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Snow cover analysis and snow water equivalent calculation in northern Iraq

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ABSTRACT

Snow cover refers to the amount of snow covering the ground, and includes concepts of depth, extent, area, and density. Snow cover is a major component of the global climate system through its role in regulating energy and moisture between the atmosphere and the Earth's surface. The amount of snow on Earth aids in controlling the energy exchange between the atmosphere and the surface. Regional weather patterns can be impacted by changes in snow cover on a smaller scale. The length of time that snow covers the ground has an impact on wildlife, fire risk, permafrost thawing, and the timing and volume of river runoff. These results were particularly evident in the exceptional years of heavy snowfall in 1992, 2008 and 2015, respectively, with 2008 having the largest proportion (about 44%). determining the degree of spatial and temporal variability of SC in northern Iraq between 1990 and 2022 was the goal of this study. The study revealed regional differences in the amount of Sc, with Duhok recording the highest percentage, obtaining 47% of the total percentage of SC area. Erbil governorate had the least SC of the northern cities of Iraq. Sulaymaniyah was in between Dohuk and Erbil with (35 %) of total area of snow cover. The ratio was calculated from particular area of SC divided in to total area of SC as presently ratio area. We notice that in the years (1998, 2008) there is a large difference in the SWE settled to the SWE new. We also notice that the year 2016 represented the highest value for new and stable snow, and the lowest values were in the years 1991 and 1994. 1999, 2010, 2011, 2018, 2020 and 2021. This is due to the nature of the region and weather factors such as temperature, Humidity and water vapor.

Keywords: Snow cover, Snow depth, Snow Water Equivalent, climate change.

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تحليل الغطاء الثلجي وحساب مكافئ مياه الثلج في شمال العراق

فرح حسيب جاسم
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المستخلص

يشير مصطلح الغطاء الثلجي إلى كمية الثلج التي تغطي الأرض، ويتضمن مفاهيم العمق والمدى والمساحة والكثافة. يعد الغطاء الثلجي مكونًا رئيسيًا لنظام المناخ العالمي من خلال دوره في تنظيم الطاقة والرطوبة بين الغلاف الجوي وسطح الأرض. تساعد كمية الثلج على الأرض في التحكم في تبادل الطاقة بين الغلاف الجوي والسطح. يمكن أن تتأثر أنماط الطقس الإقليمية بالتغيرات في الغطاء الثلجي على نطاق أصغر. يؤثر طول الوقت الذي يغطي فيه الثلج الأرض على الحياة البرية وخطر الحرائق وذوبان التربة الصقيعية وتوقيت وحجم جريان الأنهار. كانت هذه النتائج واضحة بشكل خاص في السنوات الاستثنائية من تساقط الثلوج الكثيفة في عام 1992 و 2008 و 2015 على التوالي، حيث كان عام 2008 هو صاحب النسبة الأكبر (حوالي 44٪). كان تحديد درجة التباين المكاني والزماني لـ SC في شمال العراق بين عامي 1990 و 2022 هو هدف هذه الدراسة. وكشفت الدراسة عن فروقات اقليمية في كمية الثلوج المتساقطة حيث سجلت محافظة دهوك اعلى نسبة حيث بلغت 47% من اجمالي نسبة الثلوج المتساقطة بينما سجلت محافظة اربيل اقل نسبة ثلوج متساقطة من بين مدن شمال العراق اما محافظة السليمانية فكانت بين دهوك واربيل بنسبة 35% من اجمالي مساحة الغطاء الثلجي وتم حساب النسبة من مساحة معينة من الثلوج المتساقطة مقسمة الى اجمالي مساحة الثلوج المتساقطة كنسبة مئوية حاليا ونلاحظ انه في الاعوام (1998، 2008) هناك فرق كبير في كمية الثلوج المتساقطة المستقرة عن كمية الثلوج المتساقطة الجديدة ونلاحظ ايضا ان عام 2016 مثل اعلى قيمة للثلوج الجديدة والمستقرة وادنى القيم كانت في الاعوام (1991، 1994، 1999، 2010، 2011، 2018، 2020، 2021) وذلك لطبيعة المنطقة وعوامل الطقس مثل درجة الحرارة والرطوبة وبخار الماء.

