UDC: 628.512:504.3(497.11)
DOI: 10.2298/IJGI1303239N

ATMOSPHERIC NATURAL DISASTERS IN SERBIA - MANAGEMENT EXPERIENCE AND ECONOMIC EFFECTS

Jugoslav Nikolić[1], Djordje Nikolić**, Miroljub Mitić****
* Republic Hydro-Meteorological Institute of Serbia/Geographical Institute "Jovan Cvijić" SASA, Belgrade
** UNION University - Nikola Tesla, Faculty of Ecology and Environmental Protection, Belgrade
*** Republic Hydro-Meteorological Institute of Serbia, Belgrade

Received 26 August 2013; reviewed 11 September 2013; accepted 01 October 2013

Abstract: Natural disasters occur as a result of an action of natural forces and represent limitations in spatial planning and efficient spatial development, with different consequences in terms of scope on humans, living things and tangible property. Consequences can be ecological, economic, in terms of health, demographic, social, psychological, etc. Weather modification management involves policies, methods, techniques and technologies that affect atmospheric features in order to make atmospheric water useful for humans, while eliminating its negative effects. Highly significant risk of natural disasters in Serbia is related to hailstorm disasters and droughts as atmospheric elementary disasters. The goal of this paper is to present certain methodologies and experience in Serbia in the weather modification management, mainly in the hailstorm processes. This paper provides analysis and critical review of the methodology of an action, with the analysis of the economic benefits. Cost-benefit analysis of a hail suppression project in Serbia was performed. The results point to the economic justification of some aspects of artificial influence on weather disasters.

Keywords: atmospheric hazards, storms with hail, management, economic effects

Introduction

Atmospheric natural disasters encompass hailstorm disasters, droughts, heavy rainfall or snowfall, extreme temperatures, frost, black ice, fog etc. The greatest interest in Serbia refers to artificial influence on hailstorms, stimulation of precipitation, fog dispersion and prevention of the adverse effects of frost. Highly significant risk of natural disasters in Serbia relates to hailstorm disasters and droughts as atmospheric elementary disasters. The goal of this paper is to present certain methodologies and experience in Serbia in the weather modification management, mainly in the hailstorm processes.

[1] Correspondence to: jugoslav.nikolic@hidmet.gov.rs

In Serbia, hailstorm suppression on contemporary basis began in 1967 organized by the Republic Hydrometeorological Service of Serbia. Consequently, there is 45 years of experience regarding effects on hailstorms in Serbia.

The estimation of the efficiency of a hail suppression project in Serbia is especially significant when considered in the light of very high investments in the operative implementation and development of the project, the starting point being the fact that the investments are economically justified if their value is smaller than or equal to the value of the agricultural production preserved by those investments.

In contemporary scientific practice, the estimation of hail suppression efficiency includes the following aspects:

– estimation of physical efficiency;
– numerical modeling of hailstorms;
– estimation of statistical efficiency of protection;
– estimation of economic effects of hail protection.

Estimation of physical efficiency of hail protection aims at determining the difference between the natural and modified characteristics of hail clouds and hailstones occurring from the moment of cloud seeding until the termination of the storm.

Numerical modeling of hailstorms entails the simulation of the development of clouds and hail processes within those clouds, along with the simulation of artificial cloud seeding using the crystallization reagents. Numerical modeling produces cloud models, which provide realistic representations of the natural process of hailstone formation. Real efficiency indices for the applied methodology of hail processes modification can be obtained by combining real physical measurements with contemporary 3-D models.

Statistical efficiency estimation is performed on the basis of a data series representing hail-induced losses before and during the hail suppression activities. Average, minimum and maximum values of hail damage calculated by comparing statistical data on hail damage show whether there has been a decrease of losses in agricultural production.

The main input data this method is based upon are the following: extent of damage to agricultural crops, damaged area and statistically examined area. A control area allows for a comparative analysis to be performed and the conclusions on the hail protection system efficiency to be drawn.

Economic estimation of hail suppression effects determines and specifies the cost-benefit differences achieved by the hail suppression activities. Such estimation is performed by using the following data:

- – costs of hail protection activities;
- – data on agricultural production;
- – value of crops;
- – damage caused to agricultural crops, etc.

Based on these and derived parameters, it is possible to determine whether it is justifiable to invest in the operative implementation and development of the hail suppression system.

