Evaluation of Pixelbase and Subpixel Methods for Snow Cover Studying in Regional Scale

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ABSTRACT

Monitoring snow cover changes are important to water resource researches because it supplies electricity and freshwater. Although operational snow cover mapping by optical sensors has been used for more than 4 decades in the world but In Iran, traditional data collection methods are still common. Using these methods have a lot of problems. Usually the ground observation network is not dense enough to provide required information - especially in rugged regions- and also mountainous situation makes difficult accessible to ground stations.

In this research, Modis satellite images after changing their PDS format to L1B, used for snow cover studying in Karaj and Latian Basins. These Basins that bounded between 51° 20' to 51° 36' longitude and 35° 52' to 36° 11' latitude supply consumption water for capital city of Iran.

Two methods used in this research. NDSI used as a Pixel-base Method that determines snow/no snow pixels and linear spectral unmixing algorithm used for Pixelbase method.

Results shows that subpixel method in comparison to NDSI – NDSI.0.4 that is proposed for global scale monitoring- has better result but using NDSI after atmospheric correction and changes its threshold, has best result. In order to atmospheric correction, Bulk correction method used.

For subpixel method, Endmembers determined using IRS- P6 image and MNF algorithm used for decrease noises. Thereafter, spectral curves determined for each endmembers and finally spectral unmixing performed. For evaluation the accuracy of both of the pixelbase and subpixel methods, IRS-P6 Images – 23.5 m spatial resolution - used.

Keywords: snow cover; pixelbase; subpixel; NDSI, linear spectral unmixing; MODIS; Karaj and Latian Basins

INTRODUCTION

Monitoring snow cover changes, are important to water resource researches because it supplies electricity and freshwater and has a substantial impact on climate processes and weather .It is also source of avalanches and floods. In Iran, Annual precipitation is less than 250 mm and because of Climate conditions, rainfall is unequal in different seasons so studying snow cover as an accumulation source for supplying water during the warm seasons is too important. On the other

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hand, accurate snow cover determination is essential to compute the volume of water that flows toward rivers during snow melt seasons.

Although operational snow cover mapping by optical sensors has been used for more than 4 decades in the world but In Iran, traditional data collection methods are still common. These methods usually don't provide enough detail and suitable quality for snow cover (Cea et al, 2005). Also, they are time consuming and spatially limited (Butt,2002) On the other hand, at high elevation and remote areas of the globe, where very little in situ data exists, remote sensing is the only mean to observe the snow cover distribution.

During 4 decades in snow cover studying, large range of methods has been used for snow-cover mapping but still there are lot of demands for more accurate snow cover maps. Most methods have been applied for snow-cover mapping, classify each pixel as a snow and no-snow pixels but subpixel methods, classify snow into several coverage classes or onto a continuous scale. (Solberg, 2000)

In this research, Pixelbase and Subpixel methods compared for determining the suitable method for snow cover detection in Karaj and Latian Basins using MODIS images .for this reason, NDSI Index and Linear Spectral Unmixing methods used.

MODIS is an imaging spectroradiometer that employs a cross-track scan mirror, collecting optics, and a set of individual detector elements to provide imagery of the Earth's surface and clouds in 36 discrete narrow spectral bands from approximately 0.4 to 14.0 µm (Barnes et al., 1998). The spatial resolution of the MODIS instrument varies with spectral band, and ranges from 250 m to 1 km at nadir. These images are suitable for snow cover mapping because of their spatial and temporal resolution.

For NDSI Index, at-satellite reflectance for MODIS bands 4 (0.545–0.565 µm) and 6 (1.628–1.652 µm) is used (Hall et al, 1995). The NDSI is basically for snow cover studying in global scale. Equation 1 presents NDSI Index.

$$NDSI = MODIS4 - MODIS6 / MODIS4 + MODIS6$$

Equation 1. NDSI index for snow cover detection.

NDSI > 0.4 has been determined for snow cover detection because of its ability to separate snow and water from other features. This threshold were used in different researches like (cea et al ,2005) (Beck et al,2005) (Dini,2003) but in these research didn't have attention just to 0.4 because this threshold is for global scale snow mapping and it have to test for snow cover mapping in regional scale.

Addition to NDSI > 0.4, other thresholds have been specified for snow determination from all other features. NDSI > 0.11 for band2 and NDSI > 0.10 for band 4 (Equation 2) are 2 other criteria for MODIS snow mapping (Klein et al ,1998).

$$\text{Ref band2} >= 11\%$$
$$\text{Ref band 4} > 10\%$$

Equation 2. Threshold for separate snow from other features.

