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Using Cloud Seeding to Combat Drought and Food Insecurity in Niger

Niger is one of the most vulnerable countries facing the adverse effects of climate change, particularly in the arid region of Zinder. Recurring droughts, high temperatures, and water scarcity are some of the main results that have exacerbated food insecurity among the rural population. Given that agriculture employs over 80% of Niger's workforce and is highly dependent on rainfall, solutions that stabilize water availability are essential. The goal of this research is to explore the use of cloud seeding technology as a sustainable intervention to reduce drought and promote food security in Niger.

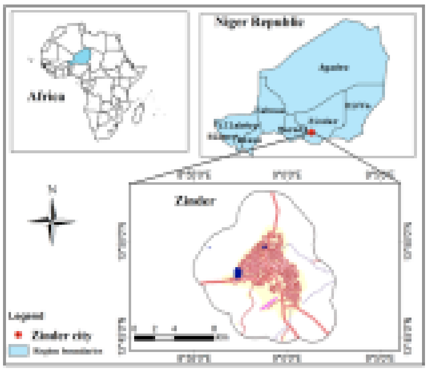
Niger is a landlocked country located in the Sahel region of West Africa, with a population of approximately 26 million inhabitants. More than 84% of the population lives in rural areas, where families depend almost entirely on traditional agriculture and livestock production. Households are typically large, averaging seven to ten members, and daily incomes are usually less than $2. Food consumption is limited to locally grown products like millet, sorghum, cowpeas, and peanuts. Access to vegetables, fruits, and animal protein is uncommon. Water is extracted from wells or rivers, and in many communities, women and children walk many kilometers daily to collect water, which in many cases is not even drinkable. Electricity, sanitation, and health care services are scarce in rural areas. Educational attainment is low, especially among girls, who often leave school prematurely due to arranged marriages or domestic responsibilities. Infrastructure, such as paved roads and telecommunications, remains underdeveloped in most parts of the country. Traditional knowledge and customs are strongly present in daily life. Communities are generally organized around ethnic groups such as the Hausa and Kanuri. Islam is the predominant religion and defines cultural practices, including approaches to agriculture and education (Munshi, 2023).

Figure 2. School Classroom in Tillaberi

Munshi, M. (2023). School Classroom in Tillaberi. RAD-AID international.
https://rad-aid.org/wp-content/uploads/Niger_CR-1.pdf

The Zinder region is located in southeastern Niger, which is particularly affected by climate change. Located between the parallels 13°44′ N, 13°54′ N, 8°54′ E and 9°40′ E, Zinder is the second biggest urban area nationwide. Its rapid population growth, projected at 118% between 2020 and 2035, has intensified environmental degradation (Doulay Seydou et al., 2024). Rising temperatures, low and erratic rainfall, and more frequent extreme weather events have made agriculture difficult. The ThinkHazard report (2020) identifies extreme temperatures and water scarcity as high-risk in Niger. Desertification has advanced, degrading previously arable land and reducing crop yields. According to UNDP (2022), precipitation in the region has decreased by approximately 30% since the 1970s. These conditions have created generalized food insecurity, with more than 4 million people affected across the country. Livestock farming is becoming increasingly unsustainable due to the drying up of grazing areas and water sources. As a result, pastoralist and farming communities experience frequent conflicts over resources.

Figure 1. Study area in the Republic of Niger

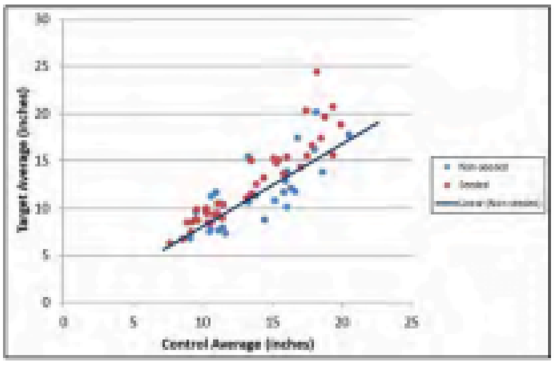


Kadiza Doulay Seydou , Wole Morenikeji, Abdoulaye Diouf, Kagou Dicko, Elbek Erdanaev, Ralf Loewner and Appollonia Aimiosino Okhimamhe. (2024). *Location of the study area with road network*. MDPI. https://doi.org/10.3390/su162310263

Climate change has also increased health and social vulnerabilities. Water shortages create hygiene problems and waterborne diseases. Children suffer malnutrition, and women, responsible for food preparation and water collection, are the most affected by the crisis. Damage to infrastructure caused by flash floods and heat waves is exacerbating the situation, making access to markets, clinics, and schools increasingly difficult. Migration to urban areas is increasing, and young people are abandoning their agricultural lives. Economic losses from crop failures and livestock deaths exacerbate the cycle of poverty. Climate-driven displacement is on the rise, with families leaving their villages in search of food security. In Zinder, some communities have reported a decline in production of more than 50% in the past decade (IPCC, 2021).

