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Determination of Potential Agricultural Lands Using Landsat 8 OLI Images and GIS: Case Study of Gokceada (Imroz) Turkey

Rahmi Kafadar, Levent Genc

Abstract**—**In present study, it was aimed to determine potential agricultural lands (PALs) in Gokceada (Imroz) Island of Canakkale province, Turkey. Seven-band Landsat 8 OLI images acquired on July 12 and August 13, 2013, and their 14-band combination image were used to identify current Land Use Land Cover (LULC) status. Principal Component Analysis (PCA) was applied to three Landsat datasets in order to reduce the correlation between the bands. A total of six Original and PCA images were classified using supervised classification method to obtain the LULC maps including 6 main classes ("Forest", "Agriculture", "Water Surface", "Residential Area-Bare Soil", "Reforestation" and "Other"). Accuracy assessment was performed by checking the accuracy of 120 randomized points for each LULC maps. The best overall accuracy and Kappa statistic values (90.83%, 0.8791% respectively) were found for PCA images which were generated from 14-bands combined images called 3-B/JA.

Digital Elevation Model (DEM) with 15 m spatial resolution (ASTER) was used to consider topographical characteristics. Soil properties were obtained by digitizing 1:25000 scaled soil maps of Rural Services Directorate General. Potential Agricultural Lands (PALs) were determined using Geographic information Systems (GIS). Procedure was applied considering that "Other" class of LULC map may be used for agricultural purposes in the future properties. Overlaying analysis was conducted using Slope (S), Land Use Capability Class (LUCC), Other Soil Properties (OSP) and Land Use Capability Sub-Class (SUBC) properties.

A total of 901.62 ha areas within "Other" class (15798.2 ha) of LULC map were determined as PALs. These lands were ranked as "Very Suitable", "Suitable", "Moderate Suitable" and "Low Suitable". It was determined that the 8.03 ha were classified as "Very Suitable" while 18.59 ha as suitable and 11.44 ha as "Moderate Suitable" for PALs. In addition, 756.56 ha were found to be "Low Suitable". The results obtained from this preliminary study can serve as basis for further studies.

Keywords**—**Digital Elevation Model (DEM), Geographic Information Systems (GIS), LANDSAT 8 OLI-TIRS, Land Use Land Cover (LULC).

I. Introduction

AGRICULTURAL lands as well as natural resources like forests, wetlands and pastures are mostly under threat of expanding urban areas due to growing population in developing countries [1]. In case of lacking sustainable land use plans, rural expansion process may lead inappropriate use of lands for their potential [2]. On the other hand, determination of suitable lands for agricultural production and their protection became an important concern among decision makers. This is due to the fact that agricultural production on inappropriate lands may cause not only food issues but also economic losses and environmental problems.

It is an important but not sufficient effort to protect and maintain current agricultural lands. Horizontal enlargement of agricultural lands is also known to have key role in emerging countries where there is still a potential. Therefore, identification of suitable lands for agriculture and their suitability levels became an interest of researchers in these regions. In this context, Land Suitability Analysis (LSA) plays a key role in land use planning [3], [4] which evaluates whether the requirements of land use are adequately met by the properties of the land [5]. However, it is reported that there is no certain criteria for this evaluation [2], and may change depending on specific conditions of study area. Since LSA requires consideration of various criteria simultaneously, performing of this analysis using GIS and remote sensing technologies provides rapid, reliable and relatively economic assessments for ecological, geological, agricultural studies and regional plans [4]-[10].

Gokceada (Imroz), the largest island of Turkey, is widely acknowledged as a candidate for becoming major center for organic agriculture activities [11]. Thus, it is anticipated that there would be demand for new spaces for increasing agricultural attempts in the foreseeable future. Hence, overall objective of this study was to determine the potential agricultural lands (PALs) in Gokceada (Imroz) Island of Canakkale province using Landsat 8 OLI images, GIS and other ancillary data. Specific objective of this study was to test whether PCA provide any advantages to produce LULC maps for purpose of identifying the locations and suitability levels of PALs.

II. Materials and Methods

A. Study Area

Study was conducted in Gokceada (Imroz) Island which is the largest land of Turkey with an area of approximately 290 km^2. Gokceada is one of the 12 districts of Canakkale province. The Fig. 1 shows the location of the study area and Formosat II imagery (8 m spatial resolution) coverage.

