FORUM: Environmental Commission 1

QUESTION OF: Evaluating cloud seeding as a means to combat drought

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INTRODUCTION

Droughts are caused by low precipitation over an extended period of time. This weather phenomenon leads to a shortage of water which negatively impacts health, agriculture, economies, energy and the environment.

An estimated 55 million people globally are affected by droughts every year[1], as they are the most serious hazard to livestock and crops in nearly every region of the world. When communities don't have enough water for drinking, sanitation and agriculture it can lead to issues such as food insecurity, the spread of disease, malnutrition, forced migration and economic losses. One solution to mitigate these problems is Cloud Seeding.

Cloud seeding, often called weather modification, is a scientific process to enhance rainfall, reduce hail, damage and alleviate fog. This process of producing artificial rain dates back to 1946[2] where scientists working at the General Electric Research Laboratory first discovered that silver iodide and dry ice could be used to enhance ice crystal formation in clouds.

Weather modifications have been previously used to prevent droughts in hope of mitigating the hazards caused by the lack of water. Countries such as The United States, Russia, India, UAE and Thailand[3] have used cloud seeding as they heavily rely on rainfall for crops and livestock. Cloud Seeding could combat water scarcity by producing artificial rain which would massively reduce the impacts of droughts.

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[1]World Health Organization. "Drought." *World Health Organization*, 2022, www.who.int/health-topics/drought#tab=tab_1.

[2]*Common Questions and Answers about Cloud Seeding*. www.library.nd.gov/statedocs/WaterCommission/SeedingQ&A2010Web20140214.pdf.

[3] Adigun, Abisola, and Abisola Adigun. "Full List: Countries That Use Cloud Seeding Alternatively for Rainfall." *Tribune Online*, 17 Apr. 2024, tribuneonlineng.com/full-list-countries-that-use-cloud-seeding-alternatively-for-rainfall/.

DEFINITION OF KEY TERMS

Cloud Seeding

"the act of spreading substances such as certain chemicals in clouds, in order to try to make them produce rain, or more rain"[4]

Drought

"a long period when there is little or no rain"[5]

Ice Nuclei

particles with an ice crystal structure that water needs to freeze[6]

Precipitation

"water that falls from the clouds towards the ground, especially as rain or snow"[7]

Supercooled Liquid Water (SLW)

water that stays in its liquid form even in below-freezing conditions, a special state of matter that's possible high up in the atmosphere[8]

Weather Modification

"The act of intentionally altering or manipulating the weather, typically to increase precipitation or reduce hail"[9]

[4]Cambridge Dictionary. "Cloud Seeding." *@CambridgeWords*, 6 Sept. 2023, dictionary.cambridge.org/dictionary/english/cloud-seeding.

[5]"Drought." *Dictionary.cambridge.org*, dictionary.cambridge.org/dictionary/english/drought

[6]"Ice Nucleus." *Wikipedia*, 29 Jan. 2023, en.wikipedia.org/wiki/Ice_nucleus.

[7]"PRECIPITATION | Meaning in the Cambridge English Dictionary." *Dictionary.cambridge.org*, dictionary.cambridge.org/dictionary/english/precipitation.

[8]Clayton, Adam. *What Is Supercooled Water?* 14 Jan. 2023, www.wkbn.com/weather/what-is-supercooled-water/.

[9]"Weather Modification." *Wikipedia*, 16 Apr. 2021, en.wikipedia.org/wiki/Weather_modification.

BACKGROUND INFORMATION

The Process of Cloud Seeding

Cloud seeding requires specific weather conditions to be possible in the first place. The presence of clouds that contain supercooled liquid water (SLW) is necessary. That means air temperatures in the sky need to be below freezing but not too cold , typically from -15°C to 0°C[10].

During the process, scientists add tiny particles called ice nuclei in the clouds. The seeding agents, such as silver iodide, sodium chloride or dry ice, act as cloud condensation nuclei or ice nuclei, around which water droplets or ice crystals can form. These nuclei help increase the precipitation production of the cloud by freezing the SLW.

