Change Detection of Snow and its impact on NDVI and Land surface Temperature, using landsat 8 imagery on Takhar Province of Afghanistan

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Abstract: In this paper, we investigated on a seasonal snow change and its impact on normalized-deference vegetation index (NDVI) and land surface temperature (LST), by using Landsat 8 imagery from January to October 2016, in Takhar province of Afghanistan. The result showed that the snow melting can increase NDVI which have effects on LST. For accuracy assessment of the study, we used 8000 random samples to see the linear correlation between those parameters that could affect each other. The validation result showed R-square values of .668 and .833 of the predictors (snow and NDVI) for independent variable (LST).

Keywords: (Snow change detection, NDVI and Surface Temperature (LST), Takhar, Afghanistan)

1. Introduction

In recent years, GIS and remote sensing applications are becoming very interesting tools in research areas for the purpose of earth's surface study, land use management, and study of environmental changes. Afghanistan is a landlocked country which is located in the central and south Asia. Mostly, the natural water resources for an agricultural purpose are supporting by the seasonal snow melting during the spring season. Therefore, snow is a very important parameter for life-saving in Afghanistan. The snow falling period usually starts from September continues to late January on some provinces. During spring and summer seasons snow melting process is one of the major sources of surface runoff and water balance for either cultivation or drinking water. Meanwhile, the permanent snow covers play a key role on land surface temperatures (LST) and normal deference vegetation index (NDVI) changes. Example, a strong relationship between landcover indices such as NDVI and LST exist [1]. Accurate representation of snow based on numerical models is a potential way not only to understand local climate but also to facilitate seasonal prediction [2]. But, aerial snow mapping and change detection could also be a vital source of information for landuse and water management projects. The overall goal of this study is to analyze the snow coverage changes and see its impact and relationship with surface temperature and normal vegetation index (NDVI). Because loss of snow cover due to changes of temperature result in water shortages and agricultural impacts on the study area. When the temperature increase more precipitation will fall as rain, not snow, therefore, that could affect earlier snowmelt in the spring. Because of the high runoff (melted snow) through early spring when it's not needed will not help in summer when it is needed. We should not ignore the early snowmelt and reduced late summer stream flows affect aquifer recharge for underground water supplies. The method we used for snow extraction is the Landsat 8 reflectance bands which are band- 3 visible green and band-6 near-infrared. The normal difference snow index

(NDSI) can be analyzed by using equation NDSI = GREEN-NIR/GREEN+NIR reflectance bands.

And the NDVI and LST also have their own formula which has been described in equations number 2 and 3.

2. Study area and data collection

The climate of Afghanistan is uniformly classified as arid to semiarid, meaning it gets insufficient rainfall for sustaining much any plant life. The study area is located at the Paropamisus xeric woodlands (Deserts and xeric shrublands) and Hindu Kush/Karakoram alpine meadows (Montane grasslands) zones. But in terms of geology, it has a very complex geological formation which is mostly covered by stratified formation and intrusive rocks. Such as, Sandstone, siltstone, clay, conglomerate, coal (North Afghanistan); limestone, marl, sandstone, shale, siltstone (Middle Afghanistan); sandstone, shale, siltstone, and acid volcanic rocks in different geological time scales. The important characteristics of the area are landcover type which can be easily affected by snow melting. Different landcover types are present that are: Rangeland (NHS), Barren and Rangeland (BRS/NHS), Forest and Shrubs (NFS), and Irrigated agricultural lands (AGI), respectively (Table 1). The study area is 1290.15 square kilometers which are located in the Landsat 8 path 152 and row 35. The Universal Transverse Mercator (UTM) projection (within Zone 42North) and the World Geodetic System (WGS)—1984 datum were applied to the images. The pixel sizes of the images were 30 × 30 m. For the purpose of the snow change detection, a period of 10 months (January to October) 2016 data were downloaded from the official website of the USGS, using Earth Explorer.