Classifying pixels into only snow and no-snow pixels -like NDSI method- may be sufficient for large-scale applications in global scale but for medium and small-scale applications, like mapping snow cover in basins, subpixel methods are needed (Solberg, 2000).

On the other hand, high temporal resolution images are suitable for daily snow cover studying, but majority of these images have low or medium spatial resolution. So, their number of Mixed-Pixels are high and in this situation, subpixel method is required. Mixed-Pixel is a pixel that records all spectral reflectance in a region. Different parameters cause to create a mixed-pixel. In highlands because of topographic conditions and rugged surface, by using medium resolution image like MODIS sensor, features vary in smaller scale than sensors resolution (Hongen et al,2005) . In this situation, detectors measure spectral reflectance of all features like snow, soil and vegetation synchronously. Therefore pixelbase methods that divide pixels to snow and no-snow pixels, couldn't have desired results .

Spectral Unmixing technique uses for estimate the abundance of different features in each pixel. This technique is useful for sensors with high number of bands.

Spectral Unmixing method usually is base on the Linear Spectral Unmixing model. In this model assumes that measured radiances are the linear mixture of endmembers reflectance that each of them has a special spectral signature. Each endmember shows the pure pixels reflectance that is relevant to each feature. Equation 3 shows linear mixed method for each band.

$$R_{S,\lambda} = \sum_{i=1}^{M} F_i R_{\lambda,i} + \varepsilon_\lambda .$$

Equation 3. linear mixture for different band.

In this equation assumes that M kind of pure covers exist in image.Fi shows features frequency in each pixel and R_S, λ shows EM_i reflectance for λ wavelength
(Gillespie et al.1990).

There are two requirements for linear spectral unmixing. First the spectral signature of the end-members needs to be known and The number of end-members have to be less or equal to the true spectral dimensionality of the scene. (Omran et al,2001).

In this research, at the first step of linear Spectral Unmixing, suitable bands selected then MNF algorithm used for decrease noise in images. Thereafter, Endmembers detected and according to detected EMs, linear spectral unmixing used and snow subpixel map derived.

STUDY REGION

The Study area of this research, Karaj and Latian Basins, are located in the Alborz highlands at the north of Iran. This area is bounded between 51° 20' to 51° 36' longitude and 35° 52' to 36° 11' latitude.

Karaj and Latian basins supply 54% of drinking water of Capital city of Iran also these basins supply water for farming and also generate energy for Tehran and its suburb (Iran Water Resource management organisation,2005).

Figure 1 illuminate study area in Iran.

DATA AND METHODOLOGY

1- Prepare Modis images

Used MODIS image has PDS format that is a row image .at first, by using IMMAP Software its format convert to HDF and made L1A image. Thereafter, by using orbital parameters, the image corrected geometrically and radiometrically and L1B image prepared. For these corrections, ScanMagic software used. L1B images are necessary for NDSI index.

