Utilizing Landsat, Sentinel Image to Estimate Snow Cover Duration in Gara Mountain

Dr. Dilovan Ramadhan Ismail
University of Duhok, college of humanities science, geography dept,
Dilovan.ismail@uod.ac

Karwan Ahmed Bakir
University of Duhok, college of humanities science, geography dept,
karwan.ahmed@uod.ac

استخدام لاندسات، صورة رصد لتقدير مدة الغطاء الثلجي في جبل كاره

د. دلوڤان رمضان اسماعيل
Dilovan.ismail@uod.ac
كاروان احمد بكر
karwan.ahmed@uod.ac
جامعة دهوك، كلية العلوم الإنسانية، قسم الجغرافيا

Abstract

The study area is considered a mountainous environment with climatic characteristics that suit the nature of this study. It is located in the northern part of the Kurdistan Region of Iraq, and it is part of a complex mountainous region according to the physiographic division of the surface of Iraq. On the other hand, it's one of the most significant in terms of snow cover region in winter and spring season. No study has been done on this subject in the study area. In this study, Landsat data and geographic information system (GIS) techniques were used to analyze the duration of snow cover. After apply these technologies, snow cover duration maps (SCDM) for the duration (1989 – 1990) and (2022 – 2023) were extracted and analyzed. The maps show how long snow remains in each cell during these periods. This study suggested that there is an effect of terrain on snow cover duration, and this is due to the increase in air temperature.

***Keyword**: snow cover duration (SCD), Normalized Difference Snow Index, Gare Mountain, remote sensing, geographic information system.*

.

المستخلص

تعد منطقة الدراسة بيئة جبلية ذات خصائص مناخية تناسب طبيعة الدراسة، كونها من المناطق التي تبقى فيها الثلوج حتى أواخر فصل الربيع. وتم اختيار جبل كارة كمنطقة الدراسة لتوفر الخصائص المناخية والموقعية المناسبة. وتقع المنطقة ضمن الجزء الشمالي من اقليم كوردستان العراق، وهي جزء من النطاق الجبلي المعقد حسب التقسيم الفيزيوغرافي لسطح العراق. فضلا عن عدم وجود دراسة مشابهة عن المنطقة، تم استخدام بيانات الاستشعار عن بعد وتقنيات نظم المعلومات الجغرافية للوصل الى اهداف الدراسة، وتبعا للنتائج والتي تشمل خرائط وجداول التي تمثل منطقة الدراسة للمدة **(1990 / 1989)** و **(2022 / 2023)**، وحساب الغطاء الثلجي لكل خليلة من خلايا الصور، وتبينت ان مدة بقاء الثلج تتباين بتباين الارتفاع عن مستوى سطح البحر، اذ تقل مدة بقائها في المناطق المنخفضة بسبب زيادة درجات الحرارة والعكس صحيح بالنسبة للمناطق التي تزداد ارتفاعها عن مستوى سطح البحر.

<u>كلمات الدالة</u>: خريطة مدة غطاء الثلجي، مؤشر اختلاف الثلجي، جبل كاره، الاستشعار عن بعد، نظم المعلومات الجغرافية

Introduction:

Snow cover is a globally Important climate-forcing (Hansen and Nazarenko, 2004) due to it influencing the partitioning of the surface radiation, energy, and hydrologic budgets. One of the most important sources of fresh water worldwide is melting snow, which is used by up to two billion people (Mankin et al., 2015). Snow cover areas have decreased, and dramatic shifts in water availability are projected over the next fifteen years because of climate (Dery and Brown 2007; Vaughan et al. 2013; Wegmann et al., 2017). Low-snow areas resulting from the melting process tend to increase regional warming (Armstrong and Brun, 2008; Vaughan, et al., 2013). Thus, this causes the major impacts on humans and the natural environment.

