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Analysis of spatio-temporal allocation of snow cover on the territory of Vinnytsia region

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ABSTRACT

Formulation of the problem. Snow cover has a great influence on the climate, relief, hydrological and soil-forming processes, plant and animal life. It protects the soil from deep freezing and preserves winter crops, absorbs nitrogenous compounds, thus fertilizing the soil, adsorbs atmospheric dust and cools the surface layers of the air. Snow cover and its duration are social and economic important and affect the environment. Snow-related difficulties are a dangerous factor in the human environment, and more attention should be paid to the impact of snow on the economy or its great value as a natural resource. The investigation of the spatial distribution and temporal variability of the snow cover is an urgent and important issue, especially in the conditions of modern climate changes.

The purpose of the article is to establish the characteristics of the spatio-temporal distribution of snow cover in the territory of Vinnytsia region for the period 1996-2018 and the features of its characteristics at the beginning of the XXI century.

Methods. The data of daily meteorological observations on the height of the snow cover at the stations of the Vinnytsia region were used as the initial information. To characterize the height of the snow cover, its average values are calculated not for months, but for decades of winter months. Decadal heights and their repeatability by decade were calculated for each station for the period from 1996 to 2018 based on data on the distribution of snow cover height.

Results. The analysis of the spatio-temporal distribution of snow cover for the period 1996-2018 makes it possible to describe certain features of the formation of snow cover in the territory of Vinnytsia region: the snow cover in Vinnytsia region is formed in the third decade of October, with the exception of the Vinnytsia and Khmilnyk stations, where the appearance of snow cover begins in the second decades of October; disappearance occurs in the third decade of April throughout the region; decadal heights of snow cover have the maximum repeatability in the gradation from 0 to 5 cm; average decadal heights with the largest values from 10 to 13 cm were found in January and February at the stations of Bilopillia, Vinnytsia and Khmilnyk; the formation of stable snow cover on the territory of Vinnytsia region occurs in the second decade of November; the destruction was recorded from the second decade of March to the first decade of April.

Scientific novelty and practical significance. The article provides an analysis of the distribution of snow cover and features of its formation at the end of the 20th and the beginning of the 21st centuries on the territory of the Vinnytsia region. The snow cover has a significant impact on the branches of Ukraine's economy. Agriculture is the most sensitive to the features of snow cover formation, especially when it comes to overwintering of winter crops. One of the main agrometeorological factors that determine the overwintering of winter crops is the height of the snow, its spatial and temporal variability, the period of appearance and disappearance of the snow cover. We believe that our investigation can be used to clarify the forecast of the yield of winter crops in Vinnytsia.

Keywords*: snow cover, decadal height of snow cover, dates of appearance and disappearance of snow cover, stable snow cover.*

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Formulation of the problem. Snow cover is formed as a result of the accumulation of snow on the ground during the deposition of solid precipitation, raining, when most of the precipitation subsequently freezes, as well as the deposition of additions. Accumulation and ablation of snow cover depend mainly on atmospheric conditions and the state of the earth's surface. Determining atmospheric processes are precipitation, their deposition, condensation, turbulent heat- and moisture exchange, radiation balance and movement of air masses, relief features that affect the course of atmospheric processes and the creation of a wind shadow [1]. Observation of the snow cover consists of daily observations of the state of the snow cover and periodic surveys of the state of the snow cover to determine the amount of snow and water in the natural landscape. The concept of "snow cover", in addition to the layer of snow formed on the surface of the soil, includes: layers of ice on the surface of the snow and soil, as well as melt water accumulated under the snow [2].

Snow cover has a great influence on the climate, relief, hydrological and soil-forming processes, plant and animal life. It protects the soil from deep freezing and saves winter crops, absorbs nitrogenous compounds, thus fertilizing the soil, adsorbs atmospheric dust, cools the surface layers of the air. Snow cover and its duration have social and economic importance and affect the environment [1]. Snow-related difficulties are the dangerous fac-

tor in the human environment, and more attention should be paid to the impact of snow on the domestic economy or its enormous value as a natural resource. The observation of the spatial distribution and temporal variability of the snow cover is an urgent and important question, especially in the conditions of modern climate changes. Agriculture is the most sensitive to the features of snow cover formation, especially when it comes to overwintering of winter crops. One of the main agrometeorological factors that determine the overwintering of winter crops is the height of the snow, its spatial and temporal variability, the period of appearance and disappearance of the snow cover. We believe that our investigation can be used to clarify the forecast of the yield of winter crops in Vinnytsia.

Analysis of the recent investigations and publications. Snow cover is formed as a result of a snowfall and has characteristics that are absolutely different from those, which were observed at the time of a snowfall. The temperature in a moment of the snow deposition affects the humidity, hardness and structure of the fresh fallen snow and, therefore, its stability during wind deflation [1, 3, 4]. According to the conclusions of leading experts on the climate change [5-8], under conditions of anthropogenic strengthening of the greenhouse effect, an increase in the concentration of greenhouse gases in the atmosphere is expected by 2100, which will contribute to an increase in the average air temperature by 1.4–5.8 °C [5, 8-10]. The ongoing global climate changes cause concern for their multidirectional effects. When the climate changes, there is a change in natural resources, and these are not only purely climatic resources, but also those that depend on the state of the climate and are determined by its state. Consideration of climatically determined natural resources has always been given a great importance in those branches of the economy that are closely related to the state of weather and climate [6-8]. This is, first of all, an agro-industrial complex, in which the costs of producing agricultural products are determined by the appropriate set of climatically determined natural resources [8]. The snow cover plays a very important role in the agriculture of our country as a factor that provides soil moisture, as well as protection against the frost of the winter crops and other agricultural plants [11, 12]. The main agrometeorological factors that determine the overwintering of winter crops are: the height of snow, the minimum temperature of the soil at the depth of the tiller node in different periods of winter, the sum of negative air temperatures, the depth of soil freezing, the duration of the period with a snow height of more than 30 cm, the amount of precipitation of autumn and winter periods, etc. [11, 12]. The snow in the fields is very uneven. Under the influence of the wind in open fields, there is a significant transfer of snow from one part of the field to another. The more uneven distribution of snow is bigger, the lower its average height. It has been established that a snow depth of 10cm is sufficient for the preservation of the winter crops in severe frosts and it could be in the entire field with an average snow height of 30 cm. The duration of the period with snow also has a large spatial variability. Long stay of a thick layer of snow in the fields causes damage to plants due to washing away. With a significant thickness of snow and its long stay in the fields, the condition of winter crops depends on the speed of snow melting. The period of snow formation in the fields and its thickness significantly affect the depth of soil freezing, which also has significant spatial and temporal variability, but still less than the snow thickness [11].

