Fog Water Collection

Developing Promotional Materials for COP22

Sponsored By:

Dar Si Hmad
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WPI An Interactive Qualifying Project

Developing Promotional Materials for COP22

For Dar Si Hmad: Promoting Development, Education and Culture

An Interactive Qualifying Project Report (IQP)

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Dar Si Hmad

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Abstract

Dar Si Hmad, an NGO in Agadir, Morocco is preparing material for presentation at COP22 in Marrakech. Our goal was to help design features of their booth at the conference. To meet our goal, we developed methods to promote the science of the NGO's fog collection project. We studied fog properties and the surrounding region to create several deliverables to be presented. The outcome of our deliverables gives Dar Si Hmad exposure and potentially forms new partnerships with other NGOs.

Executive Summary

Image 1: Sunrise Over Boutmezguida (Photo Credit: David Smallwood, 2016)

Introduction

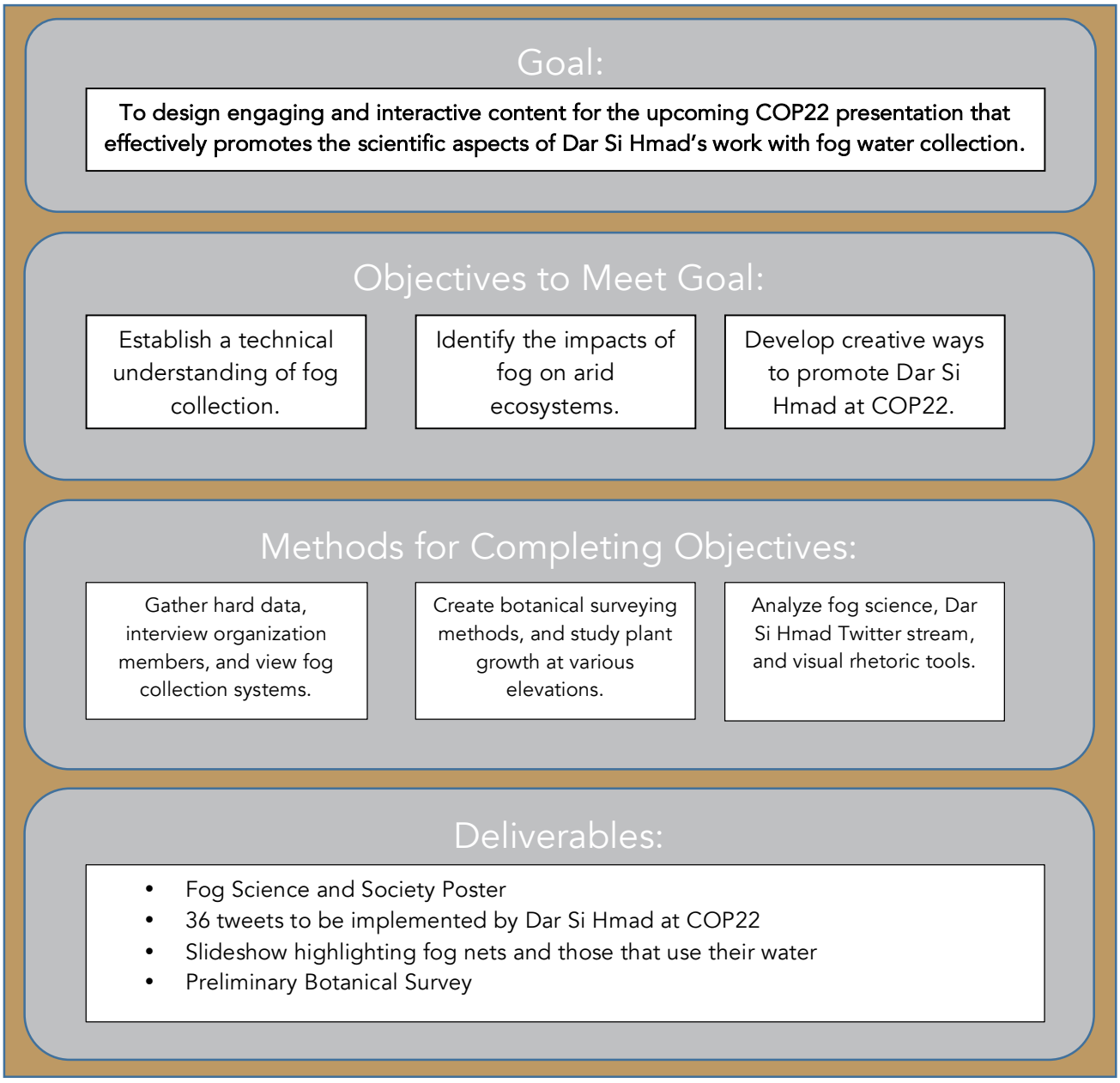
The United Nations Framework Convention on Climate Change (UNFCCC) 22nd Conference of Parties (COP22) is being held November 2016 in Marrakech, Morocco. COP22 provides non-governmental organizations (NGOs) with an opportunity to present their work to other groups present at the event, creating new connections and partnerships. Dar Si Hmad, an NGO based in southern Morocco, will be attending COP22 to present their projects, and wishes to elevate the scientific aspects of their work in an attempt to foster partnerships with a broader range of other NGOs and organizations.

