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Harvesting fresh water from fog in rural morocco: research and impact

Dar Si Hmad's Fogwater Project in Aït Baamrane

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Abstract

From climate change to poverty to women's marginalization, humanitarian problems in rural Berber communities on the edge of the Sahara Desert in southwest Morocco – as in much of the developing world – are part of an inter-related web of social and natural systems. The semi-arid southern region of Aït Baamrane is one of the poorest in Morocco and has multiple health, education and sustainable development needs. Despite the human and ecological challenges that afflict those communities, fog remains a constant. Dar Si Hmad for Development, Education and Culture, a local Moroccan NGO, along with an international consortium of engineers and researchers has designed and installed a fogwater harvesting project that provides a holistic approach to addressing complex development challenges. The fog-collection system delivers potable water to hundreds of rural residents who have never had running water. This humanitarian technology project is based on deep local engagement and a shared commitment to education and environmental stewardship, which is reflected in training local community members, particularly women, to operate and manage the new fog-water catchment system. Furthermore, research and the advancement of scientific knowledge are core components of the initiative, and Dar Si Hmad works closely with engineers and social scientists who are committed to sharing useful science and technology with developing communities.

This humanitarian technology initiative seeks to:

- promote fog as a viable source of potable water
- provide clean water to landlocked, rural communities in southwest Morocco
- free women and children from the time-consuming chore of collecting water
- contribute to stabilizing communities through sustainable development
- integrate emerging technologies to enhance water security

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- combine community participation and engineering innovation with research in a comprehensive project that serves local needs and advances scholarship
- provide a case study for collaborative partnerships in rural North Africa and other semi-arid regions.

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1. Introduction

The Aït Baamrane region of southwest Morocco is located at the confluence of three important ecotones – the Sahara Desert, the Anti-Atlas Mountains and the Atlantic Coast – but persistent drought, State neglect and structural poverty are a stark contrast to the geographical richness. Morocco, in general, is notable for its low human development ranking (the 2014 UNDP Human Development Report ranks Morocco #129 out of 187 countries), with lack of opportunity, low educational attainment and gender inequality particularly entrenched in rural areas and for low-literate rural Berber women who endure some of the greatest hardships [1]. Fetching water is a substantial burden for rural women and girls who spend up to four hours/day fetching poor-quality water from wells that are drying up due to climate change and over-use.

Despite low rainfall and depleted aquifers, there is abundant fog for six months of the year, and Dar Si Hmad for Development, Education and Culture (DSH), a local NGO, has launched a pioneering project to harvest fresh water from that fog to alleviate water scarcity in rural communities in Aït Baamrane.

The fogwater harvesting project described here serves as a case study in innovative, holistic approaches to addressing the complex challenges of water scarcity, women's marginalization, sustainable development and emerging technology. Broadly, this international development project addresses issues of natural resource management and sustainable development in North Africa. Specifically, it portrays a fogwater harvesting project that seeks to alleviate water stress and water scarcity among marginalized rural Berber populations [2].

This humanitarian technology project combines applied research in civil engineering and materials science, Information and Communication Technology for Development (ICTD), meteorology, climate science and social science with participatory sustainable development in southwest Morocco. Furthermore, this comprehensive sustainable development project relies on renewable energy sources including a hybrid conventional and solar electricity-powered UV water filtration station at the fog catchment site.

2. Project Background

Dar Si Hmad's fogwater harvesting project is one of the largest fogwater collection and distribution systems in the world, and is the only one in North Africa. The project addresses the critical need for a high-quality, effective, context-appropriate alternative water system that addresses not only water scarcity, but also social marginalization, poverty, lack of livelihoods and poor education. The initiative is both an integrated sustainable development project and an applied, field-based research project. As a case study in humanitarian technology in the Middle East and North Africa, it serves to both broaden and deepen our understanding of effective ways to design, implement, coordinate and research emerging technological solutions to pressing development challenges.

The project is an example of practitioner, researcher and community member collaboration on the design and implementation of a sustainable alternative water system in rural southwest Morocco. The fogwater harvesting project is grounded in an expansive partnership that includes engineers, technologists, meteorologists and climate scientists, social scientists and low-resource community members working with a local Moroccan NGO to help alleviate water stress in rural Berber communities on the edge of the Sahara Desert. For more than a decade, researchers, practitioners and community members have worked together to design, install, monitor and research the pilot fog water harvesting systems to supply drinking water from fog to several villages.