The depth of freezing, which is determined by the height and nature of the snow cover, should be taken into account when laying pipelines, foundations of buildings, etc. The value of the density of the snow cover is included in construction calculations when determining snow loads on structures [11]. In the construction and exploitation of various structures and roads, snow cover is a negative factor that creates loads and drifts. However, the snow cover has a great positive value in the formation of climatic and hydrological regimes [8]. The largest reserves of water in the snow accumulate before the beginning of the spring snowmelt. The water supply in the snow cover is the great practical interest for the national economy. The degree of intensity of melting of the snow cover and the amount of water in it determine the amount of spring drain, floods, and the amount of moisture in the soil. The distribution of water reserves in the snow cover on the territory of Ukraine is characterized by its decrease from north to south, what is the same regularity as the distribution of the height of the snow cover [11, 12]. Snow cover is an important source of soil moisture in the spring. The spring melting of snow in the circumstances of Ukraine causes floods, which plays a major role in the regime of surface water and in economic life [8, 11, 12].

In the circumstances of one climatic region, snow accumulates from year to year in a certain way, characterized by the specific landscape conditions [11, 13, 14]. The nature of the snow cover is directly dependent on local conditions [3, 4, 14, 15-17]. In the cold period of the year, part of the precipitation falls in the form of snow on the territory of the country. The first snow rarely lays all winter. More often it repeatedly melts and then falls out again [14, 16-18]. In the flat part of the country, the average height of the snow cover at the end of November doesn’t exceed 3 cm. From November to

December, there is a slight increase in the height of the snow cover and an increase in the area of its distribution [13, 14, 19, 20]. In the central and western regions of Polissia and the forest steppe, as well as in the north of the steppe zone, at the end of December its height increases to 10cm. In January, the increase in the height of the snow cover from decade to decade occurs more intensively compared to December, except for the steppe, where its thickness is almost doesn't increase. In February, there is a further increase of the snow layer with approximately the same intensity as in January. Stable snow cover is formed in the northeastern part of Polissia and forest steppe, where the date of its establishment should be attributed to the middle of December, and in the western and central areas of these zones - to the end of December and the beginning of January. The destruction of the stable snow cover and its dismount going faster than its formation. In general, the destruction of the stable snow cover occurs in the steppe zone at the end of February and the beginning of March, in the forest-steppe zone in the middle of March and in the extreme northeast of the country - at the end of March. The intensity of destruction of the stable snow cover and its descent depend on the local conditions. The number of days with snow cover varies widely in the flat part of the territory of Ukraine. The values decrease from north to south [3, 4, 13, 18].

Highlighting previously unsolved parts of the common problem. The presence of the snow cover, its spatial and temporal distribution significantly affect the areas of the Ukrainian economy. At the same time, the characteristics of the snow cover depend on meteorological conditions and circulation processes, which can differ significantly in different regions of the country. Snow cover as a natural resource is actively changing under the influence of the increase in temperature in the winter season and the transformation of precipitation fields. In the conditions of modern climate changes, it is necessary to carry out complex investigations, analysis and forecast of changes in climatically conditioned natural resources [6-8]. As mentioned above, in addition to meteorological conditions, the occurrence of snow cover depends on the landscape, relief, orography and other features of the area. Accordingly, the investigation of regional conditions for the formation and distribution of snow cover is relevant in matters of adaptation to new natural conditions and softening the consequences of these changes.

The purpose of the article is to analyze the spatio-temporal distribution of snow cover on the territory of the Vinnytsia region for the period 1996-2018 and the features of its characteristics at the beginning of the XXI century. The data of daily meteorological investigations of the height of the snow cover at the stations of Vinnytsia were used as the initial information.

Presentation of the main investigation material. Vinnytsia region is located in the forest-steppe zone of the central part of Right-bank Ukraine. The land area is 2,606.4 thousand hectares, i.e. 98% of the total area of the region, the rest (2%) is occupied by inland waters. In the west it borders Chernivtsi and Khmelnytskyi, in the north with Zhytomyr, in the east with Kyiv, Kirovohrad and Cherkasy, in the south with Odesa regions of Ukraine and the Republic of Moldova, including part of the border with unrecognized Transnistria. The region occupies almost 4.5% of the territory of Ukraine [21]. The Southern Bug River divides the territory of the region into two parts: the left bank, which belongs to the Dnieper Upland, and the right bank, the Podolia Plateau. The surface of Vinnytsia is a raised plateau that descends in the direction from the northwest to the southeast. Most of the territory of the Vinnytsia region is located within the boundaries of the Ukrainian crystalline shield. The modern relief of the region is mainly a wavy, hilly plain, branched by numerous river valleys, ravines and banks, especially in the region of Transnistria. In the central part of the region, the South Bug River flows from the northwest to the southeast, and the Dniester River flows along the southwestern border of the region. The rivers are used for small shipping and as sources of hydropower. 69 reservoirs and 4,827 ponds have been created in the region.

Vinnytsia region is characterized by forest steppe landscapes. The forests are dominated by broad-leaved tree species: hornbeam, maple, linden, oak, ash. The herbaceous vegetation is characterized by great diversity, there are only about a thousand species of wild plants.

Vinnytsia is located in a temperate climate zone. The climate of the region is moderately continental. A mild, long summer with a sufficient amount of moisture and a relatively short, mild winter are typical for such a climate. Due to its geographical location, the territory of the region is in the sphere of influence of the moisture saturated Atlantic air masses and the peripheral part of the Asian (Siberian) anticyclone, which is characterized by cold, dry continental air masses. Climate is also influenced by air masses from the Arctic and the Mediterranean. The coldest month of Vinnytsia region is January, the warmest is July. Average temperature in January: -6°C, average temperature in July: +19°C. Average amplitudes of temperature fluctuations during the year do not exceed 25ºC. Under the influence of continental air masses, the temperature can drop to minus 32-38ºC on some days, in summer the temperature can rise to +37ºC, the highest temperatures are observed in July-August. The average an-

nual amount of precipitation in the Vinnytsia region is 440-590 mm, of which 80% falls in the warm period. The largest amount of precipitation is observed in the northwest of the territory. The maximum precipitation occurs in May-July and is 130-170 mm. The least wet are the winter months. In the cold season, 25% of precipitation is recorded: in December-February 65-80 mm of precipitation falls. The transition from one season to another occurs gradually. The climate of Vinnytsia is favorable for agricultural production: a long warm and quite wet summer, early spring, dry autumn and winter with moderate frosts and significant snow cover - all this has a positive effect on the growth of grain, technical and horticultural crops [22].