Various adaptation measures have been tested in Niger, including community-managed irrigation systems, agroforestry projects, and drought-resistant seeds. However, many of these solutions are limited in scope, underfunded, or poorly integrated. Long-term sustainability requires more comprehensive and scalable interventions. One such promising technique is cloud seeding. This weather modification strategy disperses substances such as silver iodide into clouds to stimulate rainfall (Bruintjes, 1999). It has been successfully implemented in countries such as the United States, the United Arab Emirates, South Africa, and China. For example, in the United Arab Emirates, cloud seeding has increased rainfall by 10–15% annually and reduced dependency on groundwater (National Center of Meteorology UAE, 2023). Utah's 2022–2023 program yielded a 10% increase in precipitation and added over 70,000 acre-feet of runoff to local watersheds (Southern and Central Utah Program, 2023). These examples demonstrate the potential of cloud seeding when applied under appropriate atmospheric conditions and with strong institutional support.

Figure 3. Scatterplot of historical non-seeded (blue) vs seeded (red) data points for the eastern Tooele County precipitation evaluation. The diagonal line represents the linear regression equation for the non-seeded period.



Cammans, T. F. G. (2023). Scatterplot of historical non-seeded (blue) vs seeded (red) data points for the eastern Tooele County precipitation evaluation. The diagonal line represents the linear regression equation for the non-seeded period. NAWC Inc. https://doi.org/10.1175/1520-0477(1999)080<0805:AROCSE>2.0.CO;2

For Niger, particularly Zinder, cloud seeding could focus on the June to September rainy season. According to the World Meteorological Organization, seeding is most effective in regions with predictable weather patterns and cumulus cloud formations—conditions which Zinder meets during the monsoon season. Seeded clouds would increase rainfall, improving crop growth, recharging aquifers, and stabilizing ecosystems. Besides, recent innovations such as drone-based dispersion and advanced satellite meteorology make cloud seeding more cost-effective and precise (Yin et al., 2020).

Potential funders for this initiative could include the Green Climate Fund, the African Development Bank, the World Bank, and international development agencies such as USAID or GIZ. Public-private partnerships with aerospace companies specializing in environmental technologies, like Weather Modification, Inc. or North American Weather Consultants, could also provide financial and technical support. Additionally, several global foundations could support this initiative, including The Bill & Melinda Gates Foundation, The Rockefeller Foundation, The Ford Foundation, The Skoll Foundation, ClimateWorks Foundation, and Wellcome Trust, all of which have a strong record of supporting climate adaptation, agricultural innovation, and public health in West Africa. These organizations are successful because they combine strong financial capacity with partnerships that directly engage governments, universities, and local communities. For example, the Bill & Melinda Gates Foundation has supported agricultural innovations such as drought-resistant seeds, while the Ford Foundation and ClimateWorks Foundation focus on climate adaptation and community empowerment.

In Niger, similar work has been carried out by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and local NGOs such as the Nigerien Association for the Defense of Human Rights (ANDDH), which promote sustainable agriculture and rural development. Supporting these organizations requires long-term funding, capacity building for local staff, and policies that facilitate collaboration with universities and community leaders. By combining the expertise of international foundations with the knowledge of local groups, cloud seeding initiatives in Zinder could achieve both effectiveness and cultural acceptance.

The estimated cost of initiating a cloud seeding program in Zinder would range between $28,000 and $140,000 USD per month during 3 years for a pilot phase. This includes aircraft or drone equipment, meteorological stations, training, and chemical supplies. Maintenance and operations would add $42,000 to $84,000 USD per month. Compared to the billions spent globally on food aid and emergency response, this investment offers long-term savings and development impact.

Local universities and research centers can play a crucial role. Dan Dicko Dankoulodo University of Maradi, close to Zinder, has expertise in soil sciences and remote sensing (Doulay Seydou et al., 2024). Collaboration with international partners like WASCAL can bring technical support and facilitate knowledge transfer. These institutions could help collect climate data, monitor outcomes, and build national capacity for sustainable climate technology management.