3. Water Poverty In Context: Ecological, Social And Cultural Factors

The effects of water poverty in the Middle East and North Africa are far-reaching. In the foothills of Morocco's Anti-Atlas Mountains, less than 150 mm (< 6") of rain falls per year, and communities there struggle to cope with intermittent drought. Furthermore, evapotranspiration is intensified by hot, dry winds that blow from the Sahara Desert. In rural southwest Morocco – as in many parts of the region – overuse and mismanagement of water resources is exacerbated by climate change [3]. In rural Aït Baamrane, residents rely on rapidly depleting and highly compromised well water for domestic water and small-scale agriculture. Analysis of well water samples revealed high concentrations of chemical salts including sulfates (130-210 mg/l) and high levels of nitrates (80-280 mg/l) that are likely the result of agricultural runoff and contamination by human or animal waste [4,5,6]. Local well water also shows high levels of selenium and uranium.

Low quality, low quantity water is matched by low consumption levels. On average, rural residents consume less than 10 liters of water per day [7]. Persistent water stress, in turn, limits livelihoods opportunities. The Aït Baamrane Berber communities of southwest Morocco are predominantly pastoral agriculturalist, depending on rainfall for both activities. Primary agriculture activities include small-scale farming, beekeeping, harvesting prickly pear, Argan oil production, goat and sheep herding and tending to cattle and chickens. These few livelihood sources yield an approximate income of 1500 DHM/month, or 5 US\$/day/household. Water scarcity and climate change have weakened the social structures of ancestral tribes and rendered rural Berber communities vulnerable. Water poverty has led to substantial outmigration from villages, and while remittances from immediate and extended family members are an important source of income for rural families, the absence of the working age population weakens family and social structures. The ongoing trend of depopulation contributes to community instability and renders villages sparsely populated by women, children and the elderly [8].

Rural Berber women are responsible for upholding traditional lifestyles and customs, but their realities are precarious. Berber women expend extensive labor for limited results. They bear the brunt of the heavy workload to gather water – spending up to four hours/day fetching water from open wells. Time-consuming and laborious water-collecting duties make it difficult for women to pursue productive tasks. In addition, they suffer from low social status and traditional and institutional discrimination. The resulting financial and cultural marginalization of women represents a lost opportunity for women and girls. The Dar Si Hmad NGO, partner researchers and other stakeholders are, therefore, highly attentive to the gender dimensions of the fogwater project.

4. The Concept: Capturing Water From Fog

Despite being an arid and semi-arid region, from September to June, persistent fog drapes the foothills of the Anti-Atlas Mountains in Aït Baamrane. Scientists have determined that “water generation from unconventional resources (e.g. dew or fog) can be a reasonable addition or even alternative to groundwater use in areas with scarce precipitation” [4].

Dar Si-Hmad and its engineering partners have designed and installed two pilot fogwater catchment systems (a Phase 1 pilot project and Phase 2 experimental collection units) that allow for the distribution of water collected from seasonal fog. Collecting water from fog entails capturing water droplets suspended in fog as that moist air passes over a porous vertical net surface (Figure 1). Fogwater drips off the nets into gutters and flows to a hybrid solar and conventional electricity-powered UV filtration system. Filtered water is then transported seven kilometers downslope to a series of reservoirs where water is stored to be supplied to approximately 500 residents in five villages and four rural schools.



Figure 1. Dar Si Hmad's Phase 1 fogwater harvesting system includes 600 square meters of fog nets. Photo by Leslie Dodson.

4.1. Phase 1: Pilot Project Technical Specifications

In 2006, DSH launched Phase I of the pilot fog harvesting project based on a design developed by Fogquest, a Canadian NGO that promotes non-invasive, ecologically friendly water collection systems where fog abounds [9]. The design of the Phase 1 system of nets is similar to a project that was successfully installed in Chile. With nearly a decade of meteorological research in hand, Phase 1 was installed and tested in 2013 [2, 4, 10]. The pilot system is comprised of:

- Experimental fog collection units mounted at the peak of Mount Boutmezguida (29°12'16" N, 10°1'19" W), 1225 meters (4,020 feet) above sea level
- 20 fogwater collection units with single-ply nets totaling 600 square meters of fog net surface area
- 5980m (approx. 6km) of pipes laid from the mountain peak to the lowest village
- Gravity flow water delivery system, down a 750m change in elevation
- a 12 m³ hybrid solar and conventional electricity double-chamber UV water filtration station
- 2 storage cisterns (250 m³ and 214 m³)
- a Davis weather station measuring barometric pressure, temperature, humidity, rainfall, wind speed and direction

Data from Phase 1 showed water production from the 600 square meters of collection units yields an annual average of 6,300 liters of fresh water/day, or 2.3 million liters of water per year if current weather patterns hold.