To characterize the height of the snow cover, its average values are calculated not for months, but for decades of winter months. These values at the beginning and end of winter are calculated only if snow cover was observed in more than 50% of all winters. The average value for a decade is obtained by dividing the total height for all years of the selected period by the number of years. When snow was observed in less than 50% of winters, the average height for such a decade is not calculated. At the same time, it is accepted to put a conditional icon (•) in the tables [18]. According to the data of the distribution of the average height of the snow cover on the territory of the Vinnytsia region, decadal heights and their repeatability by decades were calculated for each station for the period from 1996 to 2018. The results of calculations are given in tables 1-6.

Table 1

Repeatability of decadal height of snow cover by decade at Bilopillia station for 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	73	86	58	70	52	53	50	45	33	46	43	50	63	87	66	100	100
6-10			18	7	26	10	14	16	15	9	19	14	5	6	6	7			
11-15				7	5	5	14		5	26	14	9	19	22	13		17		
16-20			9		11	10	10	10	15	5	10	14	9	11	13		17		
21-25							5	16		5	14	4	14	6					
26-30								5	10	5	5	4	5	6					
31-35									5	5	5				6				
36-40						5						9	5						
41-45																6			
46-50							5												

At the Bilopillia station, the highest values of repeatability are observed in the gradation of 0-5 cm in the 2nd and 3rd decade of October, 2nd and 3rd decade of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 3rd decade of December - 26%. The maximum repeatability - 26% of cases in the 3rd decade of January has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 17% in the 1st decade of April. The highest repeatability - 16% is observed in the gradation of 21-25 cm in the 1st decade of January. The gradation of 26-30 cm has a maximum repeatability of 10% in the 2nd decade of January. In the 2nd decade of March, the maximum repeatability of 6% has a gradation of 31-35 cm. The gradation of 36-40 cm is observed in three decades, the maximum repeatability is 9% in the 2nd decade of February. It can be noted that the gradations of 41-45 and 46-50 cm have the rarest cases of repeatability and are recorded only in the third decade of March and December and have a repeatability rate of 6 and 5% accordingly.

For the Vinnytsia station, the highest repeatability values are characteristic for 0-5 cm gradation in the 2nd and 3rd decade of October, the 1st decade of November, and the 2nd and 3rd decade of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 3rd decade of December - 31%. The maximum repeatability - 20% of cases in the 1st decade of March has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 13% in the 3rd decade of February and 10% in the 1st decade of April. The highest repeatability - 9% is observed in the gradation of 21-25 cm in the 1st decade of February. The gradation of 26-30 cm has the maximum repeatability – 18% in the 2nd decade of February. In the 1st decade of February, the gradation of 31-35 cm has the maximum repeatability of 13%. It can be noted that the gradation of 36-40 cm has the rarest presence of repeatability of cases, because it is recorded only in the 3rd decade of December and the repeatability is 5%. A gradation of 41-45 cm is observed in three decades, the maximum repeatability is 5% in the 2nd and 3rd decades of December. In the 2nd decade of January with the maximum re-

peatability of 9%, there is a gradation of 46-50 cm. It can be noted that the gradation of 51-55 cm has the rarest presence of cases, because it is recorded only in the 3rd decade of January with a repeatability of 9%. The gradation of 56-60 cm has a maximum repeatability of 5% and is observed in the 2nd and 3rd decades of February.

In the table 3 there is the repeatability of the decadal height at the Haysyn station. Here, the highest repeatability values are observed in the gradation of 0-5 cm in the 1st decade of November, the 3rd decade of March, and the 2nd and 3rd decades of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 1st decade of January - 37%. The maximum repeatability - 33% of cases in the 1st decade of April has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 19% in the 2nd decade of January and 16% in the 1st decade of January. The highest repeatability - 9% is observed in the gradation of 21-25 cm in the 3rd decade of January. The gradation of 26-30 cm has a maximum repeatability of 6% in the 2nd decade of December. It can be noted that the gradation of 31-35 cm has

Table 2

Repeatability of decadal height of snow cover by decade at Vinnytsia station for 1996-2018 (%)

Gradation	X		XI			XII			I			II			III			IV		
	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	100	85	75	63	65	45	47	45	44	46	53	47	45	76	94	90	100	100
6-10				15	6	21	15	31	24	28	22	18	4	10	20					
11-15					19	11	5	5	9	9	13		9	10	20	6				
16-20							5	9	4			9	4	13	5	6		10		
21-25											4	9	4	5	5	6				
26-30						5			4		4		18	5	5	6				
31-35							5		4	9	4	13	4	5			6			
36-40								5												
41-45							5	5	4											
46-50									4	9		5								
51-55											9									
56-60													4	5						

Table 3

Repeatability of decadal height of snow cover by decade at the Haysyn station for 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	75	100	90	84	65	63	58	42	43	41	40	57	60	62	67	100	67	100	100
6-10	25			8	23	25	16	37	14	14	35	15	28	19	33				
11-15					6		16		19	23	10	9	6	13			33		
16-20			10	8				16	19	9	10	9	6	6					
21-25					6	6	5			9		5							
26-30						6	5	5				5							
31-35									5	4	5								

the rarest repeatability of cases, because it is recorded only in the 2nd and 3rd decades of January and in 1 decade of February, where the repeatability is 5%.

In the table 4 summarizes the indicators for the Zhmerynka station. It can be seen from the table that the highest values of repeatability are observed in the gradation of 0-5 cm in the 1 decade of November, in the three decades of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 3rd decade of October - 50%. The maximum repeatability - 26% of cases in the 3rd decade of February has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 11% in the 2nd decade of January. The highest repeatability – 15% is observed in the gradation of 21-25 cm in the 1st and 2nd decade of February. The gradation of 26-30 cm has the maximum repeatability – 11% in the 1st decade of January. In the 1st and 2nd decade of December, the maximum repeatability of 6% has a gradation of 31-35 cm. The gradation of 36-40 cm is observed in two decades, the maximum repeatability is 8% in the 3rd decade of March. It can be noted that the gradations of 41-45 and 46-50 cm have the rarest cases of repeatability, because they are recorded only in one decade and the recurrence is 6 and 7%.