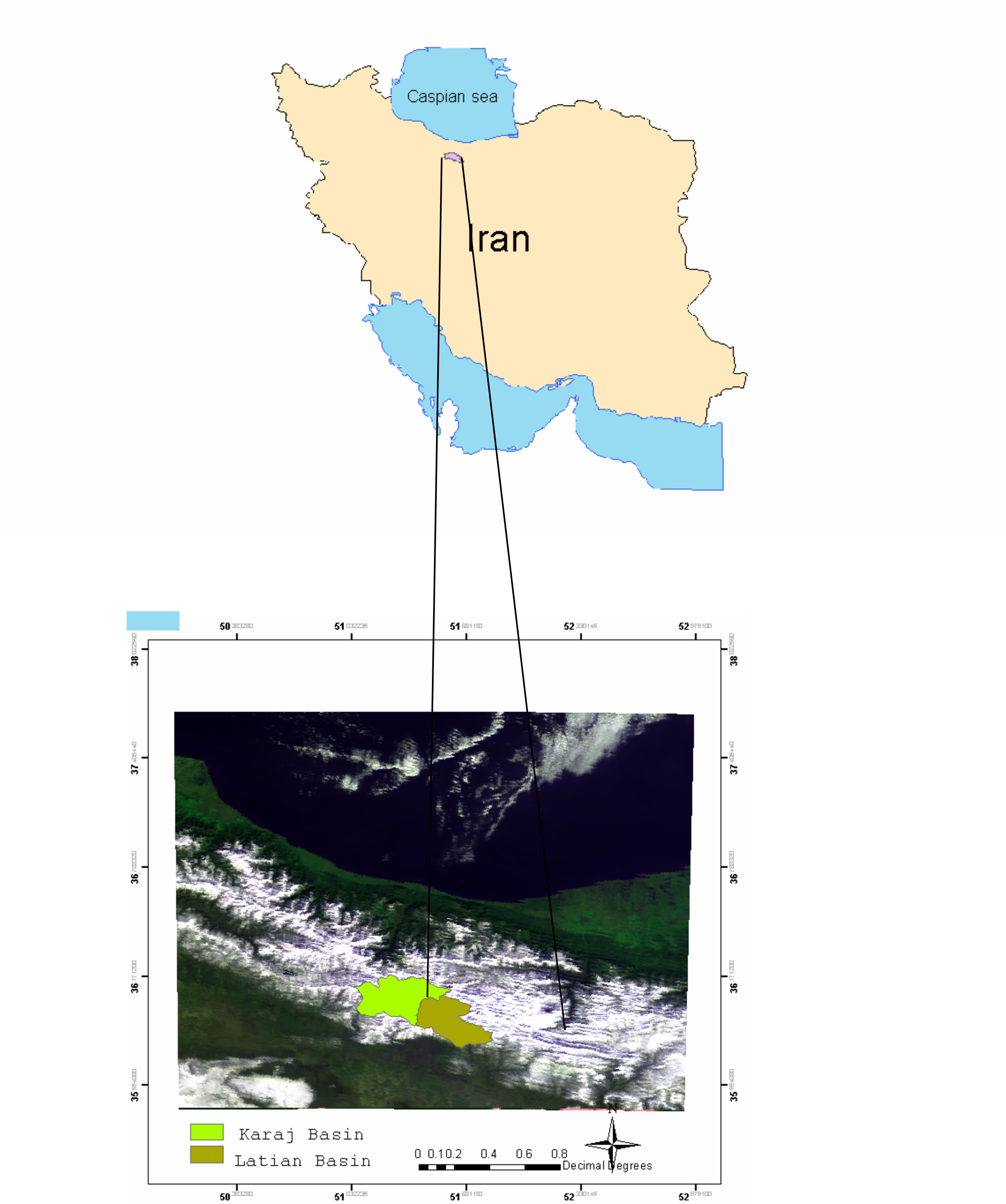


Figure 1. Situation of Karaj and Latian Basins in Iran.

2- NDSI index

For NDSI index, Reflectance bands are required. so at first, offset and gain coefficients used for obtain reflectance bands. Then PCI 's modelling used for determining thresholds according to the equations 1 and 2. Figure 2 shows the result of these equations.