The cost for Phase 1 fogharvesting nets is approximately \$200 per unit, including nets, poles, gutters and rigging. Phase 1 net units and the water distribution system are robust systems that do not require expert maintenance. Regular maintenance tasks include mending nets, basic welding, changing filters and monitoring the infrastructure. While the fogharvesting systems described in this paper are passive systems, in order for fogwater harvesting to be cost effective at scale, more research is needed to increase the water yield per square meter. Next-generation

prototypes such as the Experimental Phase 2 fog collection units (discussed below) are currently being field-tested, and the development of portable units is progressing.

4.2. Phase 2: Experimental Collection Units

Current research focuses on Phase 2 prototype experimental fog collection materials adapted to local conditions (particularly high wind speeds) [4]. That system, called The FOG|HARVESTER, was designed and constructed by Wasserstiftung, a German water foundation. It consists of:

- 6 experimental 2-ply and 3-ply fog nets, each with an area of 9m² (2.0m x 4.5m)
- Robust plastic (HDPE) grid attached to the leeward side of each experimental net
- Nets tethered with elastic ropes, anchored with steel pipe mounted to stanchions to withstand high wind speeds
- Data loggers (by Decagon Devices, Inc.) to measure water yield
- Various sensors to acquire and store data on humidity, temperature and vapor pressure for hydrodynamic modeling

In stark contrast to the contaminants, heavy metals and high concentrations of chemical salts in local well water, researchers found water sampled from fog collection units to be low in contaminants as well as minerals. According to the 2014 report on the test collectors [4], the pH value of collected fogwater samples “is within an acceptable range (7.0-8.5); nitrate (2.4-11.0 mg/l), sulfate (6.9-17.0 mg/l) and total organic carbon (1.2-3.3 mg/l) are very low as are most of the other substances. Mineral contents (calcium 2.9-9.8 mg/l and magnesium 0.9-1.8 mg/l) are also very low.”

5. Multidisciplinary Research

The fogwater harvesting project in Morocco serves the needs of rural water-stressed communities while also providing a site for ongoing research for social scientists, Information and Communications Technology for Development (ICTD) and M4D specialists, materials scientists and meteorologists.

5.1. Research Partners

The overall fogwater-collecting project is managed and operated locally by Dar Si-Hmad, but it benefits from extensive research relationships and scientific support from climate scientists and meteorologists from the University of La Laguna in the Canary Islands, Spain; Germany’s Wasserstiftung water foundation and research institute; scholars from the Department of Ecoclimatology at Technische Universität München (TUM); the Water Institute in Rabat, Morocco; and student researchers and engineers from the University of Colorado’s ATLAS Institute and the Engineering for Developing Communities program at the School of Engineering and Applied Science; as well as public and private financial support from USAID, the Munich Re Foundation and other donors.

5.2. ICTD and M4D Research

The Information and Communications Technology for Development (ICTD) component of the fogwater harvesting project helps bridge the development divide as well as the digital divide. This ICTD initiative incorporates mobile phones, PCs, tablets and custom software for natural resource management and decision support. The information system was custom-designed so that older, mono-lingual and low-literate Berber women can use their mobile phones to report on water problems. Along with training on using information and communications technologies (ICTs) for water management, local women also benefitted from training in functional and technological literacy [11]. The fogharvesting system also incorporates a multi-platform, multi-device infrastructure tracking system utilizing mobile phones, PCs, tablets and QR codes for synchronous and asynchronous data collection by local low-literate water managers who monitor and manage the water infrastructure (Figure 2). These systems were co-designed by community members and PhD and Masters students [11, 12].



Figure 2. The water manager uses a tablet computer and QR codes to monitor the fog harvesting infrastructure. Photo by Leslie Dodson.

5.3. Social and Climate Science

In addition to research on the development of information and engineering systems, social scientists support the project with robust household surveys of water use behaviors and consumption patterns, while climate scientists and meteorologists continue to record and analyze pertinent micro-meteorological data and climate trends [10, 13].