For the Mohyliv-Podilskyi station (Table 5), the highest repeatability values are observed in the gra-

Table 4

Repeatability of decadal height of snow cover by decade at the Zhmerynka station for 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	50	100	80	69	70	71	50	44	42	38	40	50	53	47	50	67	100	100	100
6-10	50		10	23	12	6	25	28	26	24	20	10	11	18	29	17			
11-15			10		12	11	5	11	11	14	20	15	26	23	7				
16-20				8			10	6	11	5		5	5		7	8			
21-25							5		5	9	15	15	5	6					
26-30						6	5	11	5	5	5								
31-35					6	6				5									
36-40												5				8			
41-45														6					
46-50															7				

dation of 0-5 cm in the 3rd decade of October, the 1st decade of November, and in the three decades of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 3rd decade of December – 22%. The maximum repeatability - 21% of cases in the 2nd decade of February has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 10% in the 2nd decade of January. The highest repeatability – 7% is observed in the gradation of 21-25 cm in the 1st decade of December. The gradation of 26-30 cm has a maximum repeatability of 6% in the 2nd decade of December and the 3rd decade of February. Gradation of 31-35 cm is observed in three decades, the maximum repeatability is 5%. It can be noted that the gradations of 36-40 and 41-45 cm have the rarest cases of repeatability, because they are recorded only in two decades and the maximum recurrence is 6%.

At the Khmilnyk station (Table 6), the highest

Table 5

Repeatability of decadal height of snow cover by decade at the Mohyliv-Podilskyi station for 1996-2018, (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	86	84	80	77	66	68	59	50	48	63	74	70	92	90	100	100	100
6-10				8	13	11	22	17	16	20	21	21	10	15	8	10			
11-15			14						10	15	16	21	10	15					
16-20				8					10	5	5								
21-25					7		6	5		5	5								
26-30						6		5					6						
31-35								5		5	5								
36-40							6		5										
41-45						6						5							

values of repeatability occur in the gradation of 0-5 cm in the 2nd and 3rd decade of October, in the 1st decade of November, and in the 2nd and 3rd decade of April and are 100%. In the gradation of 6-10 cm, the maximum repeatability was recorded in the 3rd decade of December - 30%. The maximum repeatability - 19% of cases in the 1st decade of February has a gradation of 11-15 cm. The gradation of 16-20 cm is observed with the maximum repeatability - 17% in the 1st decade of March. The highest repeatability – 23% is observed in the gradation of 21-25 cm in the 2nd decade of February. The gradation of 26-30 cm has a maximum repeatability of 10% in the 3rd decade of December, the 1st decade of January and the 1st decade of February. In the 2nd decade of December, the maximum repeatability of 6% has a gradation of 31-35 cm. The gradation of 36-40 cm is observed in two decades, the maximum repeatability is 5% in the 2nd and 3rd decades of February. In the gradation of 41-45 cm, there are no cases of repeatability of the height of the snow cover. It can be noted that the gradation of 46-50 cm has the rarest repeatability of cases, because it is recorded only in the 2nd decade of February, where the repeatability is 5%.

In fig. 1 there is the repeatability of the decadal height of the snow cover at the stations of the Vinnytsia region during the investigation period. The

Table 6

Repeatability of decadal height of snow cover by decade at the Khmilnyk station for 1996-2018, (%)

Gradation	X		XI			XII			I			II			III			IV		
	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	100	82	81	74	76	55	62	56	46	38	47	45	50	66	100	71	100	100
6-10				8	6	21	6	30	14	14	18	9	10	15	11	13		29		
11-15				8	13		6	5		5	18	19	10	5	17	7				
16-20									14	10	5	10		10	17	7				
21-25						5				5	5	14	23	15	5	7				
26-30							6	10	10	5	8	10		5						
31-35							6			5										
36-40													5	5						
41-45																				
46-50													5							

highest repeatability is observed in the gradation of 0-5 cm at all stations, the maximum value for this gradation is 70% at the Mohyliv-Podilskyi station, and the minimum is 54% at the Zhmerynka station. The gradation of 6-10 cm also has significant repeatability, when compared with other gradations, the maximum value of 19% was recorded at the Haysyn station, and the minimum value of 12% is characteristic of the Bilopillia station. The gradation of 11-15 cm has the maximum value at Bilopillia and Zhmerynka stations, where it is 12%, the minimum value at Vinnytsia station is 7%. The gradation of 16-20 cm is characterized by the maximum value at the Vinnytsia station, which is 8%, the minimum

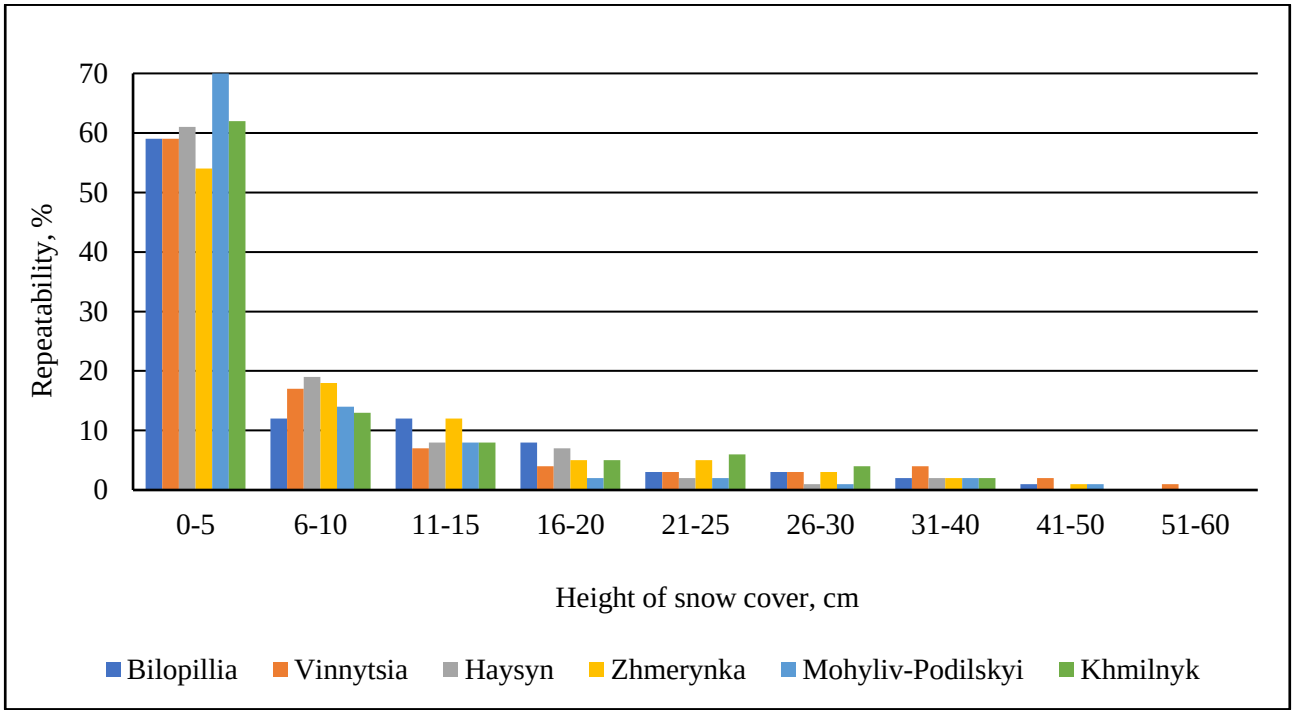

Fig. 1. Repeatability of decadal height of snow cover at stations of Vinnytsia region (%)

value is 2% at the Mohyliv-Podilskyi station.