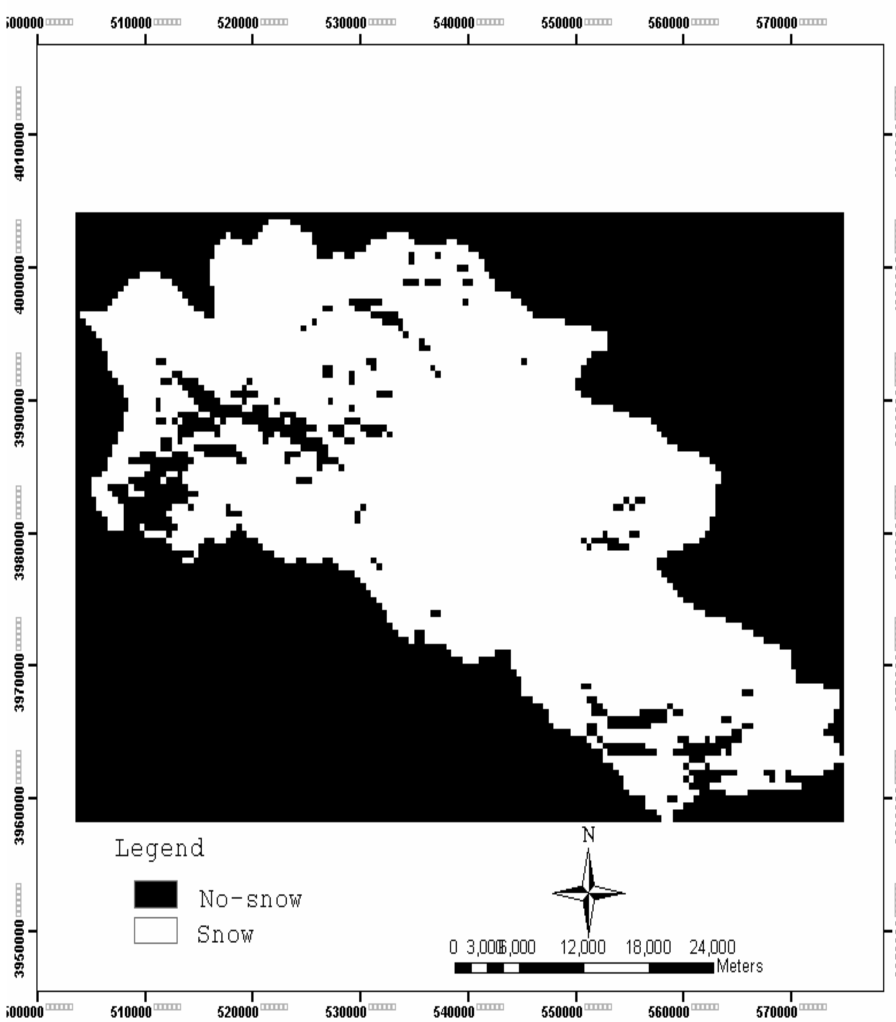


Figure 2. Snow cover for NDSI= 0.4.

For evaluation this snow cover, 100 sample in MODIS and IRS-P6 images- that are for the same time- selected and according to simple accidental method, Error Matrix generated (Table 1). For this manner,100 pixels selected accidentally in Snow subpixel image and compared to IRS-P6. In this table, earth data are in columns and subpixel data are in the rows.

Table 1. Error Matrix for NDSI = 0.4.

	Snow	No-snow	total
Snow	59	24	83
No-snow	4	14	17
total	62	38	100

The accuracy of this map, according to Overall accuracy method is 73%. This accuracy shows that NDSI > 0.4 is not suitable enough for snow cover studying in the regional scale so in this research, tried for best threshold determination.

For this reason, at the first stage, the image corrected atmospherically. Atmospheric effect is not equal in different bands, so in this research, atmospheric correction used for Band 4and6 separately and Bulk correction method applied. This method can decrease atmospheric effects relatively. The basis of Bulk Correction method is pixels that their amount must be zero or near zero (Fatemi, Rezaii, 2003). For this reason, by using the hillshade model of study area, pixels that are in high shadow, determined. In these pixels minimum reflectances are 555 and 3785 for band 4 and 6. By subtraction these amount from band 4 and 6, new NDSI map and its Error Matrix generated (Table 2).

Table 2. Error Matrix for NDSI = 0.4 after atmospheric correction.

	Snow	No-snow	total
Snow	58	14	72
No-snow	2	26	28
total	60	40	100

The accuracy for this map is 83% so accuracy increased 11%. According to Table 2, in spite of atmospheric correction, there are high numbers of no-snow pixels. For this reason, other thresholds evaluated and best threshold determined (Tables 3–7).

Table 3. Error Matrix for NDSI = 0.41.

	Snow	No-snow	Total
Snow	60	10	70
No-snow	3	27	30
Total	63	37	100

Table 4. Error Matrix for NDSI = 0.43.

	Snow	No-snow	Total
Snow	58	9	67
No-snow	2	31	33
Total	60	40	100

Table 5. Error Matrix for NDSI = 0.45.

	Snow	No-snow	Total
Snow	60	7	67
No-snow	1	32	33
Total	61	39	100

Table 6. Error Matrix for NDSI = 0.47.

	Snow	No-snow	Total
Snow	59	8	67
No-snow	4	29	33
Total	63	37	100

Table 7. Error Matrix for NDSI>=0.47.

	Snow	No-snow	Total
Snow	58	6	64
No-snow	8	28	36
Total	64	34	100

In these tables, the accuracies are respectively 86%, 87%, 92%, 89% and 87%. As it can see, the accuracy increases to 92% and decrease again. So NDSI > 0.45 has produced the most accurate snow map that Figure 3 illuminates it.