6. Community Impact

This humanitarian technology project in North Africa offers extensive human and environmental benefits that can be scaled and applied to other sustainable development projects in the Middle East and North Africa and other arid and semi-arid regions. By incorporating user-centered design techniques and participatory action research methods, practitioners from Dar Si Hmad, along with associated researchers, are able to combine community development, emerging technologies and applied research resulting in a water system that is expected to have a positive impact on marginalized rural Berber communities. Community impact includes:

- Development of a sustainable, alternative water supply from fog
- Water service to rural households and schools
- Public health benefits of clean water including lower incidences of water-borne diseases
- Community stability and increased livelihood opportunities, potentially interrupting cycles of rural poverty
- Transformation of women's duties from water gathering to water guardianship

- Release of young girls from water gathering chores, enhancing the possibility they will attend school
- Employment for local laborers
- Increase in water supply (from wells) for agriculture and reforestation
- Decrease in the need to sell animals due to lack of water
- Increased participation by women in natural resource management
- Integration of ICTs in water management
- Increased functional and technological literacy
- Development of a water, sanitation and hygiene (WASH) program for women and children
- Launch of a remedial school for rural children based on water concepts helping young people learn about water and the natural world via a scientific lens



Figure 3. Rural Berber women help manage the new water system. Photo by Leslie Dodson.

7. Future Work & Conclusion

Future practitioner and research fieldwork focuses on the installation of efficient sanitation systems including EcoSan toilets and greywater harvesting systems using ecological filtering systems enriched with algae. Dar Si Hmad is also exploring the development of a permaculture site. International researchers will test a selection of other fogwater collecting nets in upcoming fog seasons to study the applicability of the fog collecting units to other regions and to develop a fog yield model that could be applied to other sites. Additionally, future research might

focus on the correlation between fog yield and wind direction/speed; the dependence of fog occurrence on (large scale) weather patterns; and water quality with a focus on microbiology and plastic residues from the fog net materials [4]. Furthermore, there is ample opportunity to study the intricate social dynamics of water use and water management in rural Berber communities as well as research on and development of Mobiles for Development (M4D) systems for water payment.

The local and international consortium of practitioners and researchers continues to work with community members on emerging technologies to address water scarcity in semi-arid, rural Berber communities on the edge of the Sahara Desert in southwest Morocco. By linking community members, students, engineers, governments, industry and practitioners, this humanitarian technology project provides a case study in promoting science, engineering and technology in sustainable development initiatives, particularly in a part of the world often ignored by development practitioners.

References

- [1] UNDP. United Nations Development Programme. Human Development Report. Morocco country profile. 2014.
- [2] J. Bargach, L.L. Dodson. An experiment in fog-collection and equity among Berber communities in Morocco. Paper presented at the 73rd Annual Meeting of the Society for Applied Anthropology, Natural Resource Distribution and Development in the 21st Century. Denver, CO. March 19-23, 2013.
- [3] F.F. Roudi, L. Creel, R-M. De Souza. Finding the balance: Population and water scarcity in the Middle East and North Africa (pp. 8). Washington, D.C.: Population Reference Bureau. 2002.
- [4] A. Menzel, A. Summary report. Fog net project – scientific support for the test collector in Morocco. Prof. Dr. Annette Menzel, Chair of Ecoclimatology, Technische Universität München. Freising, Germany. 2014, August 26.
- [5] WHO. Sulfate in Drinking Water. Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization. 2004. WHO/SDE/WSH/03.04/114.
- [6] WHO. Nitrate and nitrite in drinking-water Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization. 2011. WHO/SDE/WSH/07.01/16/Rev/1.
- [7] J. Bargach. Executive Summary of “Water from Fog-Collectors” Proposed by Dar Si-Hmad for Development, Education & Culture.
- [8] J. Bargach. Fog collection technology and gender equity in a Berber village. Sidi Ifni, Morocco: Dar Si-Hmad for Development, Education and Culture. 2011.
- [9] FogQuest. Sustainable Water Solutions.
- [10] M.V. Marzol, J.L. Sánchez Megía, A. Yanes. Meteorological patterns and fogwater collection in Morocco and the Canary Islands. *Erdkunde*, 65(3), 291-303. doi:10.3112/erdkunde.2011.03.06.
- [11] L.L. Dodson. A Foggy Desert: Equitable Information Flow for a Fogwater System in Southwest Morocco. Ph.D. dissertation, University of Colorado at Boulder, United States Colorado. Dissertations & Theses: Full Text Publication No. AAT 3621317. 2014.
- [12] L.L. Dodson, S.R. Sterling, J.K. Bennett. The mobile utility gap: SMS use by low-literate Berber women in Morocco. Paper presented at the ACM Intelligent User Interfaces for Developing Regions: Users, Problems and Technologies Conference, Santa Monica, CA. 2013, March 19.
- [13] M.V. Marzol, J.L. Sánchez Megía. Fogwater harvesting in Ifni, Morocco. An assessment of potential and demand. *DIE ERDE: Special Issue: Fog Research*, 139(1-2), 97-119. 2008.