R. Kafadar was with Canakkale Onsekiz Mart University, Faculty of Agriculture, Agricultural Sensor and Remote Sensing Lab. (ASRESEL), Turkey (e-mail: rahmikafadar@gmail.com)

L. Genc* is corresponding author with Canakkale Onsekiz Mart University, Faculty of Agriculture, Agricultural Sensor and Remote Sensing Lab. (ASRESEL), Turkey (corresponding author; phone: +90-286-2180018-1315; fax: +90-286-2180545; e-mail: leventgc@comu.edu.tr).

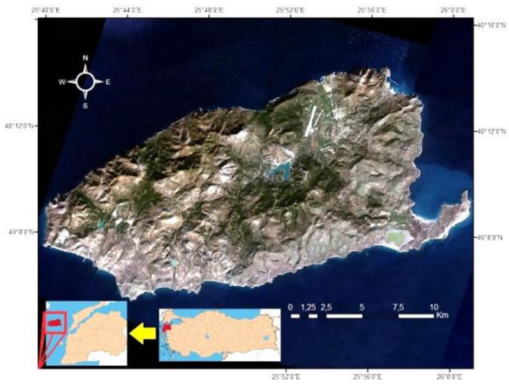

Fig. 1 Location and Formosat II imagery cover of study area

B. Image Processing

All image processing steps were conducted using Erdas Imagine software. Landsat 8 OLI images (30 m spatial resolution) relating to dates July 12, 2013 and August 13, 2013 were downloaded from USGS website. Primarily, original 7-band images; 7-band July (7B/J) and 7-band August (7-B/A) were generated using the bands given in Table I. Then, a 14-band image (14-B/JA) was formed by combining 7B/J, and 7B-A images, to utilize from the differences within period between July and August.

TABLE I
LANDSAT 8 OLI BANDS USED IN STUDY

Band	Region	Wavelength
1	Coastal / Aerosol	0.43 - 0.45
2	Blue	0.45 - 0.51
3	Green	0.53 - 0.59
4	Red	0.64 - 0.67
5	NIR	0.85 - 0.88
6	SWIR	1.57 - 1.65
7	SWIR	2.11 - 2.29

In second step PCA was applied to original images to reduce the correlations between bands. 3-band PCA images (3-B/J, 3-B/A, and 3B/JA) were obtained from original 7-B/J, 7-B/A, and 14-B/JA images.

Finally, a total of six images including original and PCA images were classified using supervised classification Maximum Likelihood Algorithm (MLA) to create LULC maps of study area. Fig. 2 represents the LULC map generation steps.

Six main LULC classes were considered to be classified in this study. These are; Forest (F), Agricultural Land (A), Water Surface (W), Residential Area-Bare soil (RB), Reforestation (R), and Other (O) classes. Accuracy of LULC maps were assessed according to [12], and the most accurate map was used in further analysis.

C. Determination of PALs

In present study, current LULC map, DEM-derived slope map, and soil maps (Land Use Capability Classes, LUCC; Other Soil Properties, OSP; Land Use Capability Sub-classes, SUBC) were used in PAL determination and suitability level evaluation. Figs. 3 and 4 represent DEM and soil map of Gokceada Island.

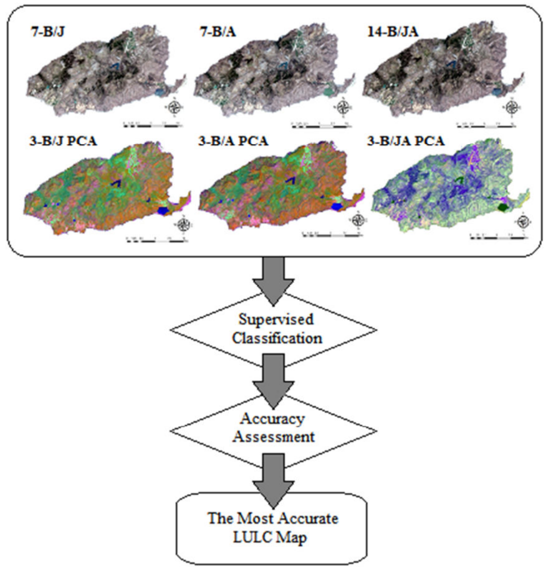

Fig. 2 Image processing and accuracy assessment steps

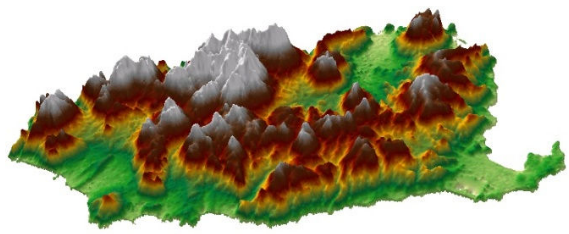

Fig. 3 DEM of study area (5 x Z factor)