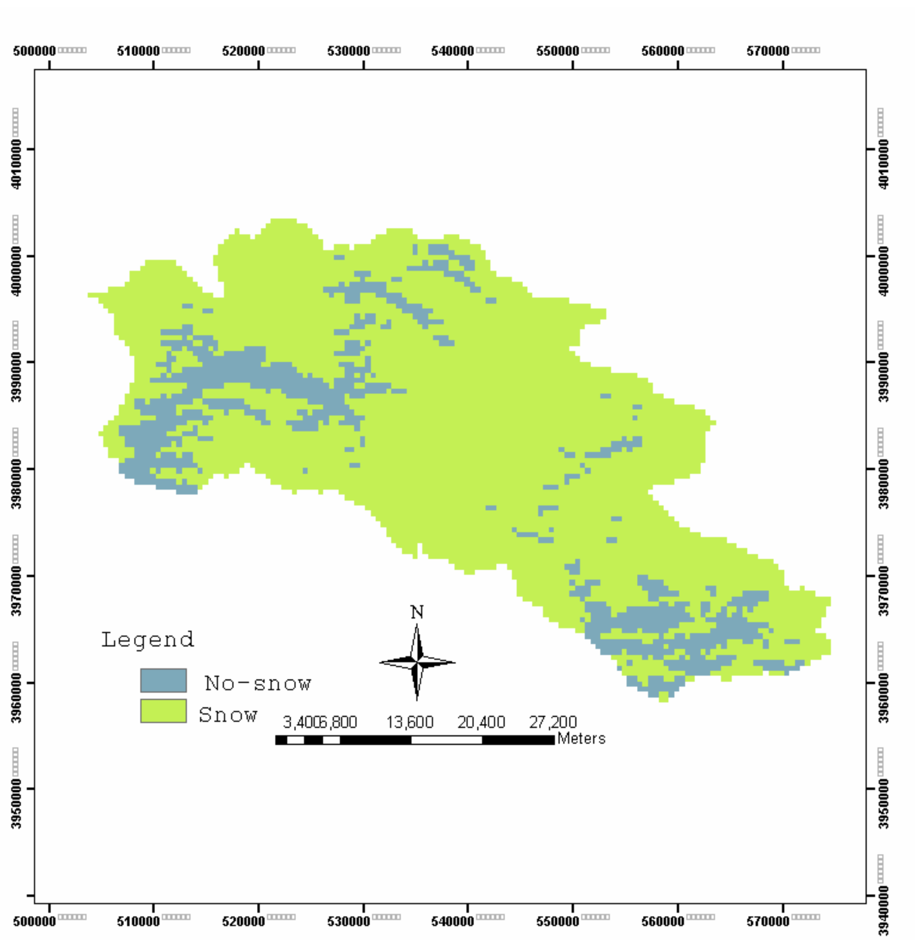


Figure 3. Snow cover map using 0.45 threshold.

3- Subpixel technique

For subpixel method, linear spectral unmixing used as following steps:

Select suitable bands

Bands 1 to 7 and 20 to 23 has been determined for studying earth features (Hall et al, 2001) and because in the spectral unmixing methods, high number of bands are required, then none of them cancelled.

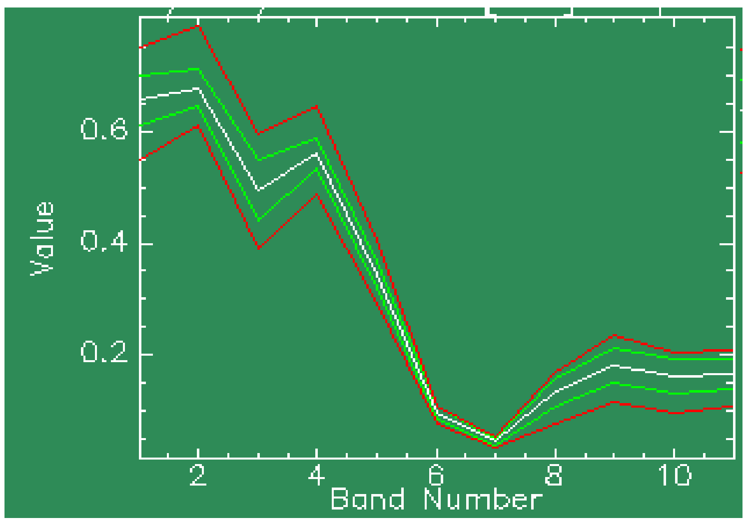
Before using these bands, reflectance and radiance bands generated by applying offset and gain coefficient.