Recently, a huge of satellite imagery has been used to observe and obtain snow data such as snow cover mapping and snow water corresponding to snowmelt runoff expectation in real-time (e.g., Kaufmann et al., 2002; Poon and Valeo, 2006; Cea et al., 2007; Chokmani et al., 2010; Dobreva and Klein, 2011; Gascoin et al., 2019 among others). Brander et al. (2000) extract snow cover duration maps using a limited number of Landsat-TM imagery. Cea and Pons (2007) applied two methods to derived snow cover using Landsat-7 ETM+ and Landsat-5 TM images, and (MOD10A1) to acquire daily Snow Cover, between 2002 and 2005. Both methodologies emanate from an NDSI threshold > 0.4. 14. (Iliyana Dancheva (2011) stated that the applicability of Artificial Neural Networks (ANN) to obtain snow-cover maps by testing Landsat Enhanced Thematic Mapper Plus (ETM+) scenes within North America highly recommended differentiating between land covers in which it is assumed a typical of the snow-

covered portions of the Northern Hemisphere. (Gascoin et al, (2019) assemble an algorithm to extract snow cover maps in Theia, using Sentinel-2 at 20m resolution and Landsat-8 at 30m resolution.

The aims of this research: (1) extract snow cover duration map (SCDM) for two seasons (1989/1990) and (2022/2023). (2) Analysis of the effect of elevation and aspect on duration of snow cover in the study region.

Methodology

Data

Satellite data

Landsat, and Sentinel-2 images were used in this study to monitor the duration of snow cover in Gare Mountain chain. These data are summarized in table 1.

Properties	Satellite Image	
	Landsat	Sentinel
Sensor	Operational land imagery (OLI) Thematic mapper (TM)	Sentinel 2
Temporal resolution	2 image per month from October 1,1989 to May 30, 1990 and from October 1,2022 to May 30,2023	
Spatial resolution	30m	10 & 20m
Time acquisition	1989 – 1990 and 2022 - 2023	

Table 1: Data information used to study the duration of snow cover in the study area

Study area

The Gare Mountain is located in the northern part in Dohuk governorate of the Iraqi Kurdistan region, stretching from 43̊ 23́ 62́ E to 43˚ 81´ 85˝ E and from 36˚ 88´ 27˝ N to 37˚ 05´ 36˝ N. Gare Mountain has an elevation of more than 1500m. This region receives tremendous precipitation in winter. Generally, in the form of snow which makes the Gare Mountain chain one of the most significant winter snow cover regions in Iraq see figure (1).