The process of cloud seeding is based on the idea that these ice crystals will grow larger as water vapor in the cloud freezes onto them, eventually becoming heavy enough to fall as precipitation. This can potentially enhance rainfall in areas where it is needed, especially in drought-prone regions.

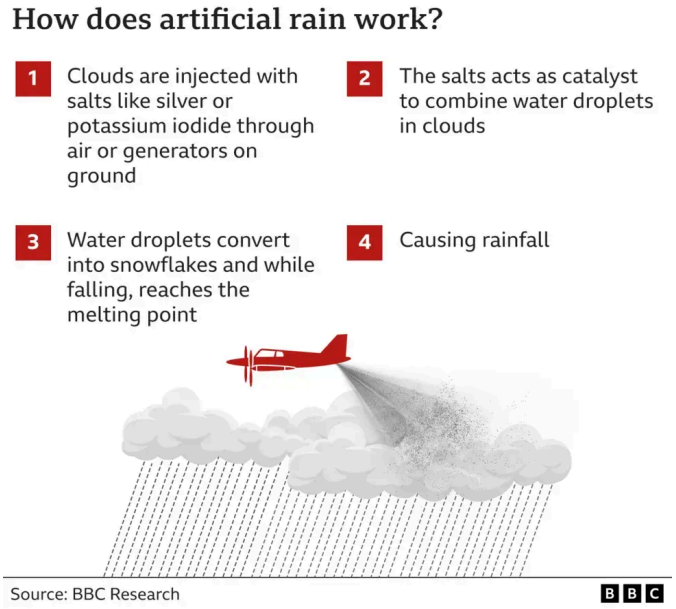

Figure 1: Shows the general process of cloud seeding[11]

[10]Harvey, Chelsea. "Why Cloud Seeding Won't Reverse Climate Droughts." *E&E News*, 17 Mar. 2021, www.eenews.net/articles/why-cloud-seeding-wont-reverse-climate-droughts/.

[11]"How Does Artificial Rain Work?" *Bbci.co.uk*, 2024, ichef.bbci.co.uk/news/1024/cpsprodpb/5D9F/production/_133176932_2cloudseeding-nc.png.webp.

Types of Cloud Seeding

Static Cloud Seeding

Static seeding involves spreading a chemical like silver iodide into clouds that already have some moisture content. The silver iodide provides a crystal around which moisture can condense. The moisture is already present in the clouds, but silver iodide essentially makes rain clouds more effective at dispensing their water. Static seeding works by exploiting the existing instability and moisture of the cloud. This method is often used in regions where clouds have insufficient natural nuclei to trigger rainfall.

The process is less complex than dynamic seeding as it targets individual clouds which makes it less expensive due to the limited resources required. The results of static seeding can generate more immediate and easier to measure, but the increase in rainfall is generally modest. The environmental risks are considered minimal as scientists haven't identified any major impacts.

Dynamic Cloud Seeding

Dynamic seeding is used when simply adding nuclei is not enough to induce significant rainfall. It aims to boost vertical air currents and enhance the overall growth of the cloud system, which encourages more water to pass through the clouds, translating into more rain. This method is considered more complex than static cloud seeding because it requires precise timing and weather conditions and it depends on a sequence of events working properly.

As dynamic seeding is used on a larger scale, often targeting entire cloud systems, it requires more extensive infrastructure and investment and isn't much preferred by LEDCs. Dynamic seeding can produce more substantial increases in rainfall by constantly amplifying cloud growth and monitoring it over a long period which makes this process more challenging to implement. Due to the larger scale and complexity, the unpredictability of dynamic seeding creates unintended weather changes and more significant environmental concerns.