الكلمات المفتاحية: الغطاء الثلجي، عمق الثلج، مكافئ مياه الثلج، تغير المناخ

Introduction

The estimating Snow Water Equivalent (SWE) using Snow depth and climate classes. The SWE values calculated within 68 cm decades at 37 sites throughout the United States, Canada, and Switzerland (STURM, et al., 2009). the long-term variability and trends in winter snowfall resulted in higher rates SCD occur in the EAR during the winter with positive patterns in the eastern Atlantic/western Russia (BALTACI, et al., 2019). More than 17 models of snow were used to estimate snow depth and snow water equivalent (SWE), for several mountain meteorological stations from Romania (AMIHAESEI, et al., 2020). carried out the changes in snow depth in Austria, snow cover duration) SCD), and snowmaking conditions were found for the years 1961–2020 - a model-based approach (OLEFS, et al., 2020). Knowledge of Snow cover duration trends observed at sites and predicted by multiple models. Trends in starting dates for seasonal snow cover have been

observed, but there are significant trends toward snow cover ending earlier (ESSERY, et al.,2020). The snow depth, snow water equivalent distribution, and anisotropy were studied in the Irtysh River basin from 2000 to 2018(GAO, et al., 2021). Recently studied snow depth or snow water equivalent was estimated from space (DAI, et al., 2022). evaluated the precision of central Alaska's SC mapping at various vegetation densities (Hall, et al., 1998). Areal Extent of Seasonal Snow Cover in a Changed Climate. Hypothetical examples for a basic basin are used to illustrate a process for determining whether a particular climate change scenario will accelerate or slow down the seasonal decrease of snow-covered area (Rango & Mattinec, 1994). studied climate change and snow cover in the European Alps. observed an overall decrease in snow depth and duration of snow cover since then End of the 80s throughout the European Alps (Marty, 2013).

Study Area

Northern Iraq extends north from Baghdad and is bordered by Syria, Turkey, and Iran. It consists of several regions of Sulaymaniyah, Erbil, Dohuk, and Zakho. Iraqi Kurdistan is largely mountainous, the highest point about 3,611 m (11,847 ft) known locally as Sheikha Dar "Black Tent". Mountains in Iraqi Kurdistan include the Zagros, Sinjar Mountains, Hamrin Mountains, Nusair Mountains and Qandil Mountains. Many rivers flow through the region, which is characterized by its fertile lands, abundant water, and picturesque nature. The Great Zab and Little Zab rivers flow from east to west in the region. The Tigris River enters Iraqi Kurdistan from Turkish Kurdistan. The mountainous nature of Iraqi Kurdistan, the differences in temperatures in its various parts, and the numerous bodies of water make it a land for agriculture and tourism. The largest lake in the region is Lake Dukan. There are also several smaller lakes, such as Lake Darbandikhan and Lake Dohuk. The western and southern parts of Iraqi Kurdistan are not as mountainous as the east. Instead, it is rolling hills and plains covered in hardwood trees.