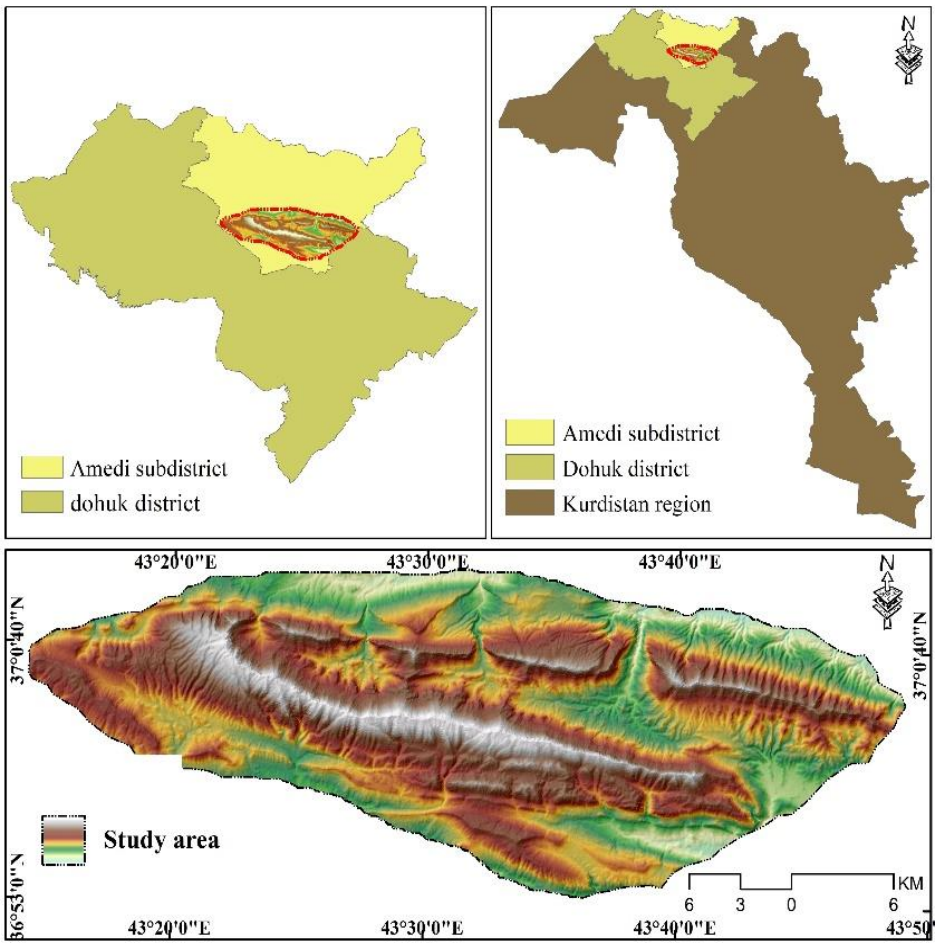


Figure 1: Study area map

Method

The snow cover area has been extracted from the Normalized Difference Snow Index (NDSI). Snow cover normally reflects high electromagnetic radiation in a red band with a scarce reflectance in the shortwave infrared part of the spectrum. To extract the NDSI model, Landsat image band 2 is ranged between (0.53 – 0.61 µm) and band 5 (1.55 – 1.75µm). while, sentinel band 3 take the mean of band 2 from Landsat which is (0.56 µm) as well the mean of band 11 from the range of band 5 in Landsat is (1.61 µm) were used. The formula of extracting NDSI show as follow:

$NDSI_{(Landsat)} = (TM_{(band2)} + TM_{(band5)}) / (TM_{(band2)} - TM_{(band5)})$ ……. (1)

$NDSI_{(Landsat)} = (OLI_{(band3)} + OLI_{(band6)}) / (OLI_{(band3)} - OLI_{(band6)})$ ……. (2)

$NDSI_{(Sentinel)} = (band\ 3 + band\ 11) / (band\ 3 - band\ 11)$ ……. (3)

The NDSI nature is based on the fact that snow cover reflects most of the visible wavelengths which are very bright in the image and very dark in the shortwave infrared. NDSI model ranges from -1 to 1 with snow typically having an NDSI of above 0.4 which highlights snow-covered areas. This model makes remote sensing in the visual part of the electromagnetic spectrum very effective for the detection and mapping of snow cover (Hall et al., 2001).

Using ArcGIS software to convert NDSI raster to snow cover duration map by using two steps. Firstly, use the reclassify analysis tool to reclassify the NDSI raster. Secondly, apply the raster to the polygon tool to convert the raster to a vector and make it ready to calculate the process. The flowchart of the complete processing chain is given in figure2.

