Possibilities of Rainfall Enhancement Experiment And Its Economic Effects Over Korea

A.A. Sinkevich*, J.Y.Kim, S.W.Lee and A.S.Suh

1. Introduction

Drought, hail, fog, hard rain continue to cause havoc in many parts of the world. The associated loss of life and property has been growing as population concentration increase. Cloud seeding as routine work to improve weather conditions, to exclude losses in economy due to dangerous atmospheric phenomena, is carried out in many countries (Argentina, Bulgaria, China, Italy, Serbia, Uzbekistan, Russia and many others)(Abshaev, 1987; Birulev, 1996; Dovgaljuk, 1998; Grickiv, 1968; Kamalov, 1999; Polovina, 1980; Sedunov, 1971; Sinkevich; 1992, Vucinic, 1999; Xu, 1999). Cloud seeding experiments were conducted in Korea also. First experiments were carried out in 1963 and 1964. It was in only in 1995-1996 that these experiments started once more(Hong, 1997). Ground based and aircraft apparatus were used to carry out cloud seeding with AgI and dry ice but these experiments have no their continuation though they clearly show possibility to obtain positive results. Possibly, discontinuation of experiments was the result of insufficient economic basis for their carrying out. Here we try to improve our knowledges in the field.

It is well known that droughts bring enormous disasters to Korea. Last severe drought of 1994-1995 had threatened lifes and industrial activities over the country. It made dams have low water level about 30% of the average value. As a result, the agricultural and the industrial activities were under the nearly stop.

Significant damage reduction can be obtained by using cloud seeding to prevent or to reduce negative consequences of many dangerous phenomena. Assessments of possible damage reduction are made in the report if cloud seeding will be carried out as routine experiments.

A lot of experiments have been carried out on precipitation augmentation with different purposes during cloud seeding history. List of some last experiments which have been carried out round the world with the aim of precipitation enhancement is presented in table 1.

It is stated now by scientific community that one can obtain on average 10-20% precipitation changers due to cloud seeding.

*Remote Sensing Research Laboratory, METRI, Invited Scientist,
A.I. Voeikov Main Geophysical observatory, RUSSIA, Chief of Cloud physics

Table 1. Projects on weather modification to enhance precipitation which have been carried out during 1990-2000

Project Area	Project goal - precipitation enhancement for benefit:	Years	Seeding effect
Yakutia, Russia	Agriculture	1995-1997	12-117%
Syria	Agriculture	1991-1998	7-17%
Iraqui	Agriculture	1992-1995	0-67%
Honduras	Hydroelectric power production	1993-1997	6-15%, calculated benefit/cost - 23.5/1
Italia	Agriculture	1988-1994	Could not be assessed using statistical methods
Turkey	Water reservoirs	1992	Could not be assessed using statistical methods
China, Baiyang river basin	Increase in annual flow	1984-1995	11.6%
China, Shandong Province	Agriculture	1989-1995	0.8-1.5% increase in wheat production
China, Xinjiang	Agriculture (to reduce annual freeze injury area of winter wheat)	1978-1994	80%
China, Hunan province	Water reservoirs	1998	252 mln RMB yuan, benefit/cost - 8/1
Uzbekistan	Agriculture	1985-1991	-3 - 43%
Taiwan	Agriculture	1992	No information
Guatemala	Hydroelectric power production	1991,1992,1994	No information
USA, Utah	Water reservoirs	1989-2000	14-20%
USA, California	Hydroelectric power production	1990-1997	No information
USA, Idaho	Water reservoirs	1992-1996	No information
USA, Colorado	Water reservoirs	1992-1995	No information
Greece	Water reservoirs	1992-1993	No information
Thailand	Agriculture	1995-1998	Averaged rain volume of seeded clouds is 109% greater than of the unseeded
Mexico	Agriculture	1997-1998	No information

(Sources: WMO, 1999; Weather modification Corp. Web page; 15th Conference on Planned and Inadvertent Weather Modification)

2. Economic assessments of losses due to lack of cloud seeding activities in Korea

2.1. Harvest

The importance of precipitation to agriculture is obvious, being the principal source of soil moisture reserves required for crops. The timing and frequency distribution of precipitation are extremely important. Short-term episodes of dryness may be of little consequence to crops in a particular phase of

their growth cycle, while a similar occurrence during a highly-sensitive phase may ultimately reduce the yield potential(WMO, 1992).

Role of precipitation is highly complicated and depends on regional climatic regime and regional agricultural zones. We do not discuss in details requirements to precipitation amount to achieve the greatest yield. It is important to emphasize the fact that for Korea Republic it is usually desirable to have greater water supplies during vegetation period(April-June). Here we discuss only the problem of rain which fall down on farmers fields (problems of reservoirs water supplies enhancement is discussed below, we clearly understand that this water is also used for agriculture). It is rather complicated task to assess influence of rain deficiency on whole agriculture production of Korea Republic so we are obliged to simplify the task. There are assessments of artificial rain enhancement on rice production carried out by Chinese scientists(Yulin, 1999). We'll use their data to assess possible losses in agriculture production due to lack of regular cloud seeding experiments. They have shown that enhancement of precipitation yield on average to 2 kg/mm.ha of rice. We are making proposal that all agricultural production of Korean Republic is rice. Territory in Republic of Korea with agricultural fields is equal to 1898925 ha. There is need in additional precipitation from April to May(2 months). Averaged precipitation amount during this period is equal to 60 mm in Korea(METRI, 1977). Regular cloud seeding experiments can enhance precipitation amount on average to 20%. So potential damage (due to absence of cloud seeding experiments) to economy of Korean Republic is equal to losses in agriculture production to $\$91 \times 10^6$. Most occurrence of droughts is observed in eastern parts of the country. So experiments on cloud seeding have to be carried out here. But due to the fact that there is no expressed agricultural regions (may be less territory is used for agriculture production in the north regions of republic Korea) it is clear that to reduce drought consequences one have to plan cloud seeding in accordance with real meteorological situation throughout the country. Losses in agriculture production due to lack of possibility to carry out cloud seeding experiments in all parts of country simultaneously may be assessed as 50%. In this case losses in agriculture production will be equal to $\$45 \times 10^6$.