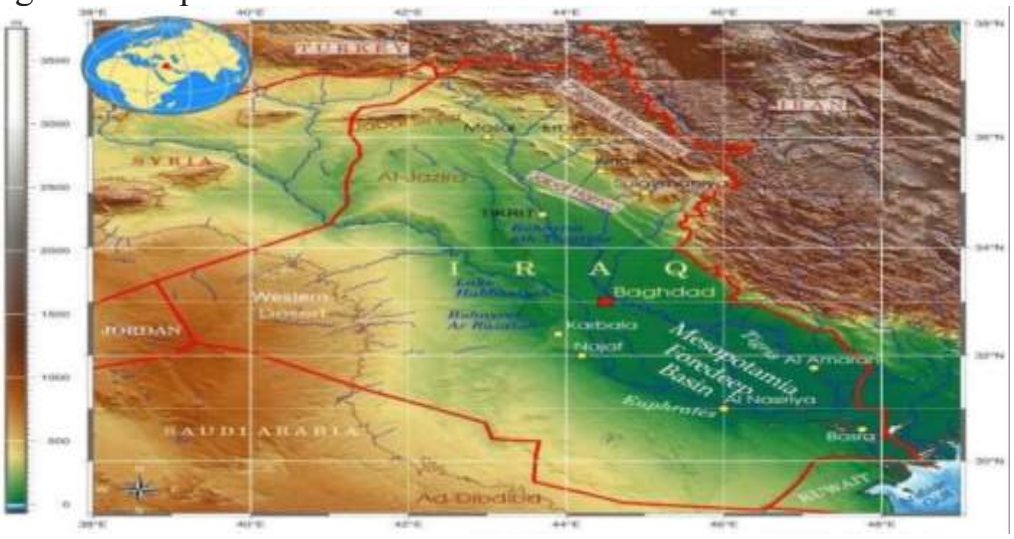


Fig (1) Topographic map of Iraq

Table (1); Longitude, latitude and elevations above sea level for study stations in Iraq.

Study Stations	Longitude (º E)	Latitude (º N)	Elevations above sea level in meter
Sulaymaniyah	45.43	35.55	882
Duhok	43.0	36.86	565
Zakho	42.69	37.13	440
Erbil	44.0	36.19	420
International borders	42.8	37.2	1200

The snow cover (SC) describes the total area of land covered in snow at any given time. Naturally, its influenced by the amount of precipitation that falls as climate change affects snow. Because the snow is white, it only absorbs a small percentage of sunlight (10 to 20 percent in the case of fresh snow) and reflects the remaining portion back into space". In contrast, darker surfaces, like bare earth and open water, heat up more quickly because they absorb most of the energy that hits them. The total amount of SC has an impact on the Earth's surface's heating and cooling patterns. More snow causes more energy to be reflected back into space, which cools the planet. Because there is less SC, the Earth's surface absorbs more energy, which causes warming. On a more local scale, SC is important for many plants and animals. They are shielded from below-freezing winter temperatures by a layer of snow. Snowmelt is also necessary for ecosystems and humans to replenish streams and groundwater. Additionally, SC maintains soil moisture, so if it melts off earlier in the spring. Early soil drying can stress plants and raise the possibility of wildfires. Snowfall in the northern part of Iraq is one of the most important climatic phenomena that characterize the climate of this region; therefore, the nature of the snow, its quantity, and the number of snow areas from the total snow area, including the study, in addition to the importance of the accumulated snow in terms of what it provides in terms of feeding returns that contribute to the Tigris River and its tributaries in Iraq; as the snow in the study area is characterized by the type that is made of hard snow that gives equivalent water when melted, equal to three times what soft snow gives. The northern cover also represents a tourist area that distinguishes the northern part of Iraq; as snowfall begins in November and continues until March, forming a large wash that covers the northern and northeastern parts of the study area, and the fresh seasonal snow line appears in the form of a strip extending with the borders of the northern and northeastern study

area. It also produces the importance of snowfall to write it for a reason above the study area, which makes it a climatic phenomenon that is almost unique to the northern part of Iraq from the parts of the Iraqi governorate.

RESULT AND DISCUSSION

The study revealed the regional differences in the amount of snow cover. as shown in the figure (2) Dohuk governorate witnessed the highest percentage of snow cover (about 47 %). Erbil governorate had the least SC of the northern cities of Iraq. Sulaymaniyah was in between Dohuk and Erbil with (35 %) of total area of snow cover. The ratio was calculated from particular area of SC divided in to total area of SC as presently ratio area.

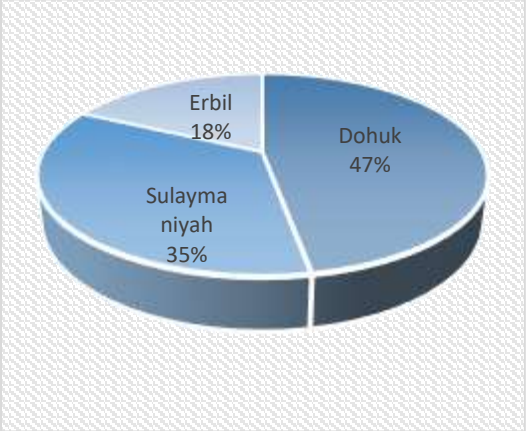


fig (2) pie-diagram of the regional differences in the amount of sc.

