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MODELING THE DISTRIBUTION OF MEAN MAX HAIL DAMAGE TO VINEYARDS ON THE TERRITORY OF MUNICIPALITIES OF KAKHETI (GEORGIA) USING DATA OF THE ZERO ISOTHERM IN THE ATMOSPHERE AND RADAR MEASUREMENTS

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Abstract. *Results of modeling the distribution of monthly mean max hail damage to vineyards (HDV) and their 99% values of the upper levels (HDV_Upp) on the territories of 8 municipalities of Kakheti (Georgia) are presented. Calculations have been carried out using data of the freezing level in the atmosphere and radar measurements of hail max sizes in clouds. The agricultural area of Kakheti (7050 km^2) was divided into 290 squares, with the range of heights – 0.21 ÷ 1.19 km. Period of investigation – from April to September. For example map of the distribution of HDV on the territory of Kakheti for April and June has been built. Data on the statistical characteristics of HDV and HDV_Upp from April to September are presented for each municipality.*

Key Words: Dangerous meteorological processes, empirical modeling, hail damage assessment, radar monitoring.

Introduction

Georgia is one of the most hail-prone countries in the world in terms of hail damage. In this regard, the problem of hail in our country is given special attention. Over many decades, including in recent years, a large number of works have been published covering a wide range of studies, including hail climatology [1-5], radar observations of hail processes [6-8], etc. To solve various problems of scientific or applied significance (the impact of climate change on hail processes, comparison of experimental data on hail processes with theoretical models of hail processes, assessment of expected damage from hail processes, planning of work on active influence on hail processes, etc.), detailed information on the spatio-temporal characteristics of hail distribution and its sizes at various points is necessary. In accordance with the above, in addition to the conducted studies, work was carried out on empirical modeling of the distribution of hailstones by average maximum diameter (D) in the territory of Kakheti (Georgia) using data on the freezing level in the atmosphere and radar measurements of the maximum sizes of hailstones in clouds [9-12]. These studies subsequently made it possible to assess the damage to some crops from hail processes in Georgia and Azerbaijan (using the example of May 28 and July 13, 2019) [13], as well as to model the distribution of mean monthly maximum values of damage to vineyards from hail in the territory of Kakheti [14].

The presented work is a continuation of the previous study [14]. Results of modeling the distribution of monthly mean max hail damage to vineyards and their 99% values of the lower and upper levels on the agricultural area of 8 municipalities of Kakheti from April to September are presented below.

Study area, material, and methods

Study area – 8 municipalities of the Kakheti region of Georgia (Akhmeta, Dedoplistskaro, Gurjaani, Kvareli, Lagodekhi, Sagarejo, Sighnaghi, Telavi).

Data of meteorological radar "METEOR 735 CDP 10 – Doppler Weather Radar" of Anti-hail service of Georgia about the max diameter of hailstones in the clouds (cm) are used (radar product HAILSZ) [15]. The

expected diameter of hailstones falling out to the earth's surface according to the Zimenkov-Ivanov model of hail melting in the atmosphere [9, 11] by taking into account the radar data about their maximum diameter in the clouds and freezing level in the atmosphere, was calculated [12]. Period of observation: April-September, 2016-2019. The degree of damage to vineyards, depending on the size of the fallen hail, was determined by compiling data on damage to these crops at different hail kinetic energy [16] and data on the average kinetic energy of hail of various sizes according to TORRO Hail Scale [https://www.torro.org.uk/research/hail/hscale].

Based on this compilation, regression equations were obtained for the relationship between the degree of damage to this crop (HDV) and the size of hailstones, which has the form of a sixth power of polynomial [13]. Calculations were carried out for the agricultural territory of Kakheti (7050 km^2), divided into 290 squares. Altitude range – 0.21 ÷ 1.19 km.

For the data analysis, the standard statistical methods are used. The following designations of statistical information are used below: Mean – average values; Min – minimal values; Max – maximal values; 99%_Upp – 99% of upper levels of the mean (below – Upp); H – altitude above sea level, km.

Results

Results in Fig. 1-2 and Table 1 are presented.