Methods of Seed Dispersal

Aerial Seeding

Aerial cloud seeding is primarily carried out using aircraft that release the seeding agents into the atmosphere at high altitudes where clouds are present. Various aircrafts are employed for such operations, depending on the type of cloud, the altitude at which seeding is needed, and the

specific seeding technology being employed. Some common types of aircraft used for cloud seeding are fixed-wing aircraft, turboprop aircraft, helicopters and unmanned Aerial Vehicles (Drones).

Aerial seeding is a more precise technique as the aircrafts are in very close proximity to the clouds and can directly target specific clouds, ensuring more efficient use of seeding materials. Aircrafts can also reach clouds at different altitudes and locations with complex terrain, including areas that are difficult to access by ground-based methods. Pilots and meteorologists can make real-time adjustments and can quickly deploy aircrafts to areas experiencing immediate drought or severe weather conditions. However this seeding method is generally more expensive due to the costs of fuel, aircrafts, maintenance and qualified personnel. Compared to ground-based generators, aircrafts have limited flight durations due to fuel constraints and poor weather conditions which may restrict the length of seeding operations and impact its effectiveness.

Ground-based Generators

Ground generators are stationary devices that burn or release seeding agents into the atmosphere, where they are carried up by updrafts. They are located in elevated areas such as mountain ranges and require air flow. This dispersal method is used in regions where continuous seeding over a large area is desired.

Ground-based generators are easy to set up and require less specialized personnel to operate. Once installed, they need minimal intervention which makes them easier to operate and maintain compared to aircrafts. This method may be preferred over aerial seeding in countries that do not have the resources as it is inexpensive and easier to sustain. These generators can also operate continuously over extended periods regardless of the weather conditions that would prevent aircraft deployment, providing ongoing cloud seeding. However, due to the generators' static location, targeting specific clouds is more challenging as they can only affect clouds that pass directly overhead which decreases precision. This method has terrain limitations as generators work best in mountainous regions where natural updrafts are stronger. Usually droughts occur in flat or low-lying areas so this method wouldn't be as effective. It can also take longer for the seeding agents to reach clouds which may be less suitable for addressing areas.

Evolution of Cloud Seeding

The first experiment on cloud seeding was conducted in 1946 by meteorologist Vincent J. Schaefer[12] using dry ice and silver iodide. Immediately after the experiment was proven successful, investigators at the General Electric Research Laboratories received support from the three armed services for a very broad theoretical, laboratory, and field program (Project Cirrus) to explore cloud modification possibilities. In the course of its five years, Project Cirrus had enhanced and refined the practical status of seeding clouds with dry ice. Despite scientists' concern with the need for more basic understanding, the project led to increasing rainfall and produced positive results with clouds of all types and its optimistic reports served as the springboard for the next era.

However there was speculation around the results project Cirrus produced due to claims being made by qualified and unqualified experimenters. The Cloud Physics Project (CPP) was introduced to ensure sufficient results and was conducted from 1948 to 1951. Using only dry ice, the CPP seeding a few clouds in Ohio, Alabama and California and concluded that results were generally positive, like Project Cirrus, but the effectiveness was minimized.

After the positive outcomes that both projects found, by the end of 1947, cloud-seeding programs had begun in Australia, France, and South Africa. In 1948, the number of nations experimenting with cloud seeding was at least 12, increasing, by the end of 1950, to about 30 nations.

Many countries faced water scarcity due to droughts and there was a dire need of rain so weather modification was introduced as a way of combating droughts. Commercial cloud seeding grew so rapidly that by the years 1951-53, cloud-seeding target areas comprised more than 200 million acres, with a peak approaching 300 million acres in 1952.

Due to the growing use of cloud seeding, the Environmental Modification treaty was founded in 1978 to prevent the hostile use of weather modification. This treaty was signed by 48 member states.

[12]The Editors of Encyclopedia Britannica. “Cloud Seeding | Atmospheric Science.” *Encyclopædia Britannica*, 29 July 2013, www.britannica.com/science/cloud-seeding.

Soon after cloud seeding was developed into dispersing the seeding agents with aircrafts, helicopters, drones and ground-based generators which now make the process of seed dispersal more efficient and quick.