Research and control of the business activities within a hail suppression project represent a significant theoretical and methodological, as well as a practical problem, the solution of which should provide managing bodies with the guidelines for the corrective actions in the current period and for determining possible directions of the project's further development. Therefore, the model for measuring the business success of a hail suppression project should improve the management activity, and, consequently, enhance efficiency and effectiveness of the project as a whole. In accordance with the above, on the basis of the cost-benefit analysis, an investment feasibility study for a hail suppression project will be performed in further text.

The main characteristic of this method lies in the evaluation of all the advantages and all the deficiencies of a certain project, which leads to the final judgment about its financial effects. This evaluation is based on a systematic aggregation of all the financial resources necessary for project realization, on the one hand, and of all the benefits obtainable from the project, on the other.

Methodology

Hail is relatively frequent meteorological phenomenon in Serbia produced by storm clouds called cumulonimbus clouds, whose appearance is related to the warmer half of the year. The hailstorm suppression system is based on an appropriate methodology and operational procedures.

Problem regarding action with the goal of process modification in hailstorm clouds is enormous energy that these clouds release, which is comparable with the energy of one megaton thermonuclear bomb. This means that we cannot resist the natural processes of hail formation with artificially produced energy, heat for example, therefore we must seek a way to accomplish large effects with small effort. That method was found in the possibility of artificial effects on microphysical processes in clouds.

The idea of an artificial effect is that by throwing the reagent, more exactly artificial nuclei crystallization, in particular cloud zones, increases the number of hail embryos, compared to a natural state. Increasing the concentration of hail embryos leads to competition for the available liquid water in the cloud, which prevents ice particles to grow too much. In such a way, instead of creating a smaller number of large embryos by natural processes, there is stimulation for formation of a sufficient number of smaller hail embryos, which are dissolved before they reach the Earth's surface.

Methodology for hail suppression in Serbia is based on radar identification of convective clouds and inserting of reagent based on silver iodide using a missile system in certain areas of hailstorm clouds in order to gain effect on microphysical processes.

The principal methods for the evaluation of hail suppression can be expressed through the following two criteria:

– present value of net benefit criterion;
– cost-benefit relation coefficient.

The present value of net benefit criterion (Kns) equals the difference between total benefits and total costs of a hail suppression project, that is:

$$\text{Kns} = \text{Ks} - \text{Ts}, \qquad (1)$$

where:

Ks = Total benefit of a hail suppression project;

Ts = Total costs of a hail suppression project.

The evaluation of a hail suppression project according to this criterion presupposes a positive difference between the indicated values, that is:

$$\text{Kns} > 0 \qquad (2)$$

This difference indicates, in fact, the positive effects of a hail suppression project.

The cost-benefit relation coefficient, K, is represented by the relation between benefits and total costs of the hail suppression project. At the same time, it indicates how much benefit may be obtained from each unit of the resources invested in the hail suppression project, and it may be expressed in the following way:

$$K = \frac{Ks}{Ts} \qquad (3)$$

According to this coefficient, the hail suppression project is efficient and financially legitimate if its value is higher than 1 (K>1).

This coefficient is very suitable for practical application due to its simplicity.

Data and results

Without area of Kosovo and Metohija Serbia is currently defending the total area of 7.75 million hectares out of which agricultural land encompasses 5.106 million hectares. Territorial development of the hail suppression system in Serbia, through gradual increase in the defended area, is represented in Figure 1.