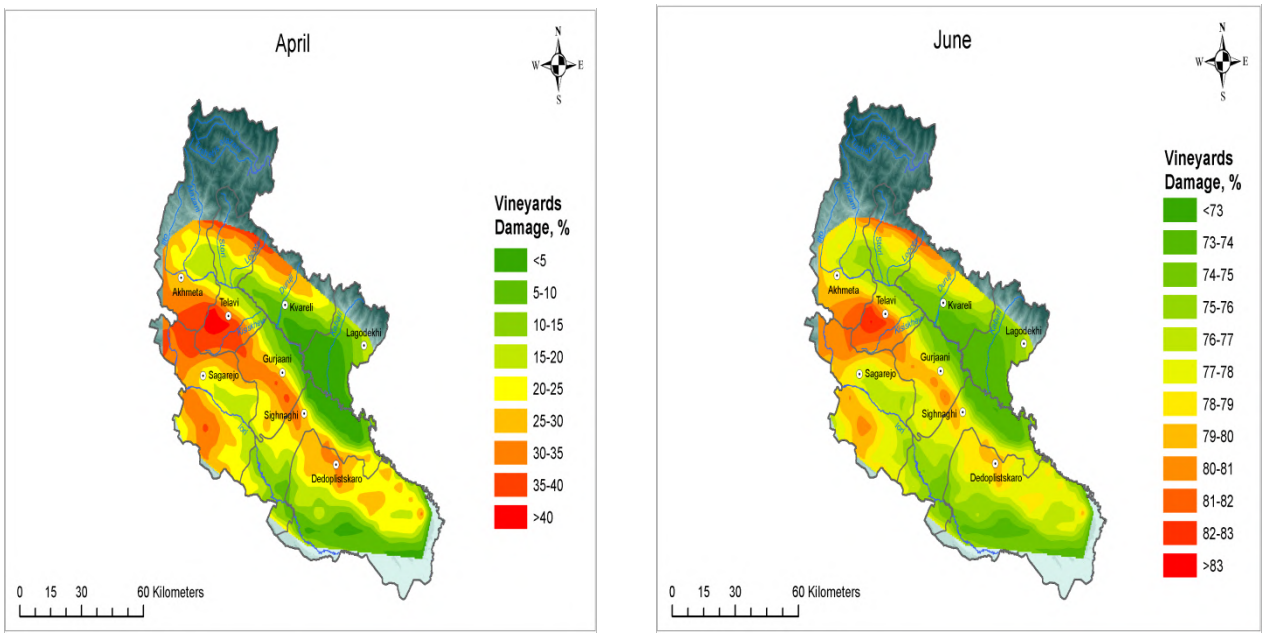

Fig. 1. Distribution of mean maximum hail damage to vineyards on the agricultural area of Kakheti in April and June.

In Fig. 1, examples of distribution of mean maximum hail damage to vineyards in the agricultural area of Kakheti in April and June are presented. In particular, as follows from these figures, the mean max of HDV in the study area is quite heterogeneous and varies from 0% to 43.3% (April) and from 73.0% to 83.1% (June). Similar pictures for other months are observed.

In Table 1 the statistical characteristics of mean maximum damage to vineyards from hail in the agricultural area of 8 municipalities of Kakheti from April to June is presented.

In particular, Table 1 shows that the variability of the mean maximum of HDV on the territory of 8 municipalities of Kakheti is as follows:

HDV_Mean. 0.0 % (August, all municipalities) ÷ 83.1% (June, Telavi municipality).

HDV_Upp. 44.3 % (August, Lagodekhi and Sighnaghi municipalities) ÷ 92.2 % (June, Telavi municipality).

The average seasonal (April – September) values of HDV_Mean and HDV_Upp for the municipalities of Kakheti are, respectively. Akhmeta: 50.5 and 74.8 %; Dedoplistskaro: 48.9 and 73.8 %; Gurjaani: 51.6 and 75.6 %; Kvareli: 47.9 and 73.1 %; Lagodekhi: 44.8 and 71.0 %; Sagarejo: 52.2 and 76.1 %; Sighnaghi: 48.2 and 73.3 %; Telavi: 52.8 and 76.8 %.