How Cloud Seeding can be used to Combat Droughts

Supporting Agriculture

Droughts reduce the water availability and water quality necessary for productive crops which negatively impact the agricultural sector. Cloud seeding provides agricultural benefits such as preventing crop failures and supporting food insecurity in drought-stricken areas through producing artificial rain. This is especially important for regions heavily dependent on rain-fed agriculture. Cloud seeding operations conducted by the Bureau of Soils and Water Management (BSWM) during dry spells and droughts have helped in saving immeasurable amounts of agricultural crops from total destruction.

Enhancing Rainfall

The process of cloud seeding involves dispersing substances like silver iodide, potassium iodide, or sodium chloride into clouds. These particles serve as nuclei around which water droplets can condense and form larger droplets that can fall as rain. By increasing the amount of rainfall, cloud seeding can directly counteract the effects of drought. The artificial rain will replenish water in dried out regions and will reduce the secondary impacts of droughts.

Targeting Specific Areas

Cloud seeding can be conducted over specific regions experiencing drought and provides localized application. Aircrafts and drones can detect droughts and seed specific clouds to enhance the chance of rainfall, whereas the clouds that produce rain naturally do not detect dry areas. This targeted approach allows for the concentration of efforts in areas facing water shortages, helping to replenish dried water sources such as reservoirs, lakes, and aquifers.

The impact of drought

When droughts cause water and food shortages there can be severe consequences on the health of the affected population, which could possibly increase the risk of disease and death. Drought may cause health effects such as malnutrition due to the decreased availability of food which could lead to an increased risk of infectious diseases. Cloud seeding could massively reduce the health risks by enhancing rainfall to fuel agriculture.

Challenges of Cloud Seeding

Causes Health Issues

One concern is that the agents used for cloud seeding can contaminate the air and water. This can lead to health problems for humans, such as respiratory issues, skin irritation, and gastrointestinal problems. However scientists haven't declared cloud seeding agents as the main pollutant for air and water.

Changing Climate

Scientist Geerts and his colleagues conducted a series of model simulations to visualize and predict how the world might look like in 2050 under a severe climate change scenario. As the temperature rises, the simulations suggest there could be as much as a 50% reduction in the times that conditions are suitable for cloud seeding.

French, the University of Wyoming scientist, proposed that cloud seeding shouldn't be the primary tool when combating droughts. "I wouldn't make cloud seeding the centerpiece [of water management plans], even if we knew that it worked," he said. "It's a tool — it could be part of the toolbox for sure."[13]

Ethical concerns

Regarding aerial cloud seeding, this dispersal method faces criticism and skepticism, particularly related to its effectiveness, ethical concerns, and potential unintended consequences. Many believe that artificial rain, especially aerial cloud seeding, is offensive towards their culture as it isn't a natural process in the water cycle. In some cultures rain is a symbol of renewal and rejuvenation. It is seen as a blessing from the gods, as it brings life to the earth and allows crops to grow. In Hinduism it's worshiped as Rain God or Varuna Deva.

Effectiveness of cloud seeding on droughts

The effectiveness of cloud seeding can vary depending on various factors, including the type of clouds, the availability of moisture, and the prevailing atmospheric conditions[14]. The scientific community continues to study and debate cloud seeding practices' effectiveness, environmental impact, and ethical considerations.

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[13]Harvey, Chelsea. "Why Cloud Seeding Won't Reverse Climate Droughts." *E&E News*, 17 Mar. 2021, www.eenews.net/articles/why-cloud-seeding-wont-reverse-climate-droughts/.

[14]Ryan, Patrick. *Aerial Cloud Seeding | the Rainmakers of Aerial Work Aviation*. 21 Sept. 2023, www.avbuyer.com/articles/special-missions-aircraft/aerial-cloud-seeding-the-rainmakers-of-aerial-work-aviation-113771.