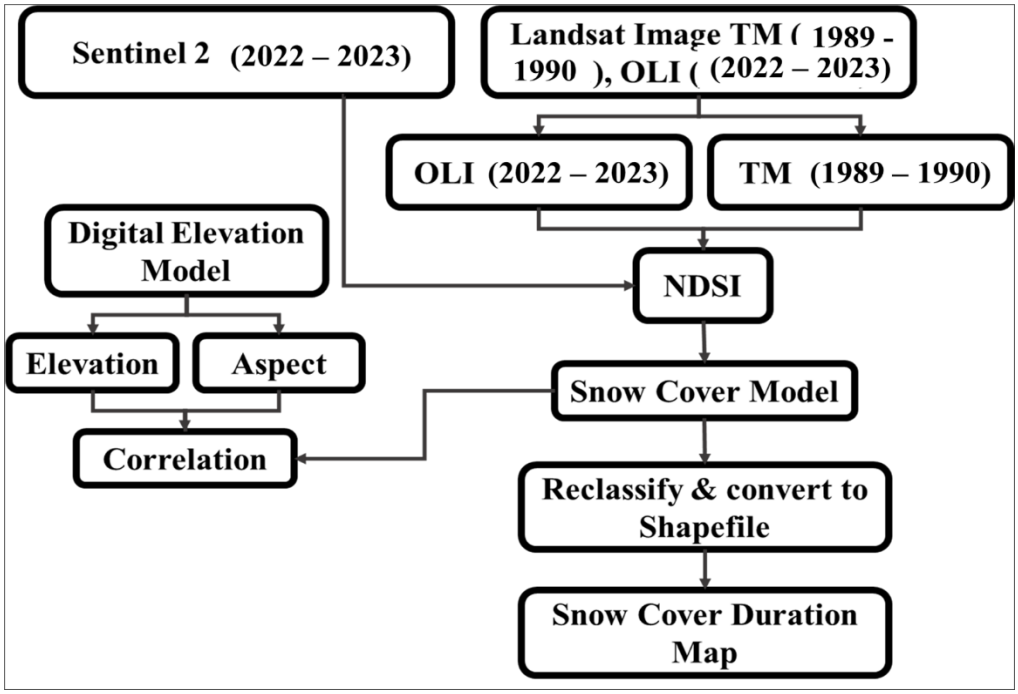


Figure 2: Flow chart of the data processing and snow cover duration map extraction

Result and discussion

Snow cover duration

The two sessions of snow cover duration from satellite images in Gara mountain indicate the variability of duration of the snow cover period (2 and 3). Those figures illustrates that the duration of snow cover decreases between the session (1989/1990) and (2022/ 2023), the maximum snow cover duration of more than (120) days found by (8.8) kilometers square which is taken place in winter season of 1989 - 1990, while the minimum snow cover duration was seen in winter 2022 - 2023.

As shown in the table (2), the majority of the study area is covered by snow for less than 20 days, while there are limited places covered by snow for more than 100 days for both seasons. It also

shows that the duration of snow cover is greater in the first season, whereas in the season (1989 - 1990) there is about 8.8 km^{2} of snow cover in the study area remaining for more than 120 days. While in the season (2022 - 2023), the duration and area of snow cover decreases compared to the first season. Therefore, in this season, except for 7.3 km^{2} of snow cover, it remains for more than 100 days.

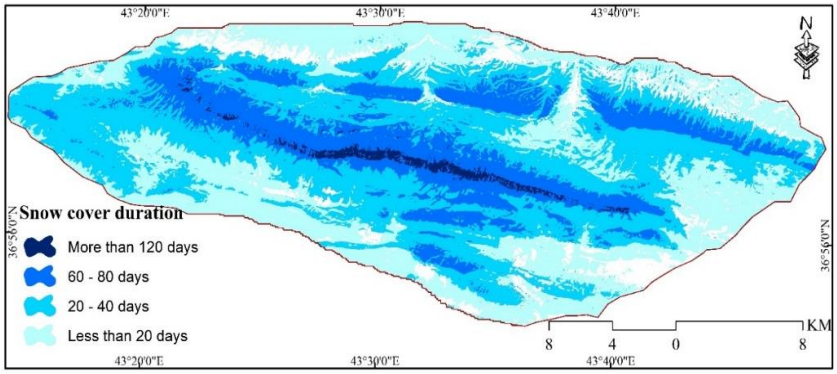


Figure 3: duration map of snow cover (1989 - 1990)

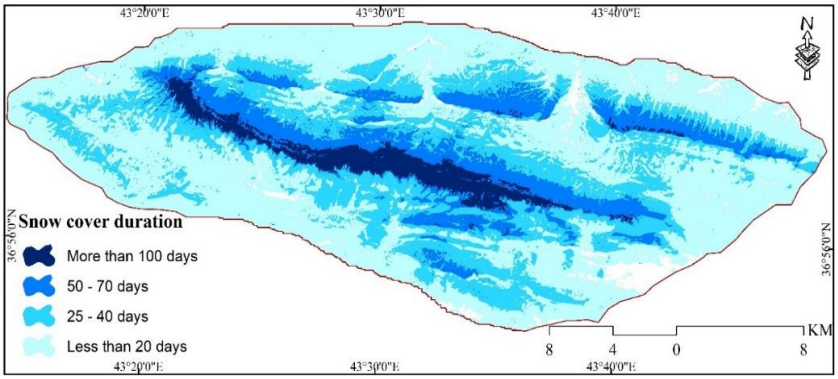


Figure 4: duration map of snow cover (2022 - 2023).