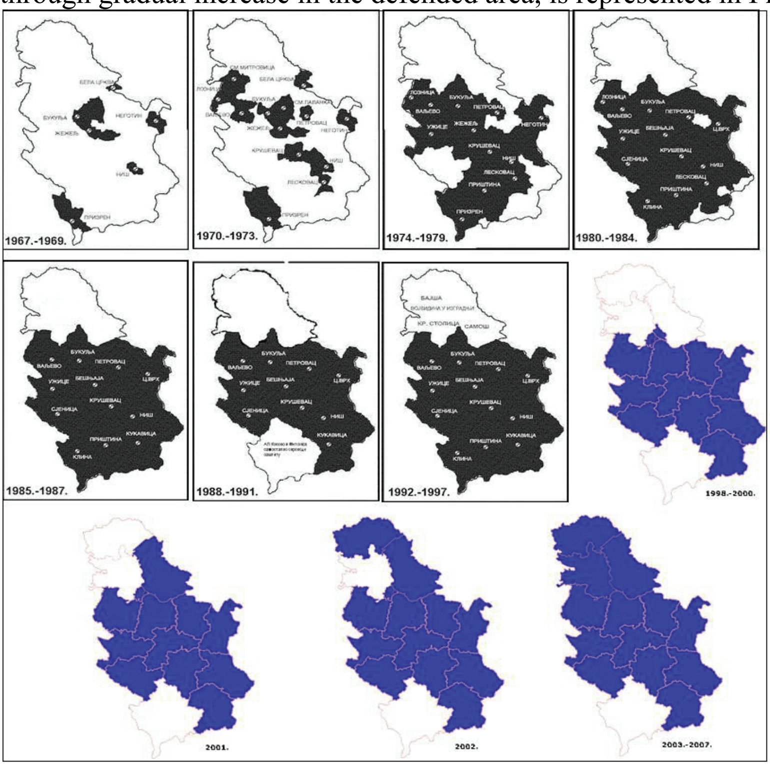

Figure 1. Territorial development of the hail suppression system in Serbia

The lower base of cumulonimbus clouds is low and is located on the positive air temperatures, while top of the cloud can be on temperatures lower than - 50 ^{0}C. The action is performed on front of the cloud, in relation to the direction of movement, by seeding an area that is located in the temperature interval of -4 ^{0}C to -12 ^{0}C.

The contemporary system of hail suppression in Serbia is comprised of:

- Operational-methodological center that coordinates the work of the entire system;
- Radar centers;
- Anti-hail stations;
- Telecommunication system.

One of radar centers located in the area of Sjenica was shown in Figure 2. At each radar center there is a meteorological radar and a typical operating room (Figure 3), where three workstations are placed.

Figure 2. Radar center "Sjenica"

Figure 3. Work area of the radar center

The main workstation controls work of the radar, collects and processes data, the second workstation is for determining seeding zone, and third workstation is for work with shooters - more exactly determination of commands for an action.

Typical anti-hail station consists of two small objects and a rocket launcher (Figure 4). In one structure rockets are placed, and from the other one rocket launch is electrically performed.

Figure 4. Anti-hail station

From multi-pipe launchers, by command from the radar center, elements are set for rocket launching: direction and elevation. For each type of rocket determined ballistic curves exist for different elevations.

Telecommunication system consists of:

- Radio-link for communication between the main operational and methodological center and radar centers:
- Radio-link with the regional air traffic control;
- Network of technical devices with radio-stations for communication between radar centers and shooters on anti-hail station.

According to statistical analysis of professor Radinovic (Radinovic, 1989; Radinovic, 1993) the efficiency of hail suppression system in Serbia is in the range of 63% to 74%, while a research of professor Mesinger (Mesinger, 1992) shows that during the operation of the hail suppression system frequency of hail appearance is reduced by 15% to 20%. The analyses of Mitic (Mitic 2006, Mitic 2007, Mitic 2009) illustrate the economic effects of the hail suppression system in Serbia.

In addition to hail, drought is the atmospheric elementary disaster with the greatest consequences in Serbia. Hail suppression system can be used in the future, among other things, to stimulate precipitation. In the past there have been attempts to stimulate precipitation by seeding with the help of generator at the ground, however the efficiency was low. Airplane or rocket seeding is a contemporary system with greater efficiency.

Cost-benefit analysis of the hail suppression project in Serbia

The data used in the analysis enable the objective deduction about the project efficiency. The period of 39 years, from 1972 to 2010, is long enough to show all the particularities in the behavior of all phenomena, while the effects of natural oscillation of the frequency and intensity of hailstorms, which in the short-term analysis may significantly influence the final effects, have been excluded.

The hail damages were measured by a commission, according to the established methodology, so it may be concluded that the percentage of the damage of agricultural crops caused by hail was determined objectively. Likewise, during the damage estimation, even those damages caused by the loss of crop quality in the areas partially damaged by hail were taken into consideration.

The damages that hail causes to agricultural crops represent a loss in the quality or quantity of the damaged crops yield. The scope of the damages depends on hail intensity, hail sensitivity of agricultural crops, their ability to regenerate, development stages of plants, weather conditions before and after hail, and the application of agro-technical measures.