Decrease noise using MNF algorithm

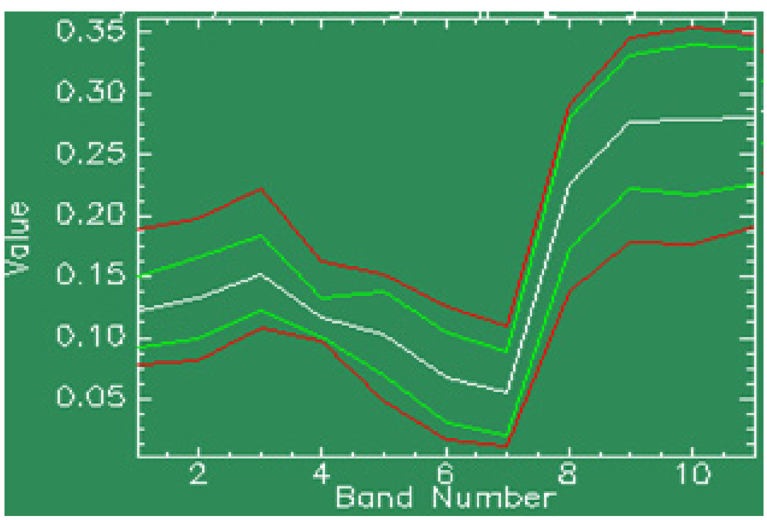
In this step, selected bands (1to 7 and 20 to 23) checked for find the noisy bands. In used image, bands 4,6,21 and 22 are too noisy, so MNF algorithm used for decrease stripping.

EM determination

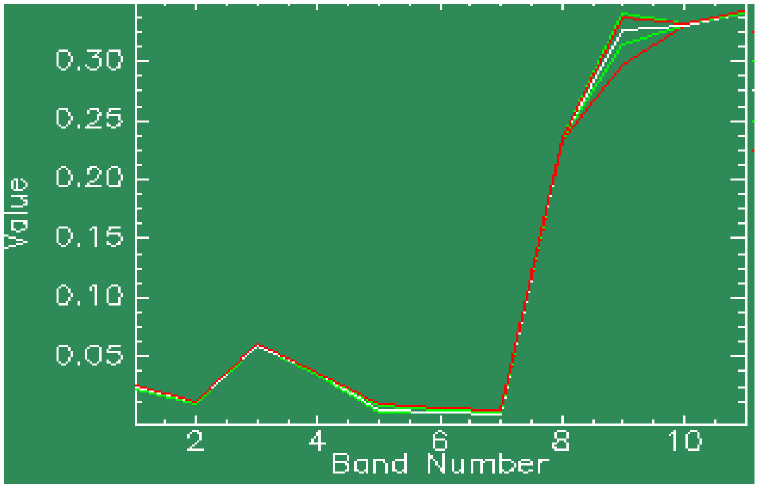
For Em determination, IRS-P6 used to find the situation of pure pixels in MODIS image more accurately and at the end, snow, no-snow and water pure pixels assigned and their spectral curve determined in MODIS image. (Figure 4).



A



B



C

Figure 4. Spectral curves for pure pixels. (A) For snow pure pixels; (B) for no-snow pure pixels; (C) for water pure pixels.

In these spectral curves, horizontal axis refers to bands 1 to 7 and 20 to 23 of Modis image. It is noticeable that there is not other features- like vegetation- in used image and area covered by snow. Water pure pixels determined according to dams water and no-snow pixels shows cliffs.

For each EM, there are 5 spectral curves. Middle spectral shows average features spectral that used for create spectral library (Figure 5).

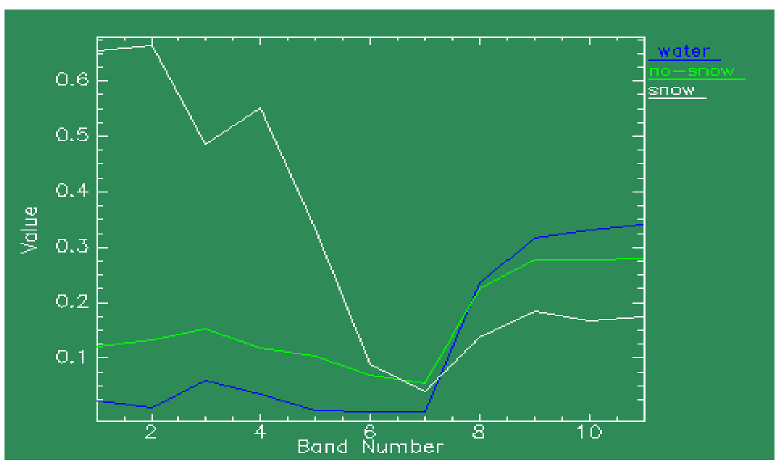


Figure 5. Spectral library for snow, no-snow and water features.