Dar Si Hmad was one of thirteen 2016 UNFCCC Momentum for Change Award winners: an initiative led by the UN Climate Change secretariat to shine a light on some of the most innovative, scalable, and replicable examples of what people are doing to address climate change. This recent recognition provides the perfect platform for Dar Si Hmad to establish new relations with other NGOs and organizations.

Dar Si Hmad asked our team to develop materials for COP22 that highlight technological achievements and facilitate collaboration with new stakeholders. In providing perspectives not previously available, we created linkages between the human aspects of their projects and the innovative technical advances that make their project possible. Through these connections we added new dimensions to their mission that make them more appealing to future partners.

Methodology

The goal of our project was to design engaging and interactive content for the upcoming COP22 presentation that effectively promotes the scientific aspects of Dar Si Hmad's work with fog water collection. The methodology by which we will accomplish this is outlined in the chart below:



Results and Analysis

Results

Our results were broken down into our three objectives described in the Methodology:

Establish a technical understanding of fog collection

This section summarizes the results of extensive literature review and research. In this section, we include the data collected and important scientific features relevant to the fog collection project, such as what fog is: types of fog, weather patterns, water chemistry, fog collection, and fog net types,

Identify the impacts of fog on arid ecosystems

The results of the Belt Transect vegetation sampling method are described in this section. These results consist of our transect lines, the vegetation coverage of the area, and the resulting transition zone from the arid base of the mountain to the vegetation zone. The average elevation of this line was calculated to be 833 m. This elevation is consistent with the transition elevation approximated by the physical survey.

Develop creative ways to promote the efforts of Dar Si Hmad at COP22

Through our extensive background research, interviews, and field work, we devised the following deliverables for Dar Si Hmad:

- A Fog Science Poster relating the technical information about fog collection with its humanitarian impacts.
- A Twitter stream of 36 unique tweets, three tweets for each day of the conference. Dar Si Hmad's current Twitter page was also examined and analyzed.
- A slideshow of our own photographs and photographs provided by previous WPI IQP teams and faculty for presentation at COP22.

Image 2: Argan Tree on Boutmezguida (Photo Credit: David Smallwood, 2016)

Analysis

We feel our fog science poster, Twitter stream, slideshow, and botanical survey will effectively promote the scientific aspects of Dar Si Hmad's projects and formulate new affiliations with other organizations. We related all components of Dar Si Hmad's work and communicated their message through our generated material. Dar Si Hmad is a unique and dynamic NGO with a large scope, and constantly aims to address and relate the scientific and social aspects of their project. We also developed an understanding of our target audience and were mindful of how COP22 attendees will interpret information. The presentation needed to be relevant, current, and engaging, while also maintaining a sense of visual appeal.

Our findings and results through the progression of this project parallel the background information from our literature review. Due to this distinct parallel, the results gathered from research, interviews, and field work did not surprise our team.

Our methods throughout this process have remained fairly consistent, with variations only occurring during the botanical survey. We did not properly account for the topography of this region, and therefore relocated to the bottom of the mountain to sample the transition zone. The greatest challenges our team experienced occurred during the poster development process. Various posters were developed and sent to our sponsor. A majority of our redesigns transpired from email miscommunications, and as a result we resorted to a trial and error design process. Each iteration refined the content and design until we and our sponsor settled on a final product.

The table below displays the analysis of our deliverables:

Deliverable	**Analysis**
Fog Science Poster	o Ties together scientific and humanitarian elements of Dar Si Hmad's work
Twitter Stream	o Dar Si Hmad is not effectively using Twitter to engage other users o The Twitter stream utilizes techniques such as active hashtags to engage attendees
Slideshow	o Photographs serve to make an impression on the viewer and attract people in a purely humanitarian way, further fostering engagement
Botanical Survey	o The catalogued species shows a clear transition between desert and rich vegetation coverage o The location of fog influence on Mount Boutmezguida is important for Dar Si Hmad to utilize as they begin their reforestation project

Table 1: Analysis of Deliverables for Dar Si Hmad

Recommendations and Conclusion

Recommendations

Our recommendations to Dar Si Hmad moving forward are located below in Table 2:

Area of focus	Suggestions
Fog Project	o Publish all photos and slideshow material to generate project interest o Schedule visits and interviews
Social Media Outreach	o Post more frequently on all social media accounts o Link all social media accounts o Employ active hashtags during the conference such as: #ClimateChange, #COP22 o Continue social media presence after conference
Botanical Survey	o Compile a plant encyclopedia o Continue further investigation and surveying of the area
General Organization	o Consistent formatting of files o Keep all files in the same location o Continuously update information

Table 2: Recommendations for Dar Si Hmad.

Conclusion

Dar Si Hmad has worked to elevate the scientific elements of their projects to facilitate collaboration with new stakeholders. Attending the 22nd Conference of Parties will provide Dar Si Hmad with an opportunity to engage with new NGOs, promote its projects, and attract potential new stakeholders and partners. The material and recommendations presented by our team will give Dar Si Hmad the necessary tools to gain better funding, new intellectual capital, and partnerships to help actualize their ideas.