A quality methodology for the estimation of the damage hail caused to agricultural crops is used in the Republic of Serbia. The percentage of damage caused to agricultural crops, size of the damaged area and potential crop yield that would be obtained in the absence of hail damage are the parameters determined when performing the final estimation of hail damage. The mentioned agricultural crops damages are expressed in percentages, with the plants being able to completely or largely recover from hail damage in the cases when the damage is minor or in the later stages of plant development. Contrary to that, if the percentage of damage is high, plants are entirely or largely destroyed, which significantly or completely decreases agricultural income.

Absolute hail damage includes all damages hail caused to the plant throughout the year, regardless of the damage degree. These damages also comprise multiple damages of the plants growing in the same area, which can, in a way, indicate that the damage was greater than the actual.

By reducing absolute damage to 100% damage, the possibility is created to compare total damage with different degrees of damage and to directly relate damage to agricultural income decrease.

One hundred percent hail damage practically indicates the areas of agricultural production that were completely destroyed by hail and that generated no income whatsoever.

The reduction of absolute damage to 100% damage is performed using the following equation:

$$P(100\%) = \sum_{i=10}^{n=100} \frac{p(s_i) \cdot S_i}{100} \qquad (4)$$

where:

P(100%) = area damaged by hail expressed in 100% damage;
p(si) = area of each damage interval of agricultural crops;
Si = degree of damage caused to agricultural crops (10, 20, 30...100%).

The data about the hail suppression costs were estimated on the basis of apposite reports made by competent state bodies, while the national product value in agriculture was officially published by an authorized state institution.

For the purposes of the indicated analysis, the initial and derived values, which should allow the determination of the economic effects of hail suppression with a high degree of certainty, are given in the Table 1.

The mentioned values are:

B – protected area (ha);
Ts – hail suppression costs expressed in fixed prices, with the year 1972 as basis (105 RSD);
d – national product in agriculture per ha (105 RSD);
S(b) – total hail damage in the protected area reduced to a 100% damaged area (ha);
S(n) – total hail damage in the non-protected area reduced to a 100% damaged area (ha);
K(n) – relation between total damage in the non-protected area and the size of the non-protected area from which hail damage data were gathered - $Kn = \frac{S(n)}{Ns} 100$ (%);
m – possible damage in the protected area K (n) · B (ha);
m-S(b) – difference between possible and actual damage in the protected area (ha);
E – effect of hail suppression - $E = \frac{m - S(b)}{m} 100$ (%);

Ks – RSD value of the savings gained by hail suppression activities - Ks = (m − S(b))d (105 RSD);
Kns – present value of net benefit criterion - Kns = Ks − Ts (105 RSD);
Ko – cost-benefit relation coefficient - $Ko = \frac{Ks}{Ts}$.

Hail suppression costs (parameter number 2) are expressed in fixed prices, with the year 1972 as basis. In that way the influence of monetary factors in the observed period has been eliminated, so that the dynamics of the hail suppression project costs can be observed from the aspect of changes within the project itself.

Parameter number 3 shows yearly values of the national product in Serbian agriculture per ha of agricultural area, in fixed prices, with the year 1972 as basis. This parameter is calculated via the following formula:

$$d = \frac{D}{P - (S(b) + S(n))} \tag{5}$$

This practically means that the areas completely destroyed by hail S(b) and S(n) are excluded from the agricultural area that is taken into consideration on a yearly basis. Fluctuations in the values of this parameter show a high level of correlation with the dynamics of the national product in agriculture, while minimum deviations mostly result from the exclusion of the mentioned areas destroyed by hail.

Values number 4 and 5 refer to total hail damage in the protected and non-protected area reduced to a 100% damaged area.

The percentage relation between total hail damage in the non-protected area and the size of the non-protected area K(n) (number 6) differs from year to year, ranging from 1.3 in 1979 to 6.16 in 1982. It should be stressed that in 1984 the non-protected area was reduced to merely 5.6% of the total agricultural area, so that the hail damage data relating to the subsequent period cannot be considered statistically representative. That is why the average values of hail damage in the period 1984-2010 in the non-protected area from which hail damage data were gathered (3.68%) were used to draw final conclusions for the needs of this analysis.

