation of cultivated crop acreage. Also, it should be noted that some agricultural products have a short life span which due to their extensiveness probably cannot be easily measured and estimated by the traditional methods.

In terms of using the satellite data, numerous researches have been conducted in several countries on the cultivated crops acreage each addressing a specific type of agricultural products. Ogawa et al investigated displaying the rice products using the radar and optical data. Their study's results indicated that due to the difference in spectrums of rice at growing season, the rice paddies can be detected by distinguishing between these spectrums. Considering this advantage of radar imaging which is viability in all of weather conditions, they managed to determine the rice paddies in Japan with a 97.7% accuracy using a combination of radar and TM images (6). McNarin & Brown conducted a study on the benefits of remote sensing in agriculture in the Canadian Center for Remote Sensing. This research has dealt with the Production Information System (CIS) and addresses the use of optical images in detection of the agricultural products besides the more effective role of radar images with the invent of Radarsat 1 and 2. At the end of the mentioned study, some information on displaying the rice products using the radar and optical images have been provided (7). Coung et al addressed the preparation of rice distribution map using SAR besides radar images and also the 6th band of TM (8).

Lacoul et al also investigated the estimation of rice cultivated acreage using the thermal band and Radarsat images in the two states Patomtany and Ayathay of Thailand (9). Ahadnejad (10) has used the ETM+ satellite images of Landsat7 and has calculated the maximum probable acreage of olive in Tarom Area using the classification algorithm. Johnson et al (11) has used the satellite images of IKONOS satellite and has prepared the maps of orchards in Hiuchica and Tokalon zones in the U.S. Other researchers have estimated the physiological age of sugarcane crop in some areas of Amir Kabir Cultivation & Industries and Daabal Khazaei combining the PASAVI and PANDVI methods and by the aid of ASTER images (12).

The current study aimed at estimation of potato crop cultivated acreage in Ardabil City using the data from Landsat 8 and the principal components analysis technique, Tassled Cap, NDVI, and monitored classification.

Body

The studied zone is Ardabil, located in latitude 38' 18' 09" to 38' 41' 00" and the longitude 48' 15' 08" to 49' 50' 00" and the average height of 1314 m above sea level with approximate 75841 surface area. In terms of the political divisions it was a part

of Ardabil and Namin city. The study area is a plain area in terms of topographic units.

Figure 1 shows the study area.

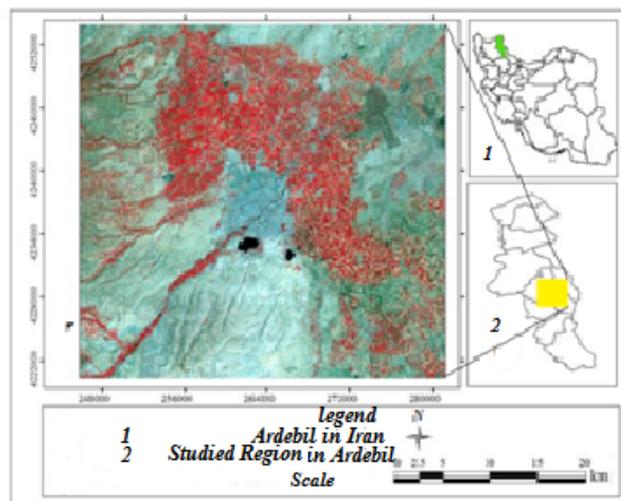


Figure 1: the studied region

For detecting the potato cultivated areas in the region, the satellite imagery Landsat 8, passing No. 33-167 which was taken on August 2013 was used. The georeferencing of the data, the digital topographic maps 25000: 1 which was prepared by the national mapping agency was utilized. Also, in order to prepare training and testing samples for classification and estimation of satellite images and measurement of classification accuracy, the GPS was utilized. The following flowchart indicates the outline of the study.