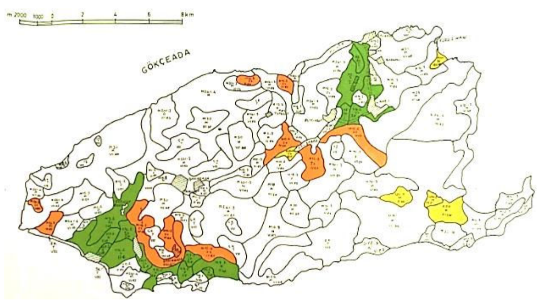

Fig. 4 Soil map of study area

Since the PALs assumed to be a function which depends on mentioned LULC class, slope and soil properties, the suitability levels were determined according to (1) and criteria denoted below (Table II). Analysis was conducted considering the assumption that "O" class may be used for agricultural purposes in future, and RB, F, R, and W classes excluded from further analyses.

TABLE II
PAL DETERMINATION CRITERIA AND SUITABILITY EVALUATION

LULC	S (%)	LUCC	OSP	SUBC	PAL Suitability Level
O	0-2	I-II	-	-	Very Suitable
O	3-6	III	-, h	-, e	Suitable
O	7-12	IV	r	e	Moderate
O	13-35	V-VII	h,r	es-se	Low suitable

Symbols of h, r, s in OSP column represents slightly salty, rocky and salty soils respectively. In SUBC column e, s, w symbols represents erosion, root zone issues and drainage problems, while the combinations states the preferential terms of two concurrent issues. Fig. 5 summarizes the GIS analysis for PAL determination.

$$PAL = O(S, LUCC, OSP, SUBC) \quad (1)$$

where; O: Other class of LULC MAP; S: Slope (%); LUCC: Land Use Capability Classes; OSP: Other Soil Properties; SUBC : Land Use Capability Sub-classes.

Analysis was conducted using ArcGIS (10.3) software.

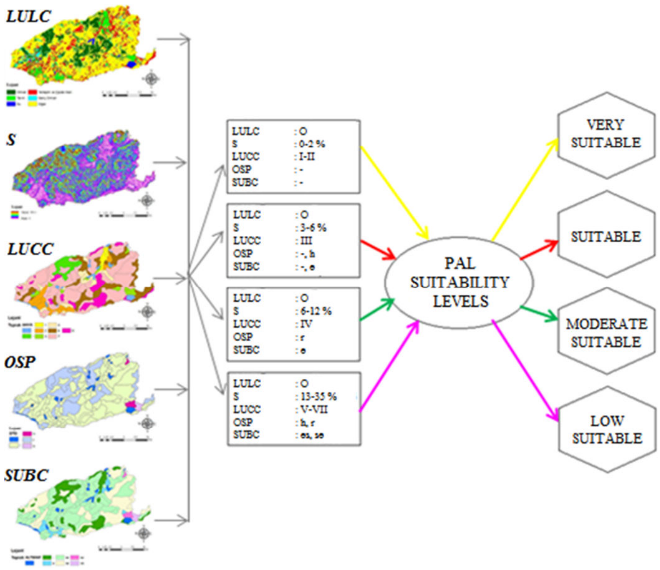

Fig. 5 Schematic representation of GIS analysis for PAL determination

III. RESULTS AND DISCUSSION

A. LULC Classification

Six Landsat 8 OLI datasets were classified using supervised classification for the test site and accuracy assessments were performed. The main objective of this process was to determine the dataset that produced the best overall and user accuracies for land cover classification. The most accurate LULC map was selected to be used in GIS analysis to identify the locations and suitability levels of PALs in study area.

It was found that the best results of overall accuracy for discrimination of 6 classes were achieved from PCA of 14-band image (3-B/JA). Overall accuracy and Kappa statistic values were 90.83 % and 0.8791 respectively (Table III) Fig. 6 shows the 3-B/JA image, and the LULC map.

According to this, a major part of study area was found to be covered by "Other" class (55.7 %) with an area of 15798.2 ha. The RB class covered 4630.95 ha area (16.3 %), while areas of F, A, and R classes found to be 4459.05 ha (15.7 %), 1194.67 ha (7.0 %), and 1109.25 ha (3.9 %) respectively. The area of W class was 371.79 ha (1.3 %).