After create spectral library for MODIS 11 Bands image, linear spectral unmixing used but its accuracy was not suitable. For evaluate this result, IRS-P6 used as an earth truth and distinct that this algorithm couldn't determine the snow areas in shadow. For this reason, hillshade model of study area extracted .According to hillshade model, shadow's area determined and new snow EM identified according to sunlit and shadows snow area and new spectral library created. At the end, according to this new spectral library, linear spectral unmixing used and subpixel images generated. Figure 6 shows a snow subpixel map. In this image, pixels value varies between 0 to 1 ,that shows the amount of snow from 0 to 100%. Figure 7 illuminate the classified subpixel image for study area.

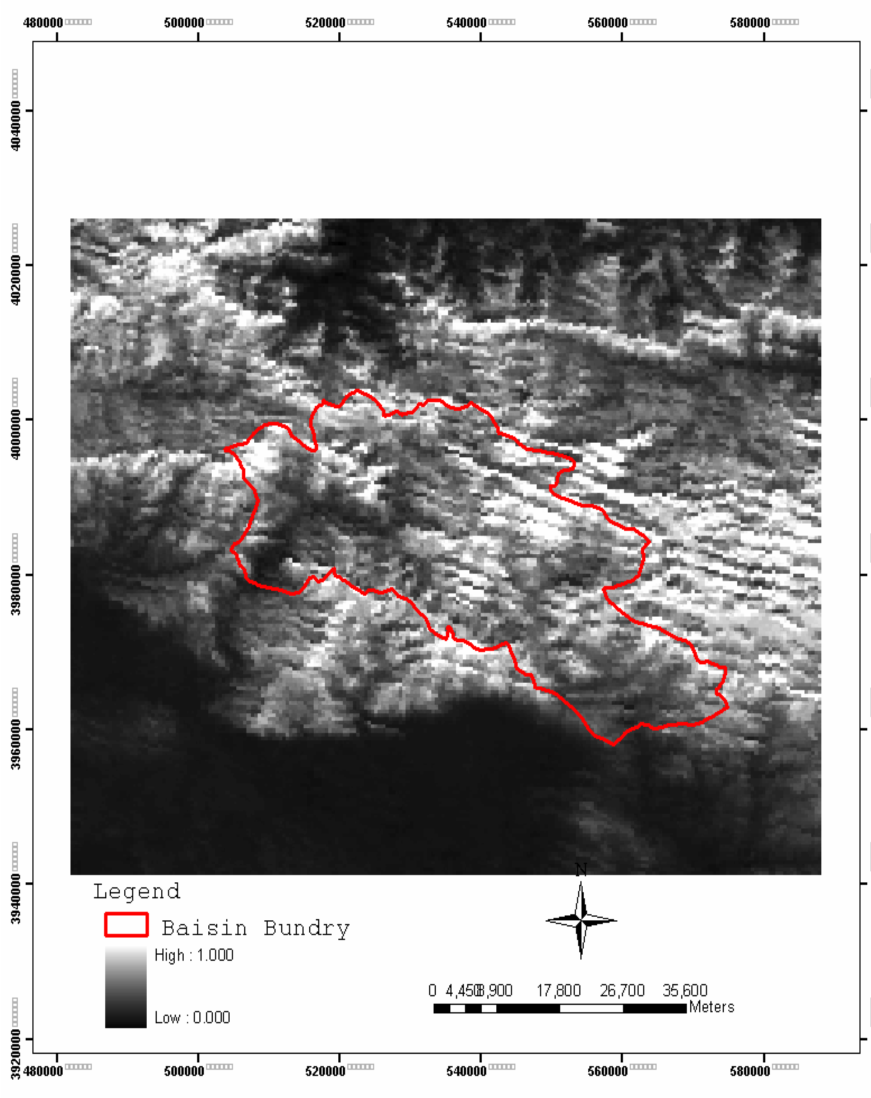


Figure 6. Snow subpixel image.