The temporal variance of snow cover area was more pronounced than the spatial variance. According the comparison of three largest areas found that 2008, 1992, and 2015, that recoded as (44%, 38%, 18%) respectively of total snow cover area. The time interval of these three cases was each eight years expect 2000 that excluded of this sequence of time. As shown in the figure (3):

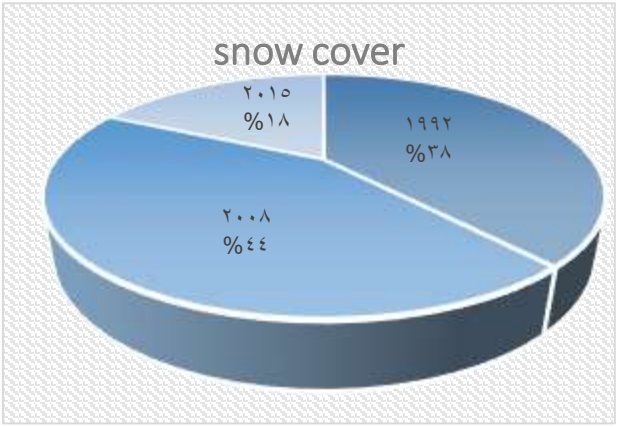
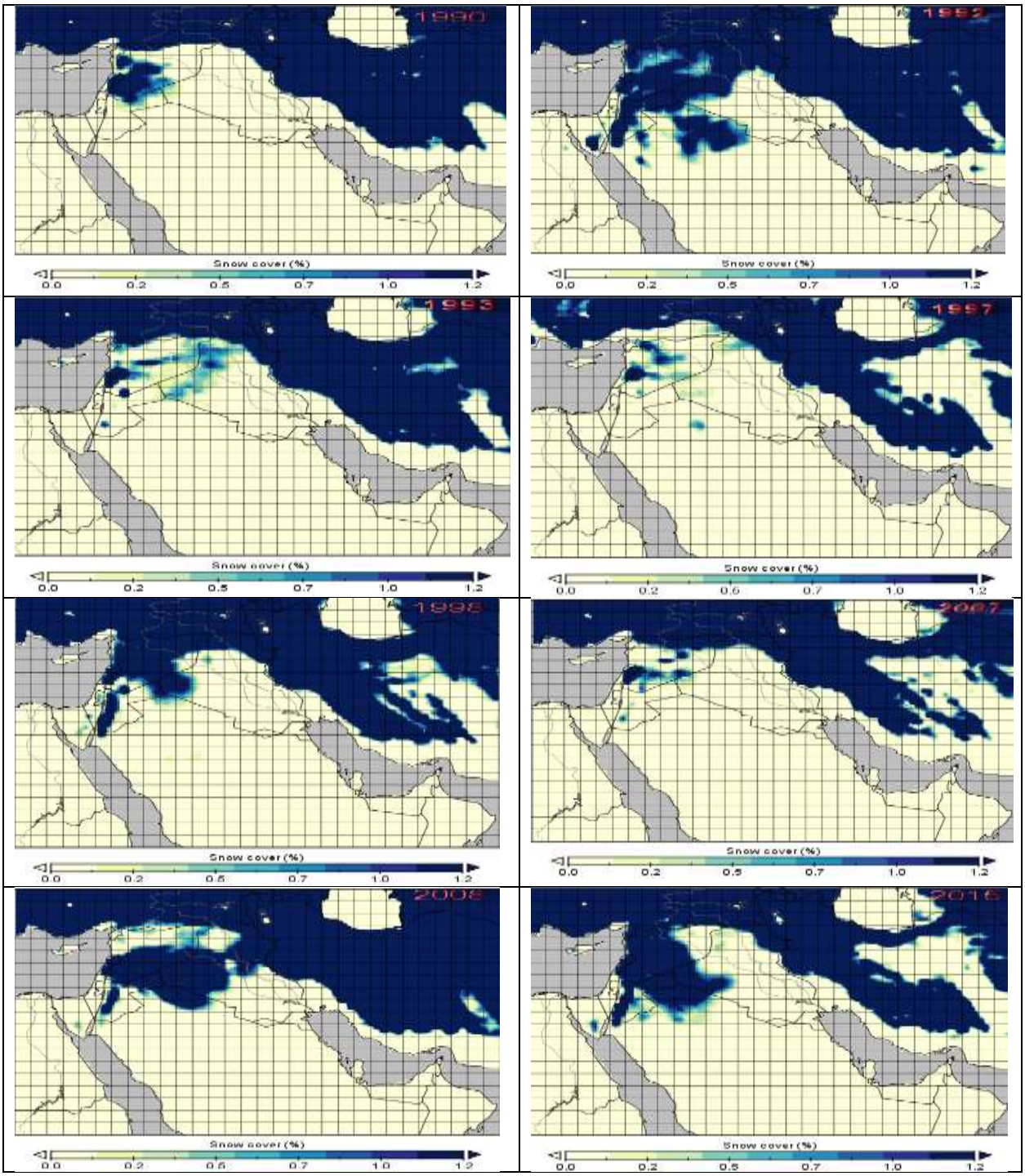