Repeatability in the gradation of 21-25 cm has the maximum value at the Khmilnyk station, which is 6%, and the minimum value is 2% at the Haysyn and Mohyliv-Podilskyi stations. The gradation of 26-30 cm has a maximum value at the Khmilnyk station and is 4%, and a minimum value of 1% is noted at the Haysyn and Mohyliv-Podilskyi stations. In the gradation of 31-40 cm, the maximum value of 4% is observed at the Vinnytsia station, 2% is at all other investigated stations. Heights in the gradation of 41-50 cm were found at Bilopillia, Zhmerynka, and Mohyliv-Podilskyi stations, where their repeatability is 1%, and at Vinnytsia station with a maximum value of 2%. Heights in the gradation of 51-60 cm were found at the Vinnytsia station, their repeatability is 1%.

In the table 7 there is the average decadal height of the snow cover along a permanent rail.

It can be seen from the table that the appearan-

Table 7

The average decadal height of the snow cover along the permanent rail at the stations of the Vinnytsia region

Station	X		XI			XII			I			II			III			IV		
	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Bilopillia		•	•	2	4	6	6	9	10	10	10	11	12	11	10	7	4	•	•	•
Vinnytsia	•	•	•	2	4	5	7	10	11	11	12	13	13	12	8	7	3	•	•	•
Haysyn		•	•	•	4	4	6	7	7	8	9	9	8	7	6	•	1	•	•	•
Zhmerynka		•	•	•	4	7	7	8	9	8	10	10	10	7	9	9	5	•	•	•
Mohyliv-Podilskyi		•	•	•	3	3	5	6	7	7	8	8	7	5	4	1	•	•	•	•
Khmilnyk	•	•	•	•	3	4	6	7	8	9	10	12	12	11	8	6	3	•	•	•

ce of snow at the stations of the Vinnytsia region has been detected since the third decade of October at all stations, except for Vinnytsia and Khmilnyk, where the appearance of snow has been recorded since the second decade of October. The melting of the snow cover occurs in the third decade of April at all stations of the region. The maximum values of the average decade height of the snow cover are observed in the third decade of January and three decades of February and are 13 and 12 cm at Vinnytsia station; in the second decade of February, the maximum value of 12 cm was recorded at the Bilopillia station; in the first and second decade of February, the maximum value of 12 cm is observed at the Khmilnyk station. The lowest height values were recorded at the beginning and end of the period with snow cover. Average, minimum and maximum values of this climatic indicator were found for each station. The maximum average value for winter is 22 cm at the Vinnytsia station, and the minimum is 16 cm at the Mohyliv-Podilskyi station. The minimum value at all stations is 0 cm. The maximum value – 59 cm was recorded at the Vinnytsia station.

It should be noted that the heights of the snow cover depend significantly on the relief conditions, they are redistributed by the wind and usually there is almost no connection between the decadal heights on the territory. The connection between the maximum decadal heights of the snow cover in winter is quite better expressed. Since the height of the snow cover has significant variability from year to year, the repeatability and availability of winters with different highest decadal snow cover heights are also calculated [18]. During the investigation the repeatability of winters with different maximum decadal height of snow cover was analyzed (Fig. 2). In the gradation of 0-5 cm, the largest value of 29% was recorded at the Mohyliv-Podilskyi station, and the minimum value is 4% and was determined for the Bilopillia station. In the gradation of 6-10 cm, the maximum value is 29% for the Haysyn station, the minimum for the Mohyliv-Podilskyi and Khmilnyk stations is 8%. In the gradation of 11-15 cm, the maximum value was recorded at the Bilopillia station and is 25%, the minimum at the Vinnytsia, Haysyn, Zhmerynka stations is 17%. Gradation of 16-20 cm has a maximum value of 17% at the Haysyn station, a minimum value of 4% at the Zhmerynka station. The gradation of 21-25 cm has a maximum value of 25% at the Zhmerynka station, and a minimum value of 4% at the Vinnytsia station. In the gradation of 26-30 cm, an insignificant maximum of 8%, which is observed at the Bilopillia station, at all other stations the repeatability is equal to 4%. In the gradation of 31-35 cm, the maximum repeatability was recorded at the Haysyn station - 17%, and the minimum value of 4% is characteristic of the Bilopillia station. The gradation of 36-40 cm has a maximum of 8% at Khmilnyk station. The maximum repeatability value of 13% for the gradation of 41-45 cm is characteristic of the Mohyliv-Podilskyi station. In the gradations of 46-50, 51-55 and 56-60 cm, cases of repeatability with a value of 4% were recorded. At all stations heights from 0 to 40 cm are almost 100% repeatable. And only at some stations 4% are characteristic for heights of 41-60 cm.