Table 1. Landcover types and their areas in S/km

Landcover Type	*Area(Sqkm)*	*Landcover Type*	*Area(Sqkm)*
AGI	29.61	BRS	57.28
AGR	153.11	BSD	0.00
AGT	5.72	NFS	120.31
AGV	0.00	NHS	867.45
URB	2.83	SNW	3.14
WAT	15.91	Total(sqkm)	1255.00

3. Snow Cover, NDVI and LST Mapping

There is no any regular base mapping of snow cover in Afghanistan to use its reliability for the regional water resource management and strategies. Therefore, it can be easily mapped and tracked by a disintegration of Landsat 8 bands and wavelengths of reflectance. Recently, remote sensing and aerial study of earth's surface has become one of the major research interest in every field, especially, in terms of time series change detection. Snow change detection analysis or tracking is one of the hardest work when it comes to the meaning of field investigation, with respect to the large area affected. But, fortunately, areal analysis and tracking of the snow cover by the remote sensing analysis made the process very suitable for researchers. An especial attention has been made to the time series of seasonal snow melting analysis in this work because of the important role of the seasonal snow melting has played to the surface runoff modeling and prediction for agriculture and drinking water purposes during the spring and summer seasons in Afghanistan. Therefore, we used the Landsat 8 snow mapping method, as it is defined and described by a lot of researchers and NASA itself as following: Normalized-difference Snow Index (NDSI) - normalized difference of two bands (one in the visible and one in the near-infrared or short-wave infrared parts of the spectrum) is used to map snow (Equation 1). Snow is highly reflective in the visible part of the EM spectrum and highly absorptive in the near-infrared or short-wave infrared part of the spectrum, whereas same parts of the spectrum, allowing good separation of most clouds and snow [3]. The two others, NDVI and LST have their own procedures and equations as following (2, 3):

$$\text{Normalized - difference snow index}\left(\text{NDSI}\right)=\frac{\text{GREEN - NIR}}{\text{GREEN + NIR}} \quad (1)$$

$$\text{Normalized - difference vegetation index}\left(\text{NDVI}\right)=\frac{\text{NIR - R}}{\text{NIR + R}} \quad (2)$$

$$\text{LST}=\frac{\text{BT}}{1+\text{W}*(\text{BT}/\text{P})*\text{Ln(e)})} \quad (3)$$

Which in, BT is Sat-temperature; W is DN; P is a constant value (P = 14380) for both TM and OLI series; e is land surface emissivity comes from below equation:

LSE = 0.004 *Pv + 0.986 (4)

Pv is a proportional vegetation index as following:

$$\text{Pv}=\left(\text{NDVI}-\text{NDVI mine}/\text{NDVI max}-\text{NDVI min}\right)^2 \quad (5)$$

Data source: Landsat 8 manual and USGS.

4. Result

In order to see snow cover changes over a period of 10 months in 2016, start from 8 January to 17 October, we used to extract the changes in square kilometers. Principally, from the early January snow started to get melt until October, but after that time, it seems to increase again because of the arrival of the fall season in Afghanistan. As we can see Figure.1, snow cover has significantly decreased during January, from 613squar kilometers to 271 square kilometers. Later on, continuously decreased through the mentioned period until first October. NDVI has an indirect relationship with snow cover. Melting snow had contributed to denser NDVI. On 8 January the NDVI area showed an increase of 270 square kilometers and then decreased 168 square kilometers, again. But, continuously from April to 15 of May was quite stable and the end of May had little more decreasing (Figure.2). It has a significant change on mid-July increased and the end of July a highest decrease can be seen. Finally, October first is the densest NDVI which is showed a slow motion decreasing after because of the fall season begin in Afghanistan, the harvesting time. The surface temperature has an indirect relationship with NDVI, and direct with snow cover, for example on January 24th due to a decrease of snow cover and increase of NDVI resulted in the high surface temperature in the study area (Figure.3). But, this relationship is not correct always because in our study area on July 16th when less snow cover resulted dense NDVI then showed less surface temperature. There will be many environmental reasons for this matter. Especially, in Afghanistan for this study area, most of the agricultural area lost their green color of every plant and that is the time of harvesting the plants. To conclude, we can see a relationship between Snow cover, NDVI and surface temperature. This result cannot be a good scientific result which does a concise prediction on environmental changes but can serve as a clue to the surface landcover change detection and management on water resources.