Snow cover duration (1989 - 1990)	Area (KM^2)	Snow cover duration (2022 - 2023)	Area (KM^2)
More than 120 days	8.8	More than 100 days	٧,٣
60 – 80 days	113.8	50 – 70 days	75.3
20 – 40 days	239.6	25 – 40 days	163.7
Less than 20 days	٣٥٠	Less than 20 days	304.5

Table 2: Area (KM^2) of snow cover duration

Relationship between SCD and Elevation

It is known that air temperatures drop by one degree whenever we rise 150 meters above sea level, this affects the duration of snow cover and its distribution between different altitudes. Therefore, the maximum snow cover duration was observed at high altitudes in the study area (Figure 4). Whereas, the duration of snow cover decreases in low-altitude areas. In other words, there is a positive relationship between snow cover and high altitude and vice versa (Figure 5, 6).

As can be observed from Figure (5), the higher of temperature degree the less snow cover duration. The duration period of snow increases to more than (120) days when the temperature is equal to (-24) C^0, especially in the high altitude of the study area. However, the snow duration period is reduced to less than 20 days when the temperature is equal to (7.8) Celsius degrees.

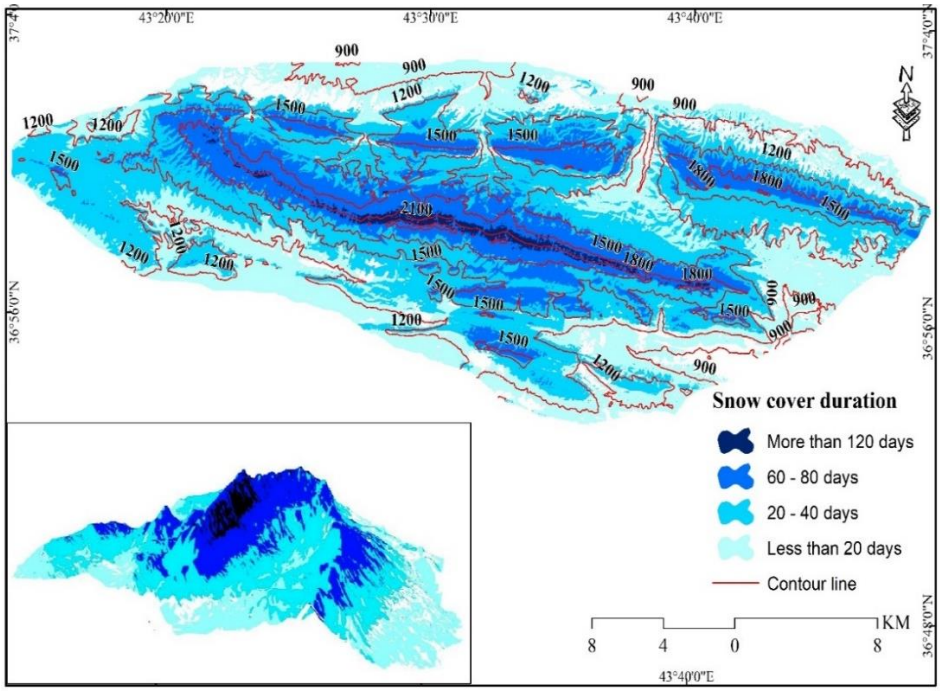


Figure 4: Duration of snow cover by the elevation

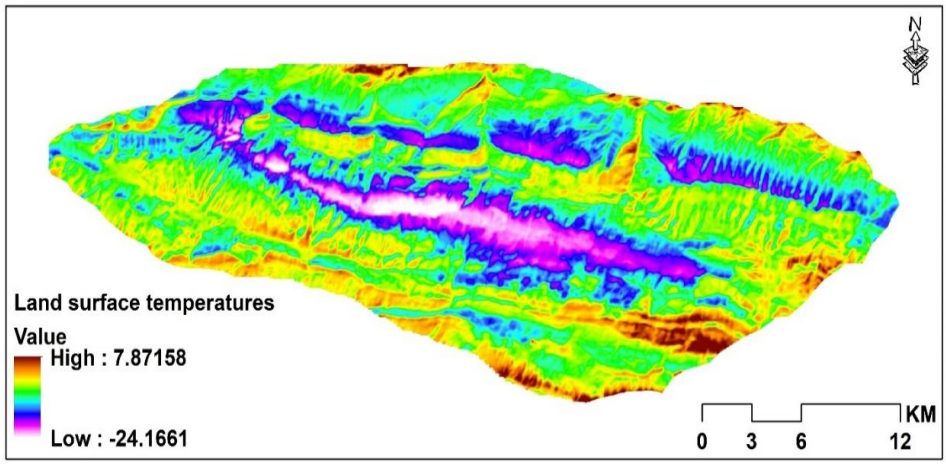


Figure 5: Land surface temperature model in the study region

Relationship between SCD and Aspect

The effect of slope direction on the duration of snow cover depends on the amount of solar radiation received. The southern directions receive a larger amount of solar radiation compared to the northern directions. As noticed in Figures (6 and 7), the maximum snow cover duration was detected in the northern direction of the slope. However, the minimum snow cover duration was found in the Southern direction of the slope in study area.

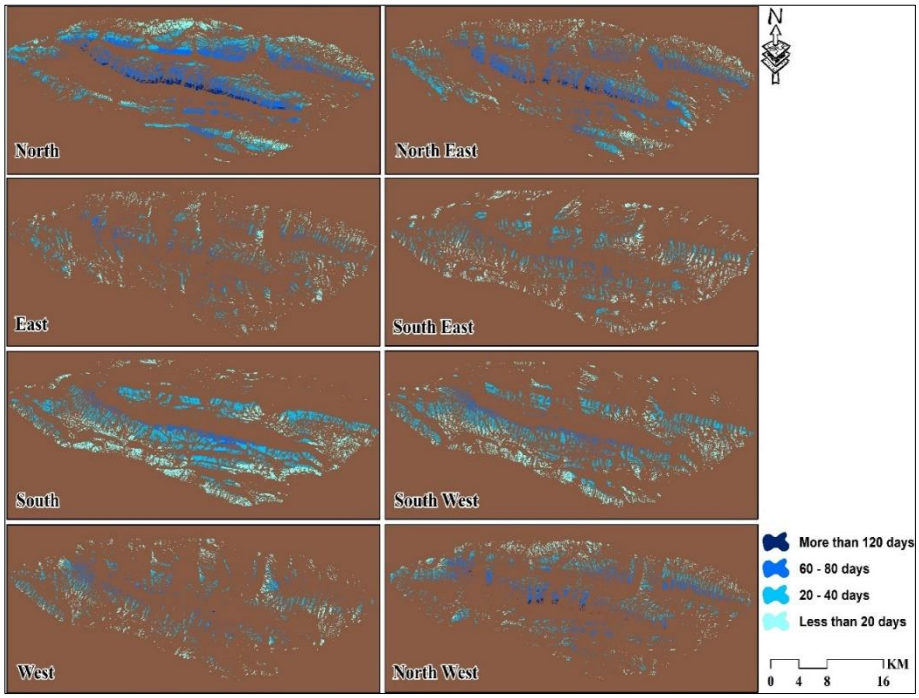
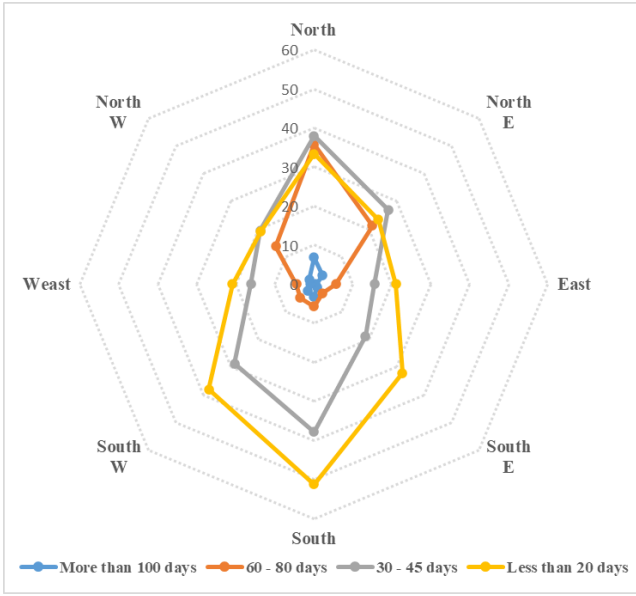