Obtaining the satellite data from Landsat 8, 2013

Detection of the satellite data

The Georeferencing of the data based on 1/25000 maps

Determination of the methods and needed indices for the current study

Tasseled Cap, Preparing the reflection profile, NDVI, principal components analysis
Creation of color composite of the components

Preparing the training samples from the potato cultivation areas using 1/25000 maps and GPS

Classification of the image based on monitored method and ARTMAP algorithm

Preparing the map of potato cultivation area and evaluation of accuracy and setting a threshold for distinguishing between potato and other crops

Transferring the data from the environment of IDRISI Selva software to GIS software

Preparing the final map of the potato cultivation area with vector format,

calculation of the area, and providing the output

Table 2: the outline of the study using remote sensing data and GIS system

For detection and identification of a specific usage, there are usually several image processing techniques each having a different result. The current study aimed at estimation of potato crop cultivated acreage in Ardabil City using the data from Landsat 8 and the principal components analysis technique, Tassled Cap, NDVI, and monitored classification.

a) The Principal Components Analysis Method

This method is one of the most common methods of remote sensing data analysis and interpretation which firstly reduces the data volume and secondly increases the ability for distinguishing the classes for image classification. After the accomplishment of the method, a color composite image was created from the first, second, and third components by IDRISI selva software. In this image, due to the high chlorophyll of the potato compared to other crops, the potato fields were to a high extent manifested with dark green color among the other crops.

b) The Monitored Classification Method (FUZZY ARTMAP):

The data processing stages in FUZZY ARTMAP are as follows:

First stage: at this stage the number of processed image bands that depend on the sensor are entered into the system individually or in a group.

Second stage: for unmonitored classification, the interval of the number of space sampling for the band is chosen. The higher the number of the sample is, the more precise it will be and takes more time for processing.

Third stage: for monitored classification, the file of the training samples which was previously prepared is introduced into the system and the number of the classes is determined by these samples.

Fourth stage: for both unmonitored and monitored classification, the ART parameters should be determined. Usually the default value for the parameter is 0.01. Then, the speed of learning is determined from 0 to 1. In case the speed is 1, the learning analysis will be done at a much higher speed. The investigations indicate that there are important points in adaptation intensity theory:

The adaptation theory is based on the neural network from a biologic theory based on cognitive processing of the data. The networks designed by this theory are flexible in especially solving the complicated problems which are less flexible, and provide

a high stability for significantly maintaining the past learnings.

This theory is a clustering algorithm that combines the input patterns (real numbers between 0 and 1) on the vectors with fuzzy analog and provides a developmental learning theory, which allows the system to constantly continue its work without lost or reduction in the past learning conditions (13). Vigilance parameter is an important parameter which strongly controls a cluster or group. A small amount of this parameter enables many patterns be connected to the same neuron and consequently leads to the irregular distribution of clusters while the higher amounts leads to the network's system to only chose one sample (pattern) (14).

c) The Normalized Difference Vegetation Index

In this method, two spectral bands, band 5, and band 4 which shows the maximum reflection of the herbs in an area were used for calculating the normalized difference vegetation index. Regarding the affluence and high greenness of the cultivated potato in this season of the year compared to other crops, the cultivated acreage of potato was detected by putting a threshold on the resulting image after applying the normalized difference vegetation index. However, since the data used in the current study were

obtained in summer, some other crops may be greener in some cases and cause lower accuracy of this method as compared to monitored classification method.

d) Tasseled Cap Index

Another index used in the current study is Tasseled Cap Index. Parameters such as brightness, greenness, soil moisture can be calculated using this index. Since the current study has aimed at evaluation of space distribution of potato cultivated area, the wetness and greenness were used for reaching that objective. After the creation of the desired image, the potato cultivated areas were detected among the other crops by putting a threshold on them. The change in Tasseled Cap is a method for modification in observation of the data in vegetation acreage studies. The researchers have introduced three axes for defining the contents of vegetation coverage.

Brightness: The total weight of all the bands that is defined for main changes in soil's reflection capability.

Greenness: Perpendicular to the brightness axis representing the brightness and the contrast between visible bands and near infrared band. This axis is entirely based on the amount of green vegetation in the scene.

Wetness: It depends on soil moisture and vegetation cover crown.

For the greenness axis, the threshold limits were set using ground sampling by GPS and samples from Google Earth, and the potato cultivated areas in the zone are detected.

The wetness axis is based on moisture and vegetation cover crown and just like the greenness, the threshold limits were set using

ground sampling by GPS and samples from Google Earth, and the potato cultivated areas in the zone are detected.

RESULTS

The figures 3 and 4 are the samples for potato cultivated fields in the area.