Table 1: Data and values of the Cost-benefit analysis of the hail suppression project in Serbia in the period between 1972 and 2010 (RSD)

God.	B	Ts	d	S(b)	S(n)	K(n)	m	(m-Sb)	E	Ks	Kns	Ko
	1	2	3	4	5	6	7	8	9	10	11	12
1972	1.093.255	102,2	0,033	22.914	85.949	4,55	49.743	26.829	53,94	885,4	783,2	8,7
1973	1.137.978	108,4	0,035	27.279	57.926	4,83	54.964	27.685	50,37	969,0	860,6	8,9
1974	1.184.775	134,6	0,036	18.615	52.443	4,16	49.287	30.672	62,23	1.104,2	969,6	8,2
1975	1.648.612	164,3	0,035	12.374	81.443	4,70	77.485	65.111	84,03	2.278,9	2.114,6	13,9
1976	1.888.658	299,2	0,038	13.049	30.259	3,05	57.604	44.555	77,35	1.693,1	1.393,9	5,7
1977	2.236.575	377,7	0,040	76.962	65.093	5,31	123.541	46.579	37,70	1.863,2	1.485,5	4,9
1978	2.455.712	417,3	0,035	36.349	22.744	3,65	89.633	53.284	59,45	1.864,9	1.447,6	4,5
1979	2.912.735	379,6	0,038	21.772	9.254	1,30	37.866	16.094	42,50	611,6	232,0	1,6
1980	3.079.377	299,1	0,040	25.091	10.848	2,34	72.057	46.966	65,18	1.878,6	1.579,5	6,3
1981	3.133.651	270,0	0,040	23.724	5.792	1,94	60.793	37.069	60,98	1.482,8	1.212,8	5,5
1982	3.330.067	288,1	0,044	24.884	21.205	6,16	205.132	180.248	87,87	7.930,9	7.642,8	27,5
1983	3.385.784	271,3	0,043	14.01	5.856	2,20	74.487	60.477	81,19	2.600,5	2.329,2	9,6
1984	3.753.002	257,1	0,042	13.802	751	3,68	138.11	124.308	90,00	5.220,9	4.963,8	20,3
1985	3.760.870	239,8	0,039	6.765	-	3,68	138.4	131.635	95,11	5.133,8	4.894,0	21,4
1986	3.760.870	256,3	0,044	22.721	538	3,68	138.4	115.679	83,58	5.089,9	4.833,6	19,9
1987	3.760.870	200,9	0,041	14.856	12	3,68	138.4	123.544	89,27	5.065,3	4.864,4	25,2
1988	3.114.280	195,4	0,048	28.244	2.133	3,68	138.4	110.156	79,59	5.287,5	5.092,1	27,1
1989	3.148.692	181,3	0,045	38.246	371	3,68	114.605	76.359	66,63	3.436,2	3.254,9	19,0
1990	3.148.692	188,9	0,041	5.428	-	3,68	114.605	109.177	95,26	4.476,3	4.287,4	23,7