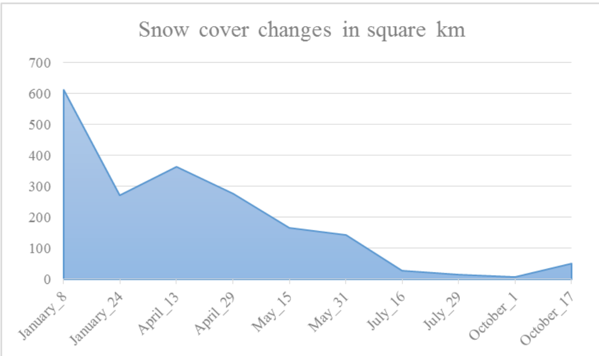

Figure 1. Snow cover changes per-months in 2016

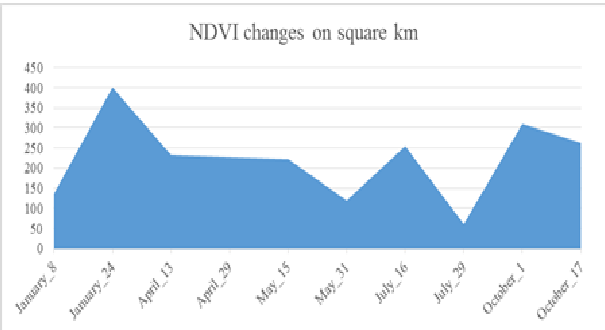

Figure 2. NDVI changes per-months in 2016

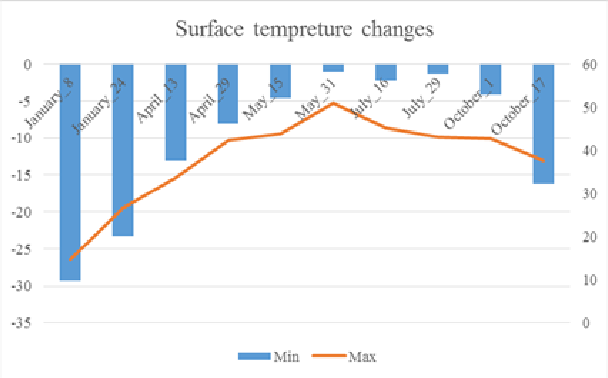

Figure 3. Surface temperature changes per-months in 2016

3. Validation

In order to see the model accuracy and changes have found by this study between snow cover, NDVI, and LST, we performed a linear regression modeling by using 8000 random sample points in the study area. For this purpose, we analyzed April and May as an example. The correlation between parameters was quite acceptable as it showed the R-squares values of .833 and .668, with standard errors of 4-5 and Sig.F changes of 0.000(Table.2). It means the predictors of snow cover and NDVI are correlated linearly and statistically significant to the model and LST.

Table 2. Model summary[b]

Date	R	Adjusted R/ Sq	Std.Error	Sig.F Change
13-Apr	.913a	0.833	4.02872	0.000
15-May	.817[a]	.668	5.3088466	0.000

a. Predictors: (Constant), NDVI, SNOW

b. Dependent Variable: LST

4. Discussion and Conclusion

A consolidated knowledge about the snow cover melting process can play a key role in environmental changes study and water supply strategies in Afghanistan. The highest amount of surface runoff resulted because of snow melting during January to April. Therefore, there will be more chance to keep the water in the reservoirs and use in water shortages time at fall season in Afghanistan. Unfortunately, recently, due to the environmental changes most of the snow cover melt early than expected time and then the agricultural lands face to the luck of water. The significant melt of snow in early spring results in the dense vegetation that contributes to a low surface temperature. The highest surface temperature at the end of May showed the low vegetation and less snow cover areas. That could facilitate for a warm weather which is lead to snow precipitation as rain. The predictors NDVI and snow with R-square of .833 and .668 revealed the linear correlation between them. The result could serve as a specification of snow melting rate and understand the water shortages and planning for the water balance in the future, but not as a concise scientific research for any specific development projects.

Acknowledgement

We highly acknowledge the support of JICA peace program for human resource development of Afghanistan and contribution of the University of the Ryukyus for this study.

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