Droughts are also associated with less precipitation and fewer clouds, which are necessary for cloud seeding. That means cloud seeding is less of an option when extra precipitation is most needed. A synthesis by the World Meteorological Organization in 2022[15] concluded that cloud seeding is least likely to be effective during drought conditions, as clouds do not have moisture to release.

However in the summer of 1948[16] Mayor Carl B. Close seeded a cloud with dry ice at the municipal airport during a drought in the humid city of Alexandria, Louisiana. Quickly 22 mm of rain fell.

Seeded clouds may actually travel to another location and not cause precipitation on the intended location. This may lead to increased rainfall in wet regions and flooding could occur which would lead to severe health and environmental consequences. Therefore, it can be argued whether or not cloud seeding is truly effective in producing rain.

MAJOR COUNTRIES AND ORGANIZATIONS INVOLVED

China

The Beijing Weather Modification Office is in charge of weather control in Beijing. It forms a part of China's nationwide weather control effort who seed clouds by firing rockets and shells loaded with silver iodide into them. The work of the Office is largely aimed at hail storm prevention or making rain to end droughts. In February 2009[17] China blasted iodide sticks over Beijing to artificially induce snowfall after four months of drought. The snowfall in Beijing lasted for approximately three days and led to the closure of 12 main roads around Beijing. The droughts were terminated, however the snow made transport more difficult and many other problems arose.

Ethiopia

Ethiopia is using weather modification to tackle the scarcity of water in arid regions of the country. To test its effectiveness, a study was done from 2021 to 2022 where results indicated that

[15]Kuhl, Laura. "Dodging Silver Bullets: How Cloud Seeding Could Go Wrong." *Bulletin of the Atomic Scientists*, 11 Aug. 2022, thebulletin.org/2022/08/dodging-silver-bullets-how-cloud-seeding-could-go-wrong/.

[16]Wikipedia Contributors. "Cloud Seeding." *Wikipedia*, Wikimedia Foundation, 26 Aug. 2024, en.wikipedia.org/wiki/Cloud_seeding#:~:text=In%20the%20United%20States%2C%20cloud.

[17]Wikipedia Contributors. "Beijing Weather Modification Office." *Wikipedia*, Wikimedia Foundation, 3 Aug. 2024, en.wikipedia.org/wiki/Beijing_Weather_Modification_Office.

cloud-seeded technology is effective over Ethiopia when the daily wind speed is less than 1.5 m/s and cloud base height is less than 1700m[18]. Furthermore, by observing relative precipitation from the improved cloud-seeded model results, rain enhancement science is now applicable for Ethiopia during the spring and slightly autumn seasons. The results were used to improve relevant cloud-seeded technologies.

United Arab Emirates (UAE)

The United Arab Emirates is one of the first countries in the Persian Gulf region to use cloud seeding technology. UAE scientists use cloud seeding technology to supplement the country's water insecurity, which stems from the extremely hot climate. The UAE has integrated advanced technologies such as drones for precision cloud seeding, enhancing the effectiveness of operations. Forecasters and scientists have estimated that cloud seeding operations can enhance rainfall by as much as 30-35% percent in a clear atmosphere, and up to 10-15% in a more humid atmosphere[19]

United States of America (USA)

From 2021 cloud seeding is used to boost precipitation in at least eight states across the western U.S to overcome droughts. Scientists recently concluded that the past two decades represent the driest span in western America since at least the late 1500s[20]. Droughts have led to limited water flow on major water systems like the Rio Grande and the Colorado River, which each supply water to millions of people. While using artificial rain to combat water insecurity, scientists have found little evidence and aren't sure how well cloud seeding works, let alone in a warmer climate.

The US has also massively contributed to cloud seeding research. After Schaefers findings, weather modification quickly captured the attention of the U.S. government. Over the next few

[18]Wondie, Megbar. *Modeling Cloud Seeding Technology* . 4 Apr. 2023, www.sciencedirect.com/science/article/pii/S2405844023021813.