Figure 6: snow cover duration by direction of the slope



Figur 7: Snow cover duration depends on the direction of the slope

As shown in Table (3), the biggest area of the first and second snow cover durations is taking place in the north slope direction by more than (120) days and more than (100) days respectively. The first duration cover nearly (6) Km^2 out of (8.8) km^2. In contrast, the second duration area is (5.1) km2 of the total area of (7.3) km^2. Generally, the snow duration shorten in other slop directions from northern directions to others. For instance, no covered area by snow found in south direction in the first duration with small area (0.88) km^2 in the east direction during the second period.

Aspect	Snow cover duration 2000_2001				Snow cover duration 2019-2020			
	More than 120 days	60 -80 days	20-40 days	Less than 20 days	More than 100 days	50-70 days	25 -40 days	Less than 20 days
North	6	42	41.2	19.83	5.1	29.54	34.74	46.93
Northeast	١	24.7	28.7	15.9	1.2	17.64	25.33	30.92
East	0.04	6.27	18.32	16.54	0.2	5.04	12.86	25.45
Southeast	0	3.76	23.86	26.26	0.17	2.52	13.53	37.96
South	0	7.57	48.2	40.45	0.12	٣,٧٢	٢٧,٤	62
Southwest	0	7	36.35	29.26	0.15	2.97	٢١	٤٦,٩٤
West	٠	6	20	15.57	0.12	٢,٩٦	١٢,٣١	26.٢٣
northwest	0.٨	16.53	22.5	12	0.24	10.٨٧	١٦,٣٤	٢٦,٤٨
Total	7.8	113.83	239.13	175.81	7.3	75	164	303

Table 3: Duration of snow cover (areas / KM^2) by the slope directions

Conclusion

the Landsat and sentinel-2 data play an enormous role in determining spatiotemporal snow cover areas. Satellite data in combination with traditional ground observations and other remotely sensed data, such as NOAA, AVHRR, could be used for time series analysis of snow cover area.

The results of the study show that there is a significant change in the duration of snow cover between the two seasons (1989 - 1990, 2022 - 2023). The results also showed that the duration of the snow cover remained more than 120 days in the winter of 1989 - 1990. While, in Winter (2022 - 2023) the duration decreased to more than 100 days. In addition, there is a positive relationship between the duration of snow cover and high altitudes. Therefore, snow cover remains in a northern direction for a longer time compared to other directions.