Some criteria of snow cover were developed according to the methodology adopted at the time in BSCGO (Boris Sresnevsky Central Geophysical Observatory). So, a day with a snow cover is taken as one when at least half of the visible district of the station is covered with snow. Such a snow cover is considered stable if it lies for at least a month with breaks of no more than three days in a row or at intervals; when a break of one day at the beginning of winter is preceded by a snow cover of at least 5 days, and a break of 2-3 days is preceded by at least 10 days. If during the winter there were several periods with stable snow cover, separated in time by no more than 5 days from each other, then the period from the first day with stable snow cover to the

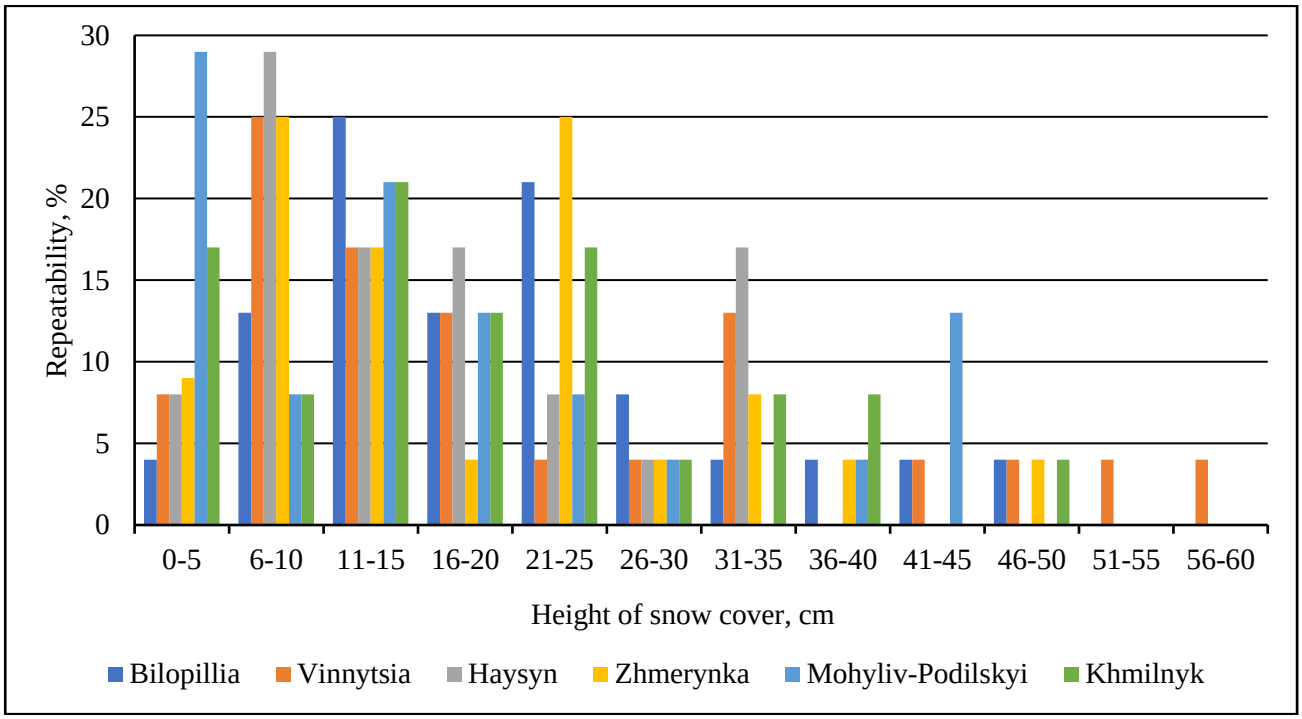

Fig. 2. Repeatability of winters with different maximum decadal height of snow cover at stations of Vinnytsia region (%)

last day of the winter is considered as a single period with stable snow cover. The average multi-year dates of formation and destruction of stable snow cover are calculated only in the case when the number of days with snow cover is more than 50% of all winters, and only for winters when there was only one period with stable snow cover. If at the end of winter, no more than 3 days after the snow cover has melted, a snow cover is formed again, which lies for at least 10 days, then its occurrence is considered continuous. All named dates of snow cover for each year are entered in the table, then the average dates are calculated and the extreme dates are chosen - the earliest and the latest dates [18]. There are the dates of the appearance and disappearance of the snow cover in the table 8.

Table 8

Dates of the appearance and disappearance of snow cover at the stations of the Vinnytsia region for the period 1996-2018

Station	Dates of the appearance of snow cover			Dates of the disappearance of snow cover		
	middle	the earliest	the latest	middle	the earliest	the latest
Bilopillia	20.11	25.10	11.12	27.03	3.03	24.04
Vinnytsia	14.11	20.10	6.12	3.04	8.03	25.04
Haysyn	24.11	25.10	11.12	22.03	27.02	24.04
Zhmerynka	22.11	24.10	20.12	27.03	25.02	24.04
Mohyliv-Podilskyi	25.11	24.10	26.12	20.03	26.01	23.04
Khmilnyk	19.11	13.10	9.12	26.03	22.02	23.04

So, we can see that at the stations of Vinnytsia, the average dates of the appearance of snow cover were found in November. The indicators range from November 14 in Vinnytsia to November 25 at the Mohyliv-Podilskyi station. We record the earliest dates of appearance in October - October 13 at the Khmilnyk station, which is located in the southern part of the region, and October 25 in the northern and central regions of the region at the stations of Bilopillia and Haysyn accordingly. The latest dates for the appearance of the cover were determined in December - at Vinnytsia station on December 6 and December 26 at Mohyliv-Podilskyi.

The average dates of the beginning of the snow cover for the stations of the Vinnytsia region are determined in the period from the second decade of March (Mohyliv-Podilskyi) to the first decade of April (Vinnytsia). The earliest date of snow disap-

pearance was found on January 26 (Mohyliv-Podilskyi), during February snow is destroyed at other stations, and in the northern part of the region we record the earliest dates of snow disappearance in the first decade of March (Bilopillia, Vinnytsia). The latest dates were recorded in the period of April 23-25.

An interesting question is whether a stable snow cover was formed at the stations of Vinnytsia during the investigation period? The received results are shown in the table 9.

Calculations make it possible to claim that in the Vinnytsia region, the formation of a stable snow cover occurs in the second and third decades of De-

Table 9

Dates of formation and destruction of stable snow cover at stations of the Vinnytsia region for the period 1996-2018

Station	Dates of formation of stable snow cover			Dates of destruction of stable snow cover			Percentage of winters with no stable snow cover
	middle	the earliest	the latest	middle	the earliest	the latest	
Bilopillia	20.12	13.11	6.02	21.02	20.12	9.04	13
Vinnytsia	22.12	13.11	20.01	14.02	17.12	4.04	8
Haysyn	24.12	12.11	6.02	12.02	15.12	20.03	17
Zhmerynka	20.12	12.11	9.02	16.02	17.12	30.03	17
Mohyliv-Podilskyi	25.12	13.11	6.02	9.02	1.01	16.03	33
Khmilnyk	21.12	12.11	9.02	19.02	20.12	6.04	17

cember, which is defined as average indicators. The earliest dates of the formation of the stability of the cover were found on November 12-13. Such almost simultaneous formation in accordance with the earliest dates is not characteristic of the latest dates, when the stability of the cover was formed from the second decade of January to the first decade of February. The average indicators of stable snow cover destruction range from February 9 to February 21, with the earliest dates recorded in December-January, and the latest in March-April.