Table 1. The statistical characteristics of mean maximum damage to vineyards from hail in the agricultural area of 8 municipalities of Kakheti from April to June (%).

Month		April		May		June		July		August		September	
Variable	H	Mean	Upp	Mean	Upp	Mean	Upp	Mean	Upp	Mean	Upp	Mean	Upp
Munic.	Akhmeta												
Mean	0.58	22.9	58.6	67.2	77.7	77.3	87.5	68.0	84.5	0.0	54.5	67.7	86.2
Min	0.43	15.2	56.0	65.0	76.2	75.6	86.3	65.5	83.1	0.0	50.7	65.4	85.0
Max	0.77	30.8	61.4	69.7	79.5	79.3	88.9	70.9	86.2	0.0	58.8	70.3	87.6
Munic.	Dedoplistskaro												
Mean	0.50	18.1	57.1	65.9	76.9	76.4	86.8	66.6	83.8	0.0	52.4	66.4	85.5
Min	0.22	0.0	52.2	61.7	74.0	73.1	84.6	61.7	81.1	0.0	44.7	61.9	83.2
Max	0.83	33.0	62.3	70.4	80.0	79.8	89.3	71.8	86.7	0.0	60.0	71.1	88.0
Munic.	Gurjaani												
Mean	0.65	25.6	59.6	68.1	78.4	78.0	88.0	69.1	85.1	0.0	56.1	68.7	86.7
Min	0.36	11.2	54.9	64.0	75.6	74.9	85.7	64.3	82.5	0.0	49.0	64.3	84.4
Max	0.93	36.4	63.8	71.7	80.9	80.8	90.1	73.2	87.5	0.0	62.1	72.5	88.8
Munic.	Kvareli												
Mean	0.45	15.3	56.2	65.2	76.4	75.8	86.4	65.7	83.3	0.0	51.0	65.6	85.1
Min	0.26	3.6	52.9	62.3	74.4	73.6	84.9	62.3	81.5	0.0	45.8	62.6	83.5
Max	0.70	28.4	60.5	68.8	78.9	78.6	88.4	69.9	85.6	0.0	57.4	69.5	87.1
Munic.	Lagodekhi												
Mean	0.29	6.0	53.6	62.9	74.8	74.0	85.2	63.0	81.8	0.0	46.8	63.2	83.8
Min	0.21	0.0	52.0	61.5	73.9	73.0	84.5	61.4	81.0	0.0	44.3	61.7	83.1
Max	0.51	19.9	57.5	66.2	77.1	76.6	86.9	67.0	83.9	0.0	53.0	66.7	85.6
Munic.	Sagarejo												
Mean	0.69	27.5	60.2	68.6	78.8	78.5	88.3	69.7	85.5	0.0	57.0	69.2	87.0
Min	0.44	16.2	56.3	65.2	76.4	75.8	86.4	65.8	83.3	0.0	51.2	65.7	85.1
Max	0.95	37.0	64.1	71.9	81.1	81.0	90.3	73.5	87.7	0.0	62.5	72.7	88.9
Munic.	Sighnaghi												
Mean	0.47	16.0	56.5	65.4	76.6	76.0	86.5	66.0	83.4	0.0	51.4	65.9	85.2
Min	0.21	0.0	52.0	61.5	73.9	73.0	84.5	61.4	81.0	0.0	44.3	61.7	83.1
Max	0.97	37.5	64.3	72.1	81.2	81.2	90.4	73.7	87.9	0.0	62.8	72.9	89.1
Munic.	Telavi												
Mean	0.75	28.7	60.9	69.2	79.2	78.9	88.7	70.4	85.9	0.0	57.9	69.9	87.4
Min	0.42	14.6	55.8	64.8	76.1	75.5	86.2	65.3	83.0	0.0	50.4	65.2	84.9
Max	1.19	43.3	67.1	74.6	83.0	83.1	92.0	76.4	89.6	0.0	66.6	75.4	90.6

Conclusion

In the future, we plan to conduct modeling and build maps of the extent of hail damage to wheat and corn in Kakheti and its municipalities in different months of the year. We also plan to conduct model assessments of damage from hail and other crops. As new experimental data is obtained, we plan to further refine the results obtained.

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