Resource

1. Armstrong R.L. & Brun E. 2008. Snow and climate: physical processes, surface energy exchange and modeling. Cambridge University Press, Cambridge.
2. Brander, D., Seidel, K., Zurflüh, M., & Huggel, C. (2000, June). Snow cover duration maps in alpine regions from remote sensing data. In Proceedings of EARSeL-SIG-Workshop Land Ice and Snow, Dresden/FRG (pp. 292-296).
3. Cea, C., Cristóbal, J., & Pons, X. (2007, July). An improved methodology to map snow cover by means of Landsat and MODIS imagery. In *2007 IEEE International Geoscience and Remote Sensing Symposium* (pp. 4217-4220). IEEE.
4. Chokmani, K., Dever, K., Bernier, M., Gauthier, Y., & Paquet, L. M. (2010). Adaptation of the SNOWMAP algorithm for snow mapping over eastern Canada using Landsat-TM imagery. Hydrological Sciences Journal–Journal des Sciences Hydrologiques, 55(4), 649-660.
5. Cea, C., Cristóbal, J., & Pons, X. (2007, July). An improved methodology to map snow cover by means of Landsat and MODIS imagery. In 2007 IEEE International Geoscience and Remote Sensing Symposium (pp. 4217-4220). IEEE.
6. Déry, S. J., & Brown, R. D. (2007). Recent Northern Hemisphere snow cover extent trends and implications for the snow-albedo feedback. Geophysical Research Letters, 34(22).
7. Dobreva, I. D., & Klein, A. G. (2011). Fractional snow cover mapping through artificial neural network analysis of MODIS surface reflectance. Remote Sensing of Environment, 115(12), 3355-3366.
8. Dobreva, I. D., & Klein, A. G. (2011). Fractional snow cover mapping through artificial neural network analysis of MODIS surface reflectance. Remote Sensing of Environment, 115(12), 3355-3366.
9. Gascoin, S., Grizonnet, M., Bouchet, M., Salgues, G., & Hagolle, O. (2019). Theia Snow collection: high-resolution operational snow cover maps from Sentinel-2 and Landsat-8 data. Earth System Science Data, 11(2).
10. Gascoin, S., Grizonnet, M., Bouchet, M., Salgues, G., & Hagolle, O. (2019). Theia Snow collection: high-resolution operational snow cover maps from Sentinel-2 and Landsat-8 data. Earth System Science Data, 11(2).

11. Hall, D. K., Foster, J. L., Salomonson, V. V., Klein, A. G., & Chien, J. Y. L. (2001). Development of a technique to assess snow-cover mapping errors from space. IEEE Transactions on Geoscience and Remote Sensing, 39(2), 432-438.

12. Hansen, James, and Larissa Nazarenko. "Soot climate forcing via snow and ice albedos." *Proceedings of the national academy of sciences* 101.2 (2004): 423-428.

13. Kaufman, Y. J., Kleidman, R. G., Hall, D. K., Martins, J. V., & Barton, J. S. (2002). Remote sensing of subpixel snow cover using 0.66 and 2.1 μm channels. Geophysical Research Letters, 29(16), 28-1.

14. Noura Zayed Aati, Ahmad Majid Abbas, Eman Shihab Hassoun, Salam Saud Hussein, & Ruqaya M. Amin. (2024). Application of Geomatics Technology to Study the Snow Cover in Amadiya District Using Satellite Image (Landsat-8)". Kurdish Studies, 12(2), 2989–3002. Retrieved from https://kurdishstudies.net/menu-script/index.php/KS/article/view/2400

15. Mankin, J. S., Viviroli, D., Singh, D., Hoekstra, A. Y., & Diffenbaugh, N. S. (2015). The potential for snow to supply human water demand in the present and future. Environmental Research Letters, 10(11), 114016.

16. Poon, S. K., & Valeo, C. (2006). Investigation of the MODIS snow mapping algorithm during snowmelt in the northern boreal forest of Canada. Canadian Journal of Remote Sensing, 32(3), 254-267.

17. Vaughan D.G., Comiso J.C., Allison I., Carrasco J., Kaser G., Kwok R., Mote P., Murray T., Paul F., Ren J., Rignot E., Solomina O., Steffen K. & Zhang T. 2013. Observations: Cryosphere. In: Stocker T.F., Qin D., Plattner G.-K., Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V. & Midgley P.M. (eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 317–382.

18. Wegmann, M., Orsolini, Y., Dutra, E., Bulygina, O., Sterin, A., & Brönnimann, S. (2017). Eurasian snow depth in long-term climate reanalyses.

19. Ahmed Majed Abbas. (2023). Using spatial interpolation to detect change in the thermal and rainfall bands of the Jazeera region in Iraq: Using spatial interpolation to detect the change of the thermal and rainfall bands of the Jazeera region in Iraq. *Medad Al-Adab*, *13* (for the Department of Geography Conference 2023), 1185-1202.