An important indicator of snow cover distribution is the percentage of winters with no stable snow cover. On the territory of the Vinnytsia region, changes in this characteristic were found in the range from 8% (Vinnytsia) to 33% (Mohyliv-Podilskyi). At almost all other stations the percentage of winters with no stable snow cover is 17%.

Conclusions. The analysis of the spatio-temporal distribution of snow cover for the period 1996-2018 makes it possible to describe certain features of the formation of snow cover in the territory of Vinnytsia region:

- the snow cover in Vinnytsia region forms in the third decade of October, with the exception of Vinnytsia and Khmilnyk stations, where the appearance of snow cover begins in the second decade of October; the snow disappearance is happening in the third decade of April throughout the region;
- decadal heights of the snow cover have the maximum repeatability in the gradation from 0 to 5 cm;
- average decadal heights with the largest values from 10 to 13 cm were found in January and February at the stations of Bilopillia, Vinnytsia and Khmilnyk;
- the formation of stable snow cover on the territory of Vinnytsia region occurs in the second decade of November; the destruction was recorded from the second decade of March to the first decade of April.

Bibliography

1. *Грей, Д. М. Снег : справочник [Текст] / Д. М. Грей, Д. Х. Мейл. – Л.: Гидрометеоиздат, 1986. – 689 с.*
2. *Настанова гідрометеорологічним станціям і постам. Випуск 3. Частина І. Метеорологічні спостереження на станціях [Текст] / УкрНДГМІ, ЦГО. – К. : Державна гідрометеорологічна служба, 2011. – 280 с.*
3. *Nedostrelova, L. Dynamics of snow cover in the Kirovohrad region at the end of the XX and the beginning of the XXI centuries [Text] / L. Nedostrelova // Journal of Geology, Geography and Geoecology. – 2021. – 30(1). – P. 133–144 doi: https://doi.org/10.15421/112112*
4. *Недострелова, Л. В. Особливості формування снігового покриву на території центральної і південної України в умовах сучасних змін клімату [Текст] : монографія / Л. В. Недострелова. – О. : ОДЕКУ, 2022. – 150 с.*
5. *Кліматичні ризики функціонування галузей економіки України в умовах змін клімату [Текст] : монографія / за ред. С. М. Степаненка, А. М. Польового. – О. : ОДЕКУ, 2018. – 548 с.*

6. *Giorgi F. Addressing climate information needs at the regional level: the CORDEX framework [Text] / Filippo Giorgi, Colin Jones, Ghassem, R. Asrar // WMO Bulletin. – 2009. – No. 58 (3). – P. 175–183.*
7. *Physical processes (CY23R4) [Text] / P.W. White // Technical report European Centre for Medium-Range Weather Forecasts (ECMWF). – 2001.*
8. *WMO, 2009: Experts agree on a universal drought index to cope with climate risk [Електронний ресурс] / Press Release. – 2009. – No. 872. Режим доступу: http://www.wmo.int/pages/mediacentre/press_releases/pr_872_en.html.*
9. *Хохлов В. М. Просторово-часова мінливість посух в Східноєвропейському секторі в умовах глобальних змін клімату [Текст] / В. М. Хохлов, Н. С. Єрмоленко // Український гідрометеорологічний журнал. 2012. – №11. – С. 128-134.*
10. *Замфірова М. С. Режим температури повітря та опадів в Україні в 2021-2050 роках за даними ансамблю моделей CORDEX [Текст] / М. С. Замфірова, В. М. Хохлов // Український гідрометеорологічний журнал. 2020. – № 25. – С. 17-27. https://doi.org/10.31481/uhmj.25.2020.02*
11. *Польовий, А.М., Божко, Л.Ю. Довгострокові агрометеорологічні прогнози [Текст] : підручник / А. М. Польовий, Л. Ю. Божко. – К. : КНТ, 2007. – 296 с.*
12. *Польовий, А.М. Сільськогосподарська метеорологія [Текст] : підручник / А. М. Польовий. – О. : ОДЕКУ, 2012. – 629 с.*
13. *Врублевська, О. О. Клімат України та прикладні аспекти його використання [Текст] : навч. пос. / О. О. Врублевська, Г. П. Катеруша. – О. : ТЕС, 2012. – 180 с.*
14. *Клімат України [Текст] : монографія / за ред. В. М. Ліпінського, В. А. Дячука, В. М. Бабіченко. – К. : Видавництво Раєвського, 2003. – 343 с.*
15. *Корнус, А. О. Характеристика снігового покрову Сумської області за результатами спостережень 2005-2017 років [Текст] / А. О. Корнус, І. О. Лисенко // Географічні науки. – 2017. – Випуск 8. – С. 3–6.*
16. *Недострелова, Л. В. Дослідження статистичних характеристик розподілу снігового покриву для Причорномор'я [Текст] / Л. В. Недострелова // Вісник Одеського національного університету. Серія: Географічні та геологічні науки. 2017. – Том 22, Випуск 1(30). – С. 27–38.*
17. *Кліматичні ресурси Одеської області для сталого розвитку: науково-практичний довідник [Текст] / за ред. Ж. В. Волошиної. – О. : Держ. гідрометслужба України, 2010. – 180 с.*
18. *Врублевська, О. О. Кліматична обробка окремих метеорологічних величин. Навчальний посібник [Текст] / О. О. Врублевська, Г. П. Катеруша, Н. К. Миротворська. – О. : ТЕС, 2004. – 150 с.*
19. *Недострелова, Л. Дослідження повторюваності декадної висоти снігового покриву по декадах на території Вінницької області [Текст] / Л. Недострелова, Д. Громенко // Polish international science journal. – 2019. – Issue 19. – С. 16-22.*
20. *Громенко, Д. Є. Аналіз кліматичних параметрів снігового покриву на території Вінницької області [Текст] / Д. Є. Громенко, Л. В. Недострелова // Вестник ГМЦ ЧАМ. – 2019. – Випуск 23. – С. 34-41.*
21. *Еколого-географічна характеристика Вінницької області [Електронний ресурс] / Режим доступу http://www.geograf.com.ua/geoinfocentre/20-human-geography-ukraine-world/267-ref22041101*
22. *StudFiles [Електронний ресурс] / Режим доступу https://studfile.net/preview/5375473/page:2/*