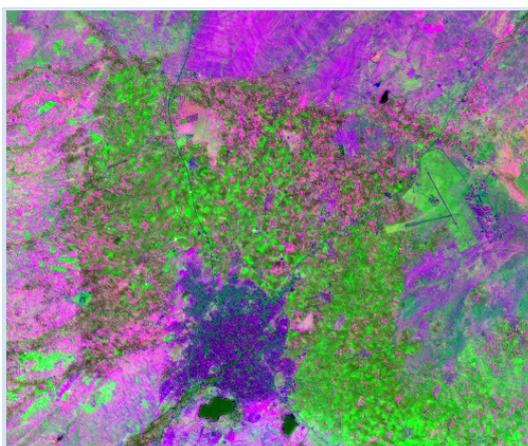


Figure 3: the combination of the 1-2-3 components

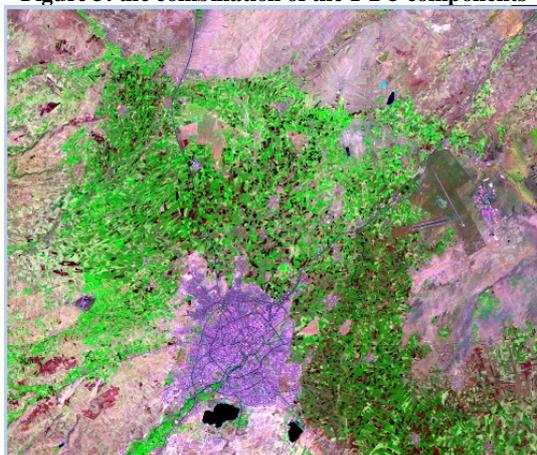


Figure 4: the color composite of 7.5.2 bands

Then, using several techniques (a combination of principal components and monitored classification techniques, Normalized Different Vegetation Index, Tasseled Cap method (greenness axis),

Tasseled Cap method (wetness axis)), the area of cultivated potato was calculated.

After accomplishment of principal components analysis and creation of the color composite image from the components, the training samples using the 1:25000 maps

and field references to the zone were chosen in order to detect the potato cultivated area. Then by creating color combinations 1, 4, and 7 bands in figure 4 and finally using fuzzy neural network classifier the potato cultivated area was classified. After this classification, the data images were transferred to GIS, so the vector map was obtained for calculation of the areas and providing the output map. According to the

results obtained in this way, the area under potato cultivation in the region has been estimated at around 15536 ha. The obtained accuracies for the classified images was 80.4 and it was 0.77 for Kappa index.

On the other hand, measurement of the area using the field mapping and GPS extracted from the province sources revealed it was 15000ha.

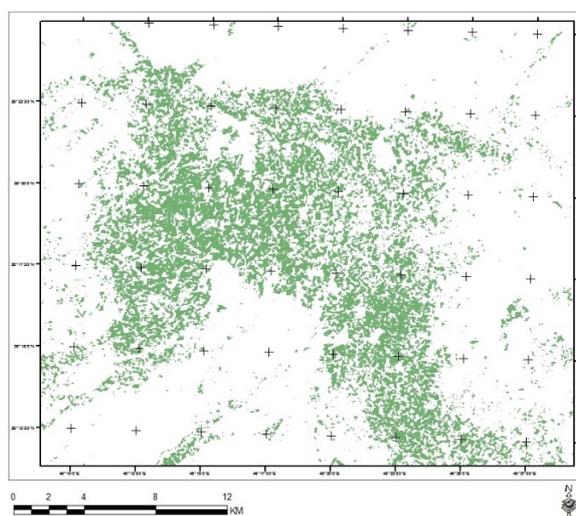


Figure 5: the space distribution map of the potato cultivation area by monitored classification (FUZZY ARTMAP) in 2013

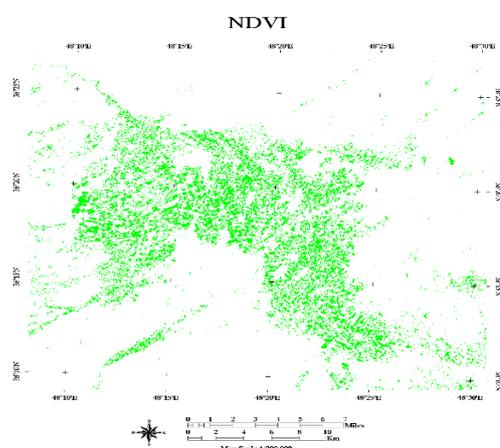


Figure 5: the space distribution map of the potato cultivation area by Normalized Difference Vegetation Index (NDVI) in 2013