[19]"Cloud Seeding in the United Arab Emirates." *Wikipedia*, 16 Feb. 2023, en.wikipedia.org/wiki/Cloud_seeding_in_the_United_Arab_Emirates.

[20]Harvey, Chelsea. "Scientific American." *Scientific American*, 2021, www.scientificamerican.com/article/eight-states-are-seeding-clouds-to-overcome-megadrought/.

decades, it would fund cloud seeding experiments on everything from drought management to military applications. In 1978, the U.S. signed the Environmental Modification Convention, which bans the use of weather modification for hostile purposes and continued to use cloud seeding to combat droughts.

International Commission on Irrigation and Drainage (ICID)

The International Commission on Irrigation and Drainage, which was established in 1950, is a leading scientific and non-governmental organization. The ICID is a professional network of experts from across the world in the field of irrigation, drainage, and flood management. Their mission is to promote sustainable agriculture water management to achieve water security around the world through sustainable rural development. This organization is mainly dedicated to the drainage of agricultural lands as floods are becoming more frequent as a result of climate change. They are large contributors in research and are collaborating with UN bodies to mitigate the effects cloud seeding may have on floods and limit any potential damage.

Weather Modification Association (WMA)

The Weather Modification Association was founded in 1950 to gain a better understanding of weather modification techniques and their impacts. Their aim is to promote ethical professional use of weather modification and share their discoveries worldwide. The WMA has adopted a statement on standards and ethics to ensure correct use by promoting research, development, understanding and application of weather modification for beneficial uses, and encouraging and promoting the highest standards of conduct in all weather modification activities.

In July 2009 The WMA stated that cloud seeding with silver iodide agents has no harmful effects towards the environment. The association finds that silver iodide is environmentally safe as it is currently being dispensed during cloud seeding programs.

World Meteorological Organization

The World Meteorological Organization adopted guidelines in 2017[21] advising members not to perform weather modification activities without considering the high levels of uncertainty in effectiveness and potential harms involved. It is, thus, recognized that cloud seeding is occurring now

[21]Kuhl, Laura. "Dodging Silver Bullets: How Cloud Seeding Could Go Wrong." *Bulletin of the Atomic Scientists*, 11 Aug. 2022, thebulletin.org/2022/08/dodging-silver-bullets-how-cloud-seeding-could-go-wrong/.

in numerous countries around the world. WMO stated cloud seeding on large scales can have environmental risks that need to be managed by careful planning and monitoring. Through research the WMO found out that cloud seeding is not that effective during drought conditions.

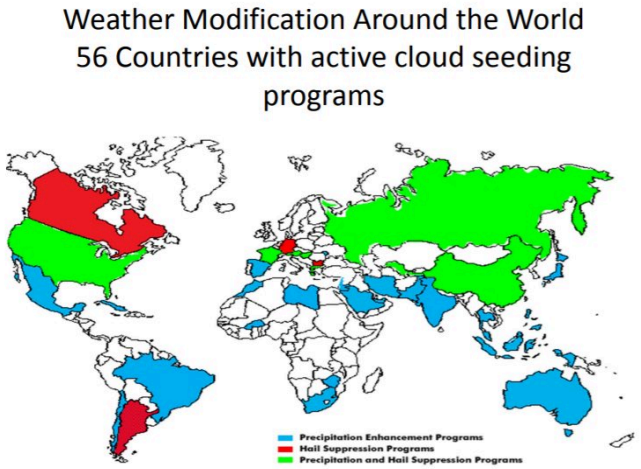

Figure 2: Countries that use weather modification in 2022[22]

TIMELINE OF EVENTS

Date	Description of Event
16th April 1891	Louis Gathmann suggested shooting liquid carbon dioxide into rain clouds
14th July 1946	Irving Langmuir and Vincent Schaefermanaged[23] to generate rainfall and create an artificial snowstorm in lab conditions by seeding clouds with dry ice
13th November 1946	Took place the first attempt to modify natural clouds through cloud seeding during a flight
18th May 1977	An international treaty bans the use of weather modification for military purposes
7th August 1987	The WMO published guidelines for cloud seeding operations
19th March 1992	Technological advancements improve the accuracy and efficiency of cloud seeding operations
18th July 2002	The UAE launches a national cloud seeding program, utilizing aircraft equipped with advanced seeding technologies