2.2. Hydro electric power stations (water reservoirs)

Hydro-electric power stations mainly depend on the runoff formed by rainfall to generate electricity. All their outflow is the result of rainfalls and snowfalls.

Assuming that cloud seeding can increase precipitation amount on 20% it is possible to assess benefit due to the use of additional water to produce electricity. It was shown(Xu, 1999) that 3.7 cubic meters of water can generate one kilowatt electricity per hour. So losses to Korean economy can be simply calculated from data on irrigation water. Calculations have shown that total losses are equal to $\$44 \times 10^6$. Distribution of losses between hydro electric power stations is presented in Table 2. It is clear that not all irrigation water is used to electricity production. There are losses during summer period when some water is let out from reservoir to prevent floods. So if we accept that these losses constitute 10% than maximum profit will be equal to $\$40 \times 10^6$.

Table 2. Losses in electricity production due to lack of cloud seeding

Reservoir	Irrigation water m^3/year	Increase in Irrigation water m^3/year $*10^5$	Losses kWt/hour $*10^5$	Losses Won $*10^7$
Soyang	1213	2426	654	654
Chungju	3380	6760	1826	1826
Andong	926	1852	500	500
Imhaho	592	1184	324	324
Hapch	599	1198	322	322
Naktong-gang	750	1500	404	404
Namgan	593	593	160	160
Najuho	489	978	264	264
Chinyang	350	700	188	188
Puan	35	70	18	18
Taech	1649	3298	890	890
Total	10576	21152	5716	5716

Greatest reservoirs are located in north and central parts of the country(Soyang, Chungju, Andong, Imhaho, Taedieong). They provide 73% of benefit in case of cloud seeding. So it is worth while to carry out cloud seeding in the north part of country. In these cases, possible reduction in profit will constitute 27% and profit will be equal to $\$29 \times 10^6$.

Most experiments is worth while to carry out during periods when there is lack of water in reservoirs These are periods October-June. Detailed experiments planning have to be carried on the base of monthly averaged precipitation data. Relative rate of monthly precipitation for north of Republic Korea territory is presented in Fig. 1.

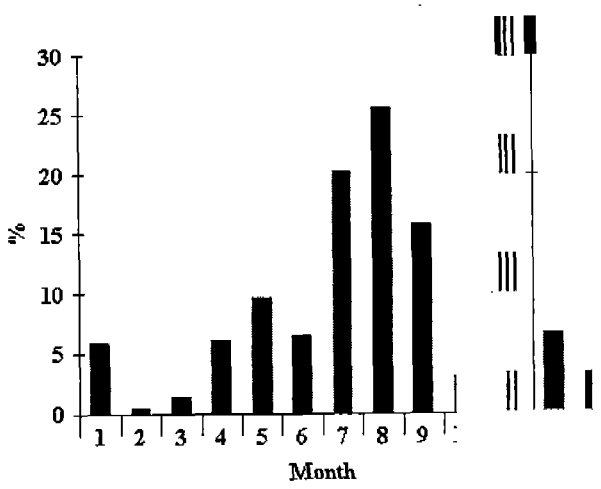

Fig.1. Relative rate of monthly precipitation for north of Republic Korea territory

It is clear that best months to carry out experiments are January, April-June . If cloud seeding will be carried only these months benefit due to additional water within reservoirs will be equal to $\$6 \times 10^6$ (precipitation water during these months constitute 21.7% of all precipitation water)

Studies of Chinese scientists have shown(Xu, 1999) that there are two kinds of benefit. One is direct financial benefit brought to hydro-electric power station itself by generating electricity by means of artificial enhancement of precipitation. Usually there are some hydro-electric power stations in lower parts of the river. So they also obtain benefit from additional water. This additional water may be used for civil or other necessities - it also bring additional benefit. So there appear some indirect economical benefit. It was assessed 70 times greater than direct one(Xu, 1999). If we assume that these indirect effect will be equal 1000% in Republic of Korea (one have clearly understand that this additional water can be used in agricultural purposes), we will receive the final benefit as great as $\$60 \times 10^6$.

So due to the absence of cloud seeding experiments to enhance water supplies in reservoirs of electric power stations in the northern regions of Korea annual losses to economy are equal to $\$60 \times 10^6$.

3. Recommendations on cloud seeding activities in Korea

We have carried out some mutual meteorological and economic analyze of economic losses in Korea due to lack of routine cloud seeding experiments. They show that total losses of Korea economy due to lack of cloud seeding experiments amounts now to 100×10^6 of US dollars.

January and April-June is a period when it is worth while to carry out experiments on precipitation enhancement to increase water supplies in reservoirs and to increase precipitation for farmers.

It is demand of progress and demand of economy to start with these works in Republic of Korea. World experience shows that these works will significantly reduce losses to Korean economy from severe atmospheric phenomena.

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