TABLE III
CLASSIFICATION ACCURACY OF LULC MAP DERIVED FROM 3-B/JA

LULC Class	Classified Totals	Number Correct	Producer Accuracy	User Accuracy
F	19	19	100 %	100 %
A	14	9	100 %	64 %
W	10	10	100 %	100 %
RB	20	19	95 %	95 %
R	12	8	89 %	67 %
O	45	44	83 %	98 %

Overall Classification Accuracy: 90.86 %, Kappa Statistic: 0.8791

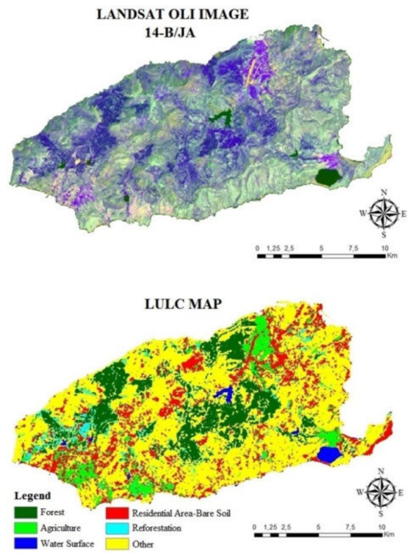

Fig. 6 The 3-B/JA PCA image derived from 14-B/JA, and LULC map derived from this image

B. GIS Analysis for PAL Determination

The GIS analysis results showed that a total of approximately 902 ha area within "Other" class of LULC map is found to be suitable for agricultural production (Fig. 7). Especially 27 ha of PALs consisted of "Very Suitable" and "Suitable" areas which have almost optimum conditions for this purpose. The "Moderate Suitable" areas (118.44 ha) have sufficient conditions for many plant species. In comparison, "Low suitable" areas are mostly considered to be used for dry farming. However, irrigation is also possible since drip lines are utilizable even on slope areas. In addition, cultivation of drought tolerant/resistant plants like some kinds of medical and aromatic plant species is also practicable. Furthermore, special plants that require less controlled conditions may be cultivated on "Low Suitable" areas. Current agricultural lands present in LULC map, PALs and their locations in study area are shown in Fig. 7.

Another study was conducted in Gokceada by [13] in 2008 to determine optimal land use for the island using ASTER imagery. Researchers suggested that optimal area (%) for agriculture is found to be 17.08 %. In this study agricultural area potential which is the total amount of current and potential agricultural lands was calculated as 10.2 %. This difference may result from temporal variations between 2008-2014 and the spatial resolution characteristics of the Landsat (30 m) and ASTER (15 m) images.

TABLE IV
PAL SUITABILITY LEVELS

Suitability Level	Area (ha)
Very Suitable	8.03
Suitable	18.59
Moderate Suitable	118.44
Low Suitable	756.56
Total	901.62

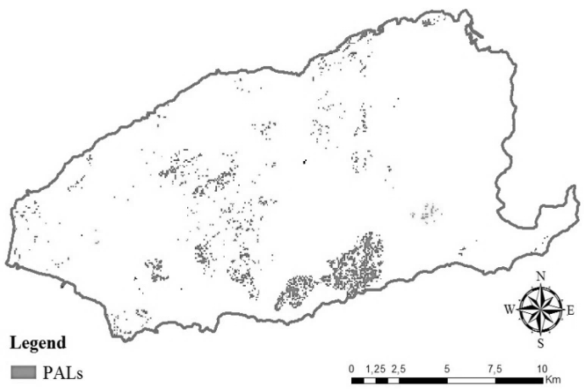

Fig. 7 Locations of PALs

IV. CONCLUSION

Datasets of Landsat OLI were developed with two different image scenes acquired in 12 July and 13 August 2013. Visible, NIR and SWIR regions sensitive bands (1-7) of Landsat OLI were stacked for each date. Then a 14-band image was generated combining these two date. One of the most widely used image enhancement technique PCA were applied to these datasets and three new images were obtained including 3 bands. A total of six images were classified using supervised classification technique to create LULC maps. Accuracy assessment was conducted to identify the most accurate LULC map. A LULC map derived from 3-B/JA image had the highest overall accuracy and kappa statistic value, and was used in GIS analysis for PAL determination. Lands belonging O" class with slope value lesser than 35%, and without permanent soil problems are considered as PALs in this study. It was also noticed that almost 902 ha area satisfy these requirements. Consequently, it was seen that remote sensing and GIS integration provides rapid, reliable and relatively economic results for land suitability analysis in Gokceada, and potential for using Landsat OLI images for this purpose could be stated in present study. However, using imageries with higher spatial resolution may lead more accurate results which may help planners and decision makers for future plans.

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