Continue

God.	B	Ts	d	S(b)	S(n)	K(n)	m	(m-Sb)	E	Ks	Kns	Ko
	1	2	3	4	5	6	7	8	9	10	11	12
1991	3.148.692	177,9	0,044	17.669	-	3,68	114.605	96.936	84,58	4.265,2	4.087,3	24,0
1992	3.930.204	233,6	0,038	22.172	-	3,68	144.631	122.459	84,67	4.653,4	4.419.8	19,9
1993	3.938.305	244,6	0,036	40.63	-	3,68	144.93	104.3	71,97	3.754,8	3.510,2	15,4
1994	3.936.455	229,9	0,038	17.09	-	3,68	144.862	127.772	88,20	4.855,3	4.625,4	21,2
1995	3.936.728	265,2	0,039	44.088	-	3,68	144.872	100.784	69,57	3.930,6	3.665,4	14,8
1996	3.914.956	198,1	0,039	11.787	-	3,68	144.07	132.283	91,82	5.159,0	4.960,9	26,0
1997	3.910.060	184,0	0,043	72.225	-	3,68	143.89	71.665	49,81	3.081,6	2.897,6	16,7
1998	3.909.845	200,3	0,042	27.952	-	3,68	143.882	115.93	80,57	4.869,1	4.668,8	24,3
1999	3.329.495	135,1	0,041	106.471	-	3,68	122.525	16.054	13,10	658,2	523,1	4,9
2000	3.321.721	192,8	0,043	25.475	-	3,68	122.239	96.764	79,16	4.160,9	3.968,1	21,6
2001	3.323.628	197,3	0,044	21.48	-	3,68	122.31	100.83	82,44	4.436,5	4.239,2	22,5
2002	3.323.725	241,9	0,044	18.33	-	3,68	122.313	103.983	85,01	4.575,3	4.333,4	18,9
2003	3.323.725	309,0	0,045	22.422	-	3,68	122.313	99.891	81,67	4,495,1	4.186,1	14,5
2004	5.106.900	351,9	0.032	40.9	-	3,68	187.934	147.034	78,24	4.774,4	4.422,5	13,6
2005	5.106.900	328,3	0.031	25.072	-	3,68	187.934	162.862	86,66	4.977,3	4.649,0	15,2
2006	5.106.900	460,0	0.03	19.198	-	3,68	187.934	168.736	89,78	5.142,4	4.682,4	11,2
2007	5.106.900	538,3	0.028	38.693	-	3,68	187.934	149.241	79,41	4.234,2	3.695,9	7,9
2008	5.106.900	518,3	0.03	11.67	-	3,68	187.934	176.264	93,79	5.367,6	4.849,3	10,4
2009	5.106.900	415,4	0.031	17.142	-	3,68	187.934	170.792	90,88	5.252,9	4.837,5	12,6
2010	5.106.900	322,9	0.031	23.305	-	3,68	187.934	164.629	87,60	5.048,5	4.725,6	15,6
∑	134.930.294	10.376,3	-	-	-	-	-	-	-	-	136.189,0	-

The relation between the hail damage in the non-protected area and the size of the non-protected area from which hail damage data were gathered enables the derivation of a parameter expressing the possible yearly hail damage, m, which would occur in the protected area if the hail suppression project did not function (number 7). Those yearly values significantly deviate from actual damages in the protected area. The absolute value of this deviation, (m-S(b)), represents the measure of the hail suppression project efficiency per year (number 8).

This measure has different values in the observed period. Its value is the lowest in 1999, equaling 16,054 ha, and the highest in 1982, equaling 180,248 ha. Its average value shows that in the territory of Serbia in the period 1972-2010 the hail suppression project activities in average prevented the destruction of crops from 98,862.5 ha of protected area per year.

The economic effect of hail suppression, E (number 9) expresses the percentage of the possible damage prevented by hail suppression activities. The average value of this parameter in the observed period equals 79.63%, in individual years ranging from 13.10% (1999) to 95.26% (1990).

What should be noted in particular are the high values of this parameter during the final years of the observed period. This fact leads to the conclusion that the hail suppression project has been brought together as a functional, technical and methodological whole, completely capable of reaching high performance efficiency level, and, therefore, providing adequate hail protection of agricultural crops.

The RSD value of the savings, Ks, gained by hail suppression activities (number 10) is calculated by multiplying the difference between the possible and actual damage (number 8) and the RSD value of national product in agriculture per ha (number 3).

The value of this parameter was the lowest in 1979 (611,6x105 RSD), and the highest in 1982 (7.930,9x105 RSD), while in the period 1972-2010 it equaled 4.231,8x105 RSD, on average.

Finally, parameters number 2 (hail suppression costs, Ts) and 10 (RSD value of the savings, Ks, gained by hail suppression activities) allow for the derivation of the main cost-benefit analysis criteria:

present value of net benefit criterion Kns (number 11);
cost-benefit relation coefficient Ko (number 12).

The present value of the hail suppression project net benefit criterion, which equals the value between total benefits and total costs of the project in the examined period of time, has positive values, which indicates its positive effects, even though these values vary between 232.0x105 RSD in 1979 and 7,642.8x105 RSD in 1982. Its average amount for the period 1972-2010 equals 3,432.2x105 RSD, or 20,381,235.16 USD, calculated according to the average annual currency rate valid in 1972 (1USD=16.84 RSD).