Fig (3) pie-diagram of the percentage of SC for the years with maximum values.

The extensive seasonal snow cover in northern India is sensitive to climate warming and strongly influences surface-atmosphere interactions. SC has identified a basic climate that plays an important role in ecosystem components such as hydrology, ecology and climatology. Figure (4) of the maps shows the snow cover for different years, and the influence of the Mediterranean climate on northern Iraq, which is characterized by its cold winters and snowfall and mild summers. It is clear that the mountainous regions have semi-permanent snow cover during the winter. However, the amount varies, snow falls in the middle latitudes as well as the high mountainous regions in the winter and is accompanied by pressure systems of both types; The cold air highs (Siberian high and European high) and the rainy air lows (Mediterranean low, Sudanese low, Icelandic low and combined low) affect snowfall in the study area. The amount of snow is directly related to the degree of latitude and the height above sea level, as ice is permanently present in the high latitudes and on the tops of high mountains. The northern part of Iraq witnesses annual recurrence of snowfall, and the mountainous region witnesses snow accumulation that is consistent with the nature of the terrain of this region Strong solar radiation and low air humidity affect snow accumulation, resulting in the formation of shallow, patchy and transient snowpacks. By analyzing the maps of the distribution of snow cover for the years studied (1999/2022), we notice that the amount of snow cover is moderate or relatively small in the years (1990-1991), which included Dohuk and Sulaymaniyah Governorates. As for the year 1992, the distribution of snow cover was relatively large, including all the northern regions and down to the region's Western regions due to their influence on weather conditions. As for the years (1993-1994-1995-1996-1997), the distribution of snow cover was moderate to relatively small due to the weakness of the weather system. In 1998, the percentage of snow cover was somewhat moderate, covering the northern regions, and a small percentage of the snow cover was in the western region. As for the remaining years from 1999 to 2007, it fluctuated between moderate and low. As for the years 2008 and 2015, the distribution of snow cover was large, covering the northern region and down to the western region. The remaining years had fluctuating snow cover.



Fig(4)distribution of annual SC in northern Iraq.

The Model for transformation snow to water equivalent

snow is composed of frozen water crystals, but because there is so much air surrounding each of those tiny crystals in the snowpack, most of the total volume of a snow layer is made up of air. that refer to the snow water equivalent of snow as the thickness of water that would result from melting a given layer of snow. An often-repeated assumption claims a ten-to-one ratio of snow to water, but that is not always accurate. The water equivalent of snow is more variable than most people realize. For instance, 25 centimeters (10 inches) of fresh snow can contain as little as 0.25 centimeters (0.10 inches) of water and as much as 10 centimeters (4 inches) of water, depending on crystal structure, wind speed, temperature, and other factors. The majority of new snowfall in the United States contains a water-to-snow ratio of between 0.04 (4 percent) and 0.10 (10 percent), depending on the meteorological conditions associated with the snowfall.