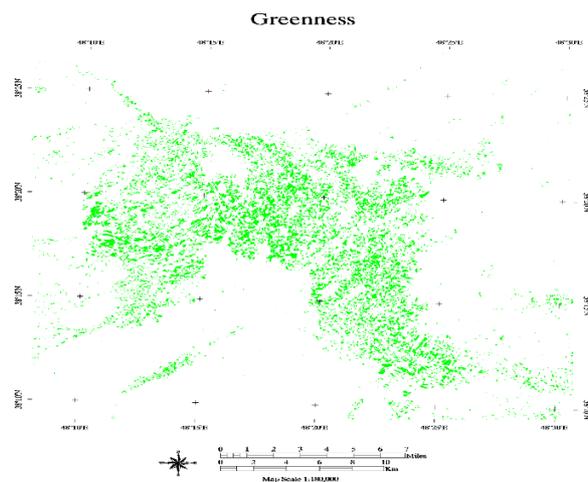


Figure 5: the space distribution map of the potato cultivation area by Tasseled Cap Method (greenness) in 2013

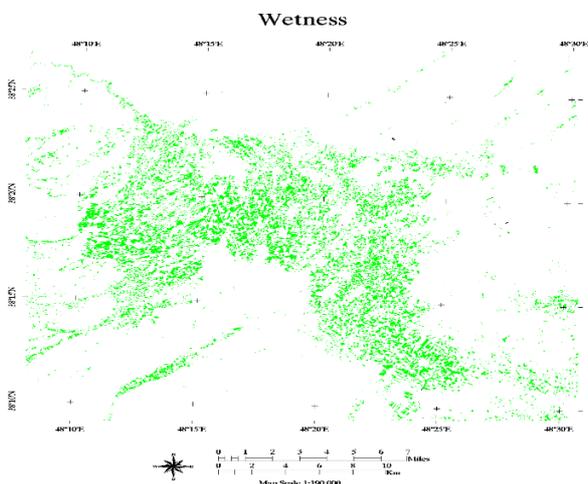


Figure 5: the space distribution map of the potato cultivation area by Tasseled Cap Method (wetness) in 2013

Regarding the maps obtained from all four methods, the potato cultivated area for each method was calculated and indicated in table 1.

Table 1: The potato cultivation area in different methods

Method	The potato cultivation area
The combination of principal components and monitored classification methods (FUZZY ARTMAP)	15536
Normalized Difference Vegetation Index (NDVI)	13781
Tasseled Cap Method (greenness)	7022
Tasseled Cap Method (wetness)	8125

CONCLUSION

Ardabil City is one of the main areas of potato production and population growth and the necessity for access to cheap and quality food, has added to importance of this agricultural product. The calculation of the area of potato cultivation can be used for estimation of production rate and economic value and marketing. The several techniques used for remote sensing are easy and useful steps that provide the users with proper information in case they are accurate enough, and the current study aimed at comparing some of them. Regarding the obtained results in the current study, the principal components analysis method can be used as a proper method for reduction of data volume and increasing the classes distinguishing index. Considering this method and the creation of color composite from the first three components of this method (which constitutes the highest data volume), the sampling from the potato cultivation area was done and finally using monitored classification method and FUZZY ARTMAP classifier, the potato cultivation area was detected and it was calculated about 15536ha by a combination of the above two techniques. Also, among the other two indices used (Tasseled Cap index with greenness and wetness axes and NDVI

index) the NDVI had better results compared to Tasseled Cap, since in NDVI the detection of the fields is more accurate due to use of thresholds. Regarding the importance of estimation of agricultural products for food planning, the satellite images with high location distinguishing abilities such as IKONOS and Quick Bird can be used in order to increase the accuracy of estimation of the agricultural products and acreage. Also, it is suggested that for more accurate estimation of potato cultivation area, the images that are obtained at the end of summer be used. The results of the current study are in line with those of (15), (16), (17), and (18).

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