Ordinary citizens would also play a central role in the program. Farmers could contribute by providing local rainfall observations and sharing traditional climate knowledge that helps guide seeding operations. Community cooperatives could assist in organizing crop distribution and ensuring that increased harvests benefit households fairly. Youth groups, trained in basic meteorology and drone operation, could support monitoring tasks, while women's associations already responsible for water collection and food preparation could help design more inclusive strategies. By working hand in hand with universities, governments, and aid organizations, citizens would not only strengthen the effectiveness of cloud seeding but also ensure that the program responds to community needs and gains widespread acceptance.

To implement cloud seeding in Zinder, a phased approach is recommended.. Phase I would involve technical assessments, environmental impact studies, and equipment procurement. Phase II would initiate test operations during the rainy season, supported by real-time weather monitoring. Community sensitization campaigns, supported by local leaders and religious figures, would build acceptance. Phase III would expand the program based on observed rainfall increases and agricultural outcomes.

The benefits of cloud seeding extend beyond water. They could catalyze economic diversification by supporting high-value crop cultivation. Stable rainfall allows farmers to plan multiple harvests and enter regional markets. With support from agricultural cooperatives and microcredit programs, households could invest in irrigation, storage, and transport infrastructure. Additionally, youth employment in data analysis, drone operation, and meteorology would grow, reducing migration pressures and fostering innovation. Zinder's transformation into a sustainable agricultural hub could have ripple effects across Niger. Cloud seeding, if scaled nationally, could feed into Niger's adaptation strategies under The Paris Agreement and the African Union's Agenda 2063. Policymakers should see this not as an isolated technical fix but as part of a broader vision for climate-resilient development (IPCC, 2021).

To further strengthen the impact of the program, public health strategies should be included to reduce waterborne diseases. Improved access to water can directly affect hygiene and nutrition. Combined with educational campaigns, communities could benefit from health gains alongside agricultural ones. For example, by ensuring safe water collection and storage practices, the program could reduce cholera outbreaks common during flood seasons in Zinder. Integrating mobile health units during the pilot phase could provide immunizations, malnutrition screening, and education (FAO, 2018).

Culturally appropriate measures are vital. Religious and community leaders should be consulted from the beginning. In Niger, Islam plays a central role in everyday life, and the support of imams could significantly improve public reception of new technologies. Translations of scientific information into Hausa and Kanuri would increase understanding and participation. Youth groups could be mobilized to lead local monitoring and communication. Technologically, cloud seeding could pair with solar-powered meteorological stations that enable continuous data transmission without dependence on unreliable electricity grids. This infrastructure would also benefit disaster early warning systems. Besides, regional integration with neighboring countries such as Nigeria and Chad, who face similar environmental challenges, could lead to shared seeding operations and cost reductions.

Beyond the technical and logistical dimensions, it is essential to consider environmental ethics and sustainability. Regular environmental impact assessments should monitor the possible accumulation of seeding agents in soil and water. International standards should guide protocol development and material use. Public disclosure of methods, results, and side effects can prevent misinformation and build long-term trust. A robust communication strategy should accompany implementation. Public radio broadcasts, widely used in Niger, can serve as platforms for weekly updates, testimonials from participating farmers, and Q&A sessions. School programs can integrate local climate science and meteorology, empowering students with real-world applications. Workshops for teachers and students could focus on weather monitoring, water cycle education, and sustainable farming. Furthermore, gender equity should be a primary objective. In Zinder, the burden of collecting water and preparing food falls on women. Involving women’s groups in planning and monitoring could make the program more inclusive and effective. Empowering women with agricultural extension services, financial literacy training, and decision-making roles would enhance resilience outcomes.

Climate change has significantly increased drought and food insecurity in Niger, especially in regions like Zinder. Traditional ways of life are threatened, and currently implemented adaptation strategies are insufficient on their own. Cloud seeding offers a promising, though not unique, solution. As part of a broader climate resilience framework, it has the potential to increase rainfall, support agriculture, and restore hope to affected communities. By leveraging international examples and adapting technologies locally, Niger has the opportunity to lead a sustainable transition in climate adaptation.

By combining science, innovation, and community engagement, cloud seeding can significantly contribute to food and water security. With coordinated support, sound planning, and inclusive implementation, it can help transform Niger's environmental challenges into opportunities for resilience and development. At the same time, its effectiveness depends on community engagement, government commitment, and the sustained involvement of international organizations.

In this sense, cloud seeding must also be understood as an innovation for change. It is not just about modifying weather patterns, but about reimagining how societies face the climate crisis together. Innovation becomes meaningful when it generates tangible improvements: farmers empowered with knowledge, women included in decision-making, young people engaged with science and technology, and institutions aligned with local needs. By considering cloud seeding as both a scientific tool and an engine of social innovation, Niger can demonstrate that resilience is built not only with technology, but also with collective creativity and the courage to change.

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