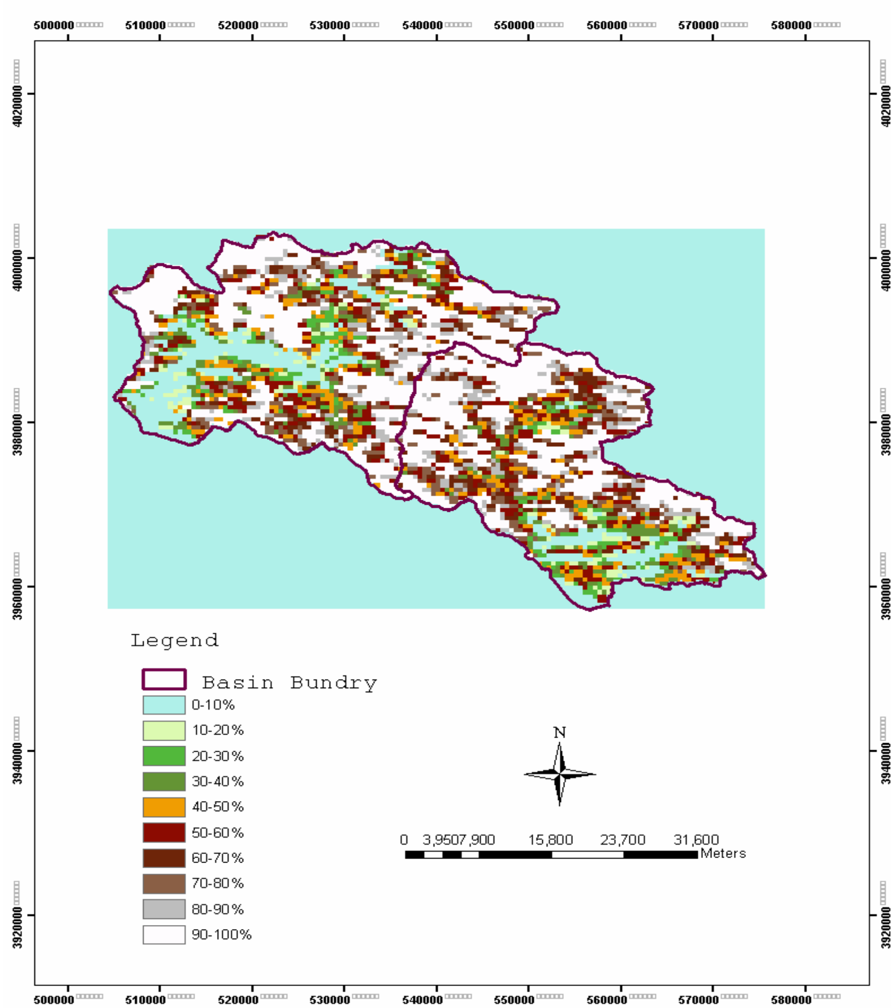


Figure 7. Classified snow subpixel image.

For evaluation the snow subpixel image, IRS-P6 used. This image is synchronized to MODIS image and used as an earth truth data. For sampling method, like evaluation NDSI map, simple accidental method utilized. Threshold equal to 50% determined for evaluation, because there is no labelling in subpixel images. In this image, pixels that contain 50% or more snow, defined as a snow pixel and pixels contain less than 50%, specified as a no-snow pixel. According to compare these new classified image and IRS-P6 image, Error Matrix formed (Table 8).

Table 8. Error Matrix for snow subpixel image.

	>50% snow	<50% snow	Total
>50% snow	56	7	63
<50% snow	7	30	37
Total	63	37	100

After that, according to Overall Accuracy method, accuracy obtained 86% .

RESULTS AND DISCUSSION

In this research, pixelbase and subpixel methods compared to select the suitable method for snow cover extraction in Karaj and Latian basins. Each of these methods has some advantages and disadvantages.

NDSI Index has defined as an automatic method that is necessary for daily snow cover determination. On the other hand, this index uses only two bands so its variable parameters are low. These are the advantages of NDSI but the noticeable point is the selecting correct threshold for NDSI. In this research, also the importance of atmospheric correction specified. In addition, the correct threshold determined for an image on November month but this threshold can be detrmined for different monthes during melting season.

The next method was pixelbase. Generally the accuracy of subpixel technique is depends on bands quality and also the kind of EM determination. Just in the desired situation, high accuracy maps can be generated.

Despite this sensitivity, one of the most advantages of subpixel method is ability to determine snow cover in pixels contain less than 50% snow cover that this is not possible in NDSI as a pixelbase method. Then, subpixel method is suitable for snow cover detection specially in bordering pixels and area with sparse snow cover.

In subpixel method, high number of bands specified much better spectral curves (Matkan et al, 2007). So in this research all proposed bands for earth surface studying used but some of them had striping that causes undesired effect on results. So for decrease these effects, MNF algorithm used and decrease it to 86%.

By comparing these 2 methods, specified that NDSI after correct threshold determination can be useful method for snow cover detection in Karaj and Latian basins although it is a pixelbase method. In this research, results shows ndsi >0.45 after atmospheric correction has better result than subpixel method. This is because of subpixel method's dependence to lot of parameters like correct Em determination. As it seen, using hillshade models for determining shadows area, for EM detection, can improve the accuracy but at the end the NDSI accuracy was better for the study area.

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