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References

1. *Grey, D. M., Meyl, D. KH. (1986). Snow: reference book. Leningrad, Gidrometeoizdat, 689.*
2. *Installation of hydrometeorological stations and posts. Issue 3. Part I. Meteorological warnings at stations (2011). UkrNDHMI, TSHO. Kyiv, Ukraine: Derzhavna hidrometeorolohichna sluzhba, 280. [in Ukrainian]*
3. *Nedostrelova, L. (2021). Dynamics of snow cover in the Kirovohrad region at the end of the XX and the beginning of the XXI centuries. Journal of Geology, Geography and Geoecology, 30(1), 133–144. doi: https://doi.org/10.15421/112112*
4. *Nedostrelova, L. V. (2022). Features of the formation of snow cover in the territory of central and western Ukraine in the minds of current climate changes. Odesa : Publ. ODEKU, 150. [in Ukrainian]*
5. *Stepanenko, S. M. & Poliovyi, A. M. (eds) (2018). Climatic risks of the functioning of the Ukrainian economy in the minds of climate change.Odesa : Publ. ODEKU, 548. [in Ukrainian]*
6. *Giorgi, Filippo, Jones, Colin, Asrar, Ghassem. (2009). Addressing climate information needs at the regional level: the CORDEX framework. WMO Bulletin. 58(3), 175–183.*
7. *White, P. W. (2001). Physical processes (CY23R4). Technical report European Centre for Medium-Range Weather Forecasts (ECMWF).*
8. *WMO, 2009: Experts agree on a universal drought index to cope with climate risk. Available at : http://www.wmo.int/pages/mediacentre/press_releases/pr_872_en.html.*
9. *Khokhlov, V. M. & Yermolenko, N. S. (2012). Spacious-hourly dryness in the Northern European sector in the minds of global climate change. Ukrayins'kyy hidrometeorolohichnyy zhurnal, 11, 128–134. [in Ukrainian]*

10. Zamfirova, M. S. & Khokhlov, V. M. (2020). Regime of temperature and precipitation in Ukraine in 2021-2050 according to the ensemble of CORDEX models. Ukrayins'kyy hidrometeorolohichnyy zhurnal, 25, 17-27. https://doi.org/10.31481/uhmj.25.2020.02[in Ukrainian]
11. Poliovyi, A. M., Bozhko, L. YU. (2007). Long-term agrometeorological forecasts. Kyiv, Ukraine : Publ. KNT, 296. [in Ukrainian]
12. Poliovyi, A. M. (2012). Agricultural meteorology. Odesa : Publ. ODEKU, 629. [in Ukrainian]
13. Vrublevs'ka, O. O. & Katerusha, H. P. (2012). The climate of Ukraine and applied aspects of its use. Odesa : Publ. TES, 180. [in Ukrainian]
14. Lipins'kyi, V. M., Dyachuk, V. O., Babichenko, V. M. (2003). Climate of Ukraine. Kyiv, Ukraine: Publ. Rayevs'koho, 343. [in Ukrainian]
15. Kornus, O. O. & Lysenko, I. O. (2017). Characteristics of snow cover in the Sumy region based on the results of monitoring 2005-2017. Heohrafichni nauky, 8, 3–6. [in Ukrainian]
16. Nedostrelova, L. V. (2017). Further research on the statistical characteristics of the distribution of snow cover for the Black Sea region. Visnyk Odes'koho natsional'noho universytetu. Seriya: Heohrafichni ta heolohichni nauky, 1(30), 27–38. [in Ukrainian]
17. Voloshyna, Zh. V. (Ed). (2010). Climatic resources of Odessa region for sustainable development: a scientific and practical guide. Odesa: State Hydrometeorological Service of Ukraine. [in Ukrainian]
18. Vrublevs'ka, O. O., Katerusha, H. P., Myrotvors'ka, N. K. (2004). Climatic analysis of certain meteorological quantities. Odesa : Publ. TES, 150. [in Ukrainian]
19. Nedostrelova, L., Hromenko D. (2019). Research on the repeatability of the ten-day height of snow cover over decades in the territory of the Vinnytsia region. Polish international science journal, 19, 16-22. [in Ukrainian]
20. Hromenko, D. YE., Nedostrelova, L. V. (2019). Analysis of climatic parameters of the snow cover on the territory of the Vinnytsia region. Visnyk HMTS CHAM, 23, 34-41. [in Ukrainian]
21. Ekoloho-heohrafichna kharakterystyka Vinnyts'koyi oblasti. Available at : http://www.geograf.com.ua/geoinfocentre/20-human-geography-ukraine-world/267-ref22041101
22. StudFiles. Available at : https://studfile.net/preview/5375473/page:2/

Аналіз просторово-часового розподілу снігового покриву на території Вінницької області

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В статті наведено аналіз розподілу снігового покриву і надано особливості його формування наприкінці XX і початку XXI століть на території Вінницької області. Сніговий покрив суттєво впливає на галузі економіки України. Найбільш чутливим до особливостей формування снігового покриву є сільське господарство, особливо, коли мова йде про перезимівлю озимих культур. Одним із основних агрометеорологічних факторів, що визначають перезимівлю озимини є висота снігу, її просторова та часова мінливість, строки встановлення та сходу снігового покриву. Метою роботи є встановлення особливостей просторово-часового розподілу снігового покриву на території Вінницької області за період 1996-2018 рр. В якості вихідної інформації використано дані щоденних метеорологічних спостережень за висотою снігового покриву на метеорологічних станціях Вінницької області. Для характеристики висоти снігового покриву обчислюють середні значення її не для місяців, а для декад зимових місяців. За даними про розподіл висоти снігового покриву розраховано декадні висоти та їх повторюваність по декадах для кожної станції за період з 1996 по 2018 роки. Аналіз просторово-часового розподілу снігового покриву дає можливість описати певні особливості формування снігового покриву на території Вінницької області: сніговий покрив на Вінниччині формується в третій декаді жовтня за виключенням станцій Вінниця і Хмільник, де виникнення снігового покриву починається з другої декади жовтня; сходження снігу відбувається в третій декаді квітня по всій території області; декадні висоти снігового покриву мають найбільшу повторюваність в градації від 0 до 5 см; середні декадні висоти з найбільшими значеннями від 10 до 13 см виявлено в січні і лютому на станціях Білопілля, Вінниця і Хмільник; формування стійкого снігового покриву на території Вінницької області відбувається в другій декаді листопада; руйнування зафіксовано з другої декади березня до першої декади квітня.

Ключові слова: *сніговий покрив, декадна висота снігового покриву, дати появи і сходу снігового покриву, стійкий сніговий покрив.*

Внесок авторів: всі автори зробили рівний внесок у цю роботу
Конфлікт інтересів: автори повідомляють про відсутність конфлікту інтересів

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