The cost-benefit relation coefficient shows how much benefit is obtainable from each unit of hail suppression project costs. The values of this coefficient are low in the initial period of project development, especially in 1979 (1.6). In a later period of hail suppression project development the values of this coefficient increase significantly, and in particular in 1982 (27.5), 1988 (27.1) and 1996 (26.0). In 1999 this coefficient vas relatively low (4.9), as, due to the war, the hail suppression system was not functional in the period of the year when the Cb clouds are usually the most intensive.

Generally looking, in the period 1972-2010, a total of 1,037,630,000.00 RSD (61,616,983.4 USD) or averagely 26,605,897.43 RSD (1,579,922.7 USD) a year were invested in the hail suppression system in Serbia. Due to good functioning of the project, the positive effects of hail suppression in Serbia reached the amount of 13,618,900,000.00 RSD (808,723,277.9 USD). That practically means that every RSD (USD) invested in the hail suppression project was regained 13 times through its positive effects.

Conclusion

According to the results of the previous analysis, it can be concluded that the hail suppression project in Serbia in the period 1972-2010 has achieved a high degree of efficiency of hail clouds suppression. Even though the values derived by years vary significantly, it can be concluded that an average efficiency of 79.63% was accomplished. This indicates a portion of the potential damage that has been avoided due to the anti-hail protection. Additionally, bearing in mind the prevented crop damage in the given period of approximately 98,862.5 ha annually, it is fully understandable that significant results have been achieved in the field of the anti-hail protection.

The average criterion of present net benefit (343,220,000.00 RSD, that is, 20,381,235.16 USD) and the individual values of the cost-benefit relation coefficient indicate the full economic feasibility of investing in the project of hail suppression in Serbia during the observed period.

In the period between 1972 and 2010, the total amount of 61,616,983.4 USD was invested in the hail suppression project in Serbia according to the average annual exchange rate between USD and RSD, valid in 1972.

In the same period, the achieved amount of positive functioning effects equaled 808,723,277.9 USD. Considering the fact that in the period 1972-2003 the size of the protected area in Serbia equaled 134,930,294 ha of agricultural area, it can be concluded that an average amount of 0.457 USD per ha of protected area was being invested each year in the implementation of the main and regional project and in the functioning of the hail suppression system as a whole. On the other hand, the effects of the hail suppression equal an average annual amount of 5.99 USD per hectare of protected area, which means that each dollar invested in the hail suppression project had been regained 13 times.

The Cost-benefit analysis allows in a concrete and comprehensive way to determine the effects of the hail suppression project in Serbia. Further statistical analysis verifies the exactness of the present net benefit criterion, as well as of the cost-benefit relation coefficient. This confirms that the conclusions about the high-level efficiency of the hail suppression project, along with the validity of the investments in its operative implementation and further development, may be considered entirely reliable.

The analysis shows that the hail suppression system in the future can be more rational, more efficient, simpler, more reliable, cheaper and it can be used for multi-purpose application.

The appropriate organizational changes are needed in order to optimally use existing human and technical resources and to introduce new technologies.

Stimulation of precipitation can be performed by seeding the cloud base from the aircraft. The general assessment is that 1m^3 of stimulated water is cheaper than any other way of providing additional 1m^3 of water.

References

Mitic, M., (2006): The management of the anti-hail suppression system in Serbia, PhD dissertation, Faculty of management, Novi Sad;

Mitic, M., Vucinic, Z., Babic, Z., (2009): Cost-benefit analysis of the hail suppression project in serbia, 5h European Conference on Severe Storms - Landshut – Germany;

Vujović, D., Vučinić, Z., Babić, Z., (2007): 40 Years of Hail Suppression in Serbia, 9th WMO Scientific Conference on Weather Modification and Weather Modification Workshop, Antalya, Turkey;

Radinovic, D., (1989): Effectiveness of the hail control in Serbia, J. Wea. Mod. 21, 75-84;

Radinovic, D., (1993): An evaluation of hail suppression cloud seeding effects on freqencies of weather phenomena in Serbia J. Wea. Mod. 25, 57-73;

Mesinger, F., Mesinger, N., (1992): Has Hail Suppression in Eastern Yugoslavia Led to a Reduction in the Frequency of Hail, Journal of Applied Meteorology, 31(1), 104-111;

Nikolic, J., (1985): Review of the structure and characteristics of a numerical tridimensional cloud model - possibility of use in examining the problem of an artificial effect on the atmospheric processes. Journal RHMSS No. 29, pp. 44-50.