Fig (5) Model for transformation snow to water equivalent.

Transformation Snow Water Equivalent (SWE) refer to the volume of liquid water present in snow determined by particularly region depended on both depth, and type of snow. The specific model that easy used for determined an amount of water equivalent as output from input the SD, SC, and snow situation if either new (same year of input) and settled (for short past time). Different classifications of snow and ice have different water densities. This model estimated the volume of water content by multiplying the area in of snow cover (km) by the snow depth (m) of the snow type. The results represented the mass of liquid water in liters. Snow density can range from 5% when the ambient air temperature is 14°F, and can be as high as 20% if the temperature is 32°F. Snow density will increase after snowfall due to gravitational settling, packing, wind effects, and melting.

Table (2) show Transformation (SWE).

year	Sd(m)	Sc(km)	Swe(L)new E10^10	Swe(L) settled E10^10
1990	0.1	832.5	5	2
1991	0	693.75	0	0
1992	2.2	2220	2.9	1.2
1993	0.1	971.25	5.8	2.4
1994	0	416.25	0	0
1995	0.1	555	3.3	1.3
1996	0.1	832.5	5	2
1997	0.2	832.5	1	4
1998	0.2	1526.25	1.8	7
1999	0	416.25	0	0
2000	0.1	1110	6.6	2.7
2001	0.1	832.5	5	2.8
2002	0.1	832.5	5	2.8
2003	0.2	832.5	1	4.1
2004	0.1	693.75	4.1	1.7
2005	0.2	1110	1.3	5.5
2006	0.1	832.5	5	2
2007	0.1	971.25	5.8	2.4
2008	0.2	1526.25	1.8	7.6
2009	0.1	832.5	5	2.0
2010	0	693.75	0	0
2011	0	693.75	0	0
2012	0.1	832.5	5	2
2013	0.1	1110	6.6	2.7
2014	0.1	416.25	2.5	1
2015	0.1	1248.75	7.5	3.1
2016	0.1	1110	6.6	2.7
2017	0.1	832.5	5	2
2018	0	416.25	0	0
2019	0.1	832.5	5	2
2020	0	832.5	0	0
2021	0	555	0	0
2022	0.1	693.75	4.1	1.7

Snowfall varies from one region to another on the Earth's surface. In some areas of the Earth, snow falls at a certain time in the winter, and only covers the

ground for a few days. There are areas where snow falls and covers the ground for several months in the winter, such as high mountains, and there are areas where snow never falls. There are areas where there is permanent snow and ice cover, as is the case in the polar regions.

This figure (6) shows the difference between SWE (new and settled). We notice that in the years (1998, 2008) there is a large difference in the SWE settled to the SWE new. We also notice that the year 2016 represented the highest value for new and stable snow, and the lowest values were in the years 1991 and 1994. 1999, 2010, 2011, 2018, 2020 and 2021. This is due to the nature of the region and weather factors such as temperature, Humidity and water vapor.