[22]"NUBI INSEMINATE – PIOGGE PILOTATE | NoGeoingegneria." *NoGeoingegneria | Portale Contro Le Manipolazioni Climatiche Ed Ambientali*, 22 June 2022, www.nogeoingegneria.com/timeline/progetti/nubi-inseminate-piogge-pilotate/.

[23]"(PDF) Cloud Seeding in the UAE Research Paper." *ResearchGate*, www.researchgate.net/publication/343878504_Cloud_Seeding_In_The_UAE_Research_Paper.

20th March 2015	The UAE's National Centre of Meteorology and Seismology (NCMS) reports successful cloud seeding operations, enhancing rainfall in arid regions
6th April 2011	The Texas Weather Modification Association (TWMA) began cloud seeding operations to alleviate drought conditions
11th July 2017	The UAE conducted cloud seeding operations to combat drought and improve water insecurity.

UN INVOLVEMENT: RELEVANT RESOLUTIONS, TREATIES AND EVENTS

Environmental Modification Convention (ENMOD)

The ENMOD is an international treaty preventing the military use of environmental modification techniques that may have widespread and severe effects. It opened for signature on 18 May 1977 in Geneva and was signed by 48[24] states. The treaty was implemented on 5 October 1978. Since the banning of military uses of cloud seeding, countries have shifted into using weather modification for combating climate change.

Food and Agriculture Organisation (FAO)

FAO is a specialized agency of the United Nations that leads international efforts to improve water and food security. Due to droughts being one of the biggest causes for water shortages which impact agriculture, FAO benefits from the use of cloud seeding to combat the weather phenomenon responsible for water insecurity.

Sustainable Development Goal 6: Clean Water and Sanitation (SDG 6)

SDG 6 was established in 2015 by the United Nations General Assembly to ensure access to water and sanitation around the world. The goal has six targets to be achieved by 2030 covering the access to safe water, sanitation and hygiene. One of the six key targets is to protect and restore water-related ecosystems including mountains, forests, wetlands, rivers, aquifers and lakes. Cloud seeding could be used as a method of restoring and replenishing water ecosystems.

[24]"Environmental Modification Convention." *Wikipedia*, 6 Mar. 2023, en.wikipedia.org/wiki/Environmental_Modification_Convention.

PREVIOUS ATTEMPTS TO SOLVE THE ISSUE

Cloud Seeding Program in California (2012-2016)

During the severe drought from 2012 to 2016, California used cloud seeding as part of its efforts to increase water supply. The state has a long history of using cloud seeding to enhance snowfall in the Sierra Nevada, which is a crucial water source. A California Department of Water Resources report suggests that cloud seeding activities in California in 2012 did lead to localized increases in precipitation. However, the overall impact was minimal. Estimates indicate that cloud seeding typically increases precipitation by about 2-15%[25]. In 2012, this likely translated into small but measurable increases in snowpack and reservoir levels in targeted areas. Despite the efforts, cloud seeding in 2012 did not significantly mitigate the overall drought in California. The state's drought was driven by large-scale climate factors, and while cloud seeding provided some local relief, it could not offset the widespread lack of rainfall.

Maharashtra Cloud Seeding Program, India (2015-2019)

In 2015, Marathwada and Madhya Maharashtra received 40% and 33% less than normal rainfall[26]. The government launched a comprehensive cloud seeding program the same year in an attempt to enhance rainfall and support farmers during the drought years. They continued it for several years, focusing on regions like Marathwada and Vidarbha. The program reportedly led to a significant increase in rainfall in some targeted areas. The government had dispatched forty-seven aircrafts over drought-prone regions between August and November which led 1,300 mm of rainfall and was deemed a success.