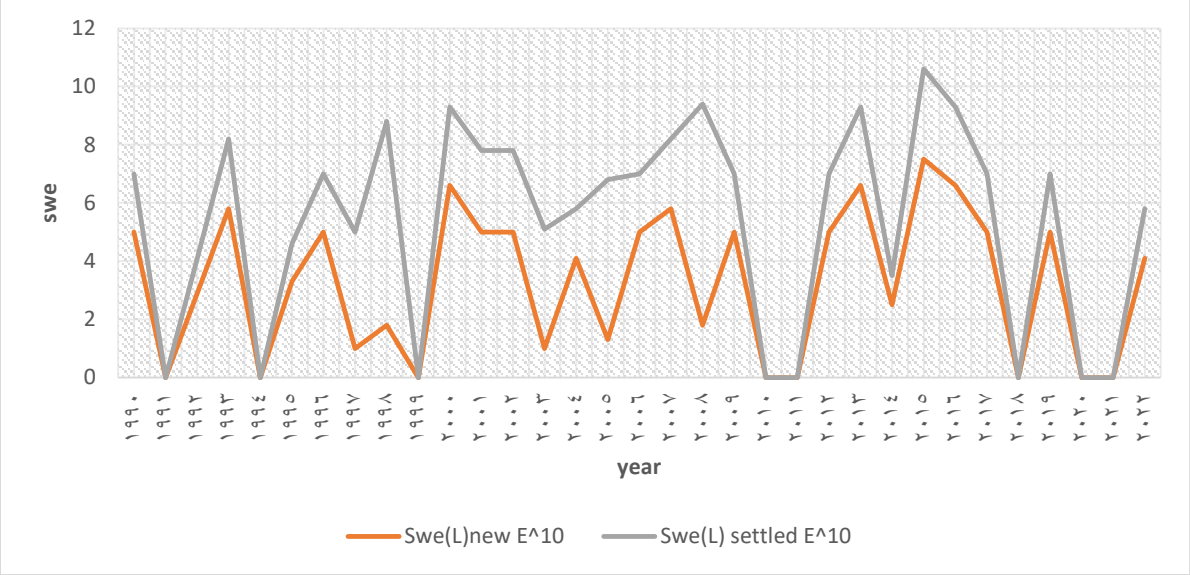


Fig (6) Comparison between SWE new and SWE settled.

The relationship between the amount of water and agricultural production

The Directorate of Agricultural Statistics provides data on various aspects of agricultural activity. The Livestock Production and Population Report is an important report that provides information about the country's food security.

Wheat and barley are considered among the oldest field crops known to be cultivated in the world as a source of food. They are grown in Iraq, which has large areas, especially in the northern governorates. The amount of irrigation water needed to irrigate one dunam of orchards per irrigation, as well as the number of irrigations per season, depends on many factors, including those related to the climatic elements prevailing in the region, such as temperatures, winds, and relative climate. climate. Humidity, and those related to the soil, such as soil type, depth, fertility, etc. There are also factors related to trees in terms of their type, age, number per unit area,

physiological condition, and stage of growth and maturity, Of fruits. Therefore, we believe that it is not possible to come up with general recommendations common to all orchards, even similar orchards in different regions. Therefore, these requirements must be determined according to different regions and locations.

Table (3) Showing the production quantity of wheat, barley and corn for the year 2023.

Crop type	Average yield (KG/Donum)	
	Irrigate	Rain falls
Barley	45.2	42.5
Wheat	504.5	403.6
Maize	1483.4	1362.4

CONCLUSIONS

The results show that SD decreased with a time series last decade. this because the effect of global warming that had less snow depth as part of water resources problem in Iraq. Obviously that fluctuations of snow depth peak were unregular, therefore classify to the annual scale to three periods. First period was with high peaks frequent three peaks ;1992, 1994, and (1997 -1998). While the second decade had two peaks with different amplitude (2003,2007) the recorded (0.06, 0.03 m) respectively. The last decade had two small peaks in (2013 - 2014), (2016 -2017) ware snow depth peaks for all these years were (0.03m). These results show significant role of climate change that effect on this parameter especially the topography of that region is moutons that had less snow depth recently years to face a crisis problem of water security in Iraq. There are three places with unique patterns that are coordinated and synchronized and are plainly more sensitive to the climatic system. Despite being dispersed, these three areas share the same SD. There is a mountain range called the Zagros in each of these places, which are in the countries of southern Turkey, northern Iraq, and western Iran. The study revealed regional differences in the spatial and temporal distribution of SC quantity. Dohuk Governorate witnessed the highest percentage of SC area, which receives 67.2% of the total percentage of SC area. Erbil Governorate has a lower percentage of SC than other cities in northern Iraq. The area of Sulaymaniyah between these cities is 28% of the total area of snow cover.

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