For instance, the Latur district, which was severely affected by drought, experienced an increase in rainfall following seeding operations in 2016. The program incorporated the use of radar and other meteorological tools to improve the targeting of clouds, making the operations more effective. Despite some successes, the overall impact of cloud seeding in Maharashtra was inconsistent. Not all seeded areas received significant rainfall, leading to mixed reviews about the effectiveness of the program.

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[25] *Precipitation Enhancement a Resource Management Strategy of the California Water Pan California Department of Water Resources*. 2016, water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/RMS/2016/10_Precipitation_Enhancement_July2016.pdf.

[26] The Weather Channel. "Maharashtra Government Plans Cloud-Seeding in Drought-Hit Regions of State in August | Weather.com." *The Weather Channel*, The Weather Channel, 29 May 2019, weather.com/en-IN/india/news/news/2019-05-29-maharashtra-government-plans-cloud-seeding-in-drought-hit-regions-of.

National Center of Meteorology, UAE (2020)

The UAE's National Center of Meteorology (NMC) has been actively engaged in cloud seeding operations as part of its broader rain enhancement program. The program aims to increase rainfall in the arid regions of the UAE to combat drought and ensure water security. NCM conducts cloud seeding operations and relies on a network of radars to monitor the country's atmosphere at all times to provide data on clouds. A team of pilots and technicians based at NCM's designated operational rooms analyze this data. The team carries out cloud seeding operations with high precision and efficiency once they detect 'seedable' clouds. A report done in 2020[27] suggest a noticeable increase in rainfall following seeding operations, contributing to water resource management in one of the driest regions in the world. However the projects require expensive technologies which isn't a feasible solution for long-term use as scientists remain uncertain on the effectiveness of cloud seeding.

POSSIBLE SOLUTIONS

Integrated Seeding Techniques (MEDCs)

One solution could be combining multiple seeding techniques to maximize effectiveness by using both ground-based and aircraft-based methods in coordinated operations. Instead of only using silver iodide, they could disperse various seedings agents like dry ice and potassium iodide. Member states could also benefit by organizing for both ground-based generators and aircrafts to work in unison to increase the chances of precipitation enhancement. This would enhance the likelihood of success by leveraging the strengths of both techniques and uses of many agents. This isn't an affordable solution because it requires many aircrafts as well as ground-based generators.

Active Research and Development

Another solution is for governments and organizations to conduct continuous research to improve seeding techniques so that they find the most suitable method that would give the most effective outcome. It is also crucial for scientists to investigate if there are any major environmental impacts from seeding agents. The UN could fund and provide scientists and meteorologists that would be responsible for actively researching and collecting results. Supporting scientific studies and field experiments is crucial for cloud seeding technologies to be developed.

[27] "(PDF) Cloud Seeding in the UAE Research Paper." *ResearchGate*, www.researchgate.net/publication/343878504_Cloud_Seeding_In_The_UAE_Research_Paper.

Strengthening the Environmental Regulatory Framework and Monitoring System

When combating droughts, which is a phenomenon that recurs more frequently as climate change worsens, countries should ensure that cloud seeding practices are environmentally sustainable and comply with regulations. One way this could be done is through developing and adhering to guidelines for safe seeding practices. This would comply with WMOs guidelines as they prohibit use of weather modification without taking relevant precautions. Monitoring environmental impacts that seeding agents have is heavily recommended when being environmentally sustainable as in the future they could have drastic impacts on habitats. The addition of sewage and drainage systems may be preferred in countries with drier climates to avoid flooding which may cause further environmental problems.

International Collaboration and Research Distribution

Member states with more advanced resources and cloud seeding technologies available could share research, technology such as aircrafts and ground-based generators and most effective practices. Sharing weather modification research among nations would benefit LEDCs that aren't abundant in technologies and resources. Clouds also travel from country to country so sharing knowledge which could then be applied worldwide would benefit all member states.

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