Dar Si Hmad wants to expand their fog harvesting project to other areas near the Aït Baamrane region, as well as incorporate a reforestation project using excess fog water. With little more to be done in the field of passive fog collection technology, Dar Si Hmad can shift their focus to active fog collection and human investment. This route is something new stakeholders, researchers, and perhaps future IQP teams will have the opportunity to explore as attention around this project continues to grow.

With heightened attention surrounding the upcoming conference and Dar Si Hmad's recent UNFCCC Momentum for Change Award, the NGO is in a terrific position to spread awareness about their sustainable and innovative fog harvesting system. Our team was fortunate enough to work with Dar Si Hmad during this pivotal time, and we are thrilled with the future prospects of this project and the NGO.

Image 3: Milky Way Over CloudFishers (Photo Credit: David Smallwood, 2016)

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Chapter 1: Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) 22nd Conference of Parties (COP22) is being held November 2016 in Marrakech, Morocco. COP22 provides NGOs with an opportunity to present their work to other groups present at the event, creating new connections and partnerships. COP22 runs from the 7th to the 18th of November 2016. Dar Si Hmad, an NGO based in southern Morocco, will be attending COP22 to present their projects, and wishes to elevate the scientific aspects of their work in an attempt to foster partnerships with a broader range of other NGO's and organizations. Dar Si Hmad's preparation for the COP22 requires developing features within an interactive booth display. This content provides participants with information about the NGO's involvement in adapting to climate change. During the conference, Dar Si Hmad will run a booth at a Green Zone Side Event, deliver presentations, and participate at roundtable discussions with the UNFCCC.

Dar Si Hmad is one of thirteen recent winners of the UNFCCC Momentum for Change Award. Wining this award positions the NGO to engage with a significant portion of the COP22 attendees, as their project will be specially highlighted. They won the award for their Fog Harvesting project, but that is just one of the many projects they are involved with. Dar Si Hmad promotes: education of children in rural villages with their Water School, teaching science and conservation; pre-professional skills for young adults near Agadir, Morocco, with their RISE&THRIVE program; women's empowerment; and cross-cultural learning in their Ethnographic Field School. All of these programs have similar themes of education and human development, but fog water is the element that ties them all together.

The primary focus of Dar Si Hmad's presentation is the fog water collection program in Aït Baamrane, with a secondary focus on the regional ecosystem that supports fog water harvesting. Being adequately prepared for the COP22 conference will allow Dar Si Hmad to present their mission to other organizations, and connect with new collaborators. The progress of their projects is dependent on acquiring funding, and bettered by partnering with research organizations and benefactors. Currently, Dar Si Hmad has partnered with engineers at the German foundation WasserStiftung to install fog nets, but looks to further expand the scientific scope of their project to other organizations.

Lack of water conservation and climate change have given rise to the global water crisis faced by billions of people. Current estimates project that 90% of freshwater stores will be depleted by the year 2030 (IUCN, 2004) and two-thirds of the world population will face severe water scarcity during at least some part of the year (Hoekstra, 2016). Villagers in Aït Baamrane, Morocco know the difficulty of severe water scarcity. In the desert foothills of the Anti-Atlas Mountains, water is already hard to come by. Wells have dried up, and extended periods of drought have forced villagers to find other water sources, some of which

require women to walk four hours to an operational well (Choukrallah, 2015). Dar Si Hmad's unique fog collection system has provided easy access to water for the villagers.

Implementing fog net systems requires research, funding, and manpower; none of which are easily obtained by Dar Si Hmad, a small non-profit organization in Agadir, Morocco. While the project was started as a relief effort to provide aid to others, Dar Si Hmad looks to expand the ecological awareness of fog on the environment. Dar Si Hmad has asked our team to elevate the scientific elements of their projects to facilitate collaboration with new stakeholders. By providing perspectives not previously available, our team will explore untouched aspects of their previous research. We utilized these new insights to create innovative deliverables for Dar Si Hmad at COP22.

Chapter 2: Literature Review

We began by taking a closer look at Dar Si Hmad and their role at the upcoming 22nd Conference of Parties. We examined the motive and the science behind their projects that provide water to arid villages in Southern Morocco using fog harvesting techniques. Finally, we discuss the unique ecology of the region in which they are working.

Dar Si Hmad

Dar Si Hmad is a Moroccan based non-governmental organization, NGO, working to provide viable water sources to arid regions of Southern Morocco. This small NGO was co-founded by President Aissa Derhem and Director Jamila Bagrach, and consists of ten board members. Based in Aït Baamrane, with headquarters in the city of Sidi Ifni, Dar Si Hmad is one of the only NGOs operating in the region. The map below (Figure 1) depicts the Aït Baamrae region, which consists of a confederation of tribes that live in the mountainous territory. Sidi Ifni, the location of Dar Si Hmad's headquarters, marks the symbolic capital of the region.

Figure 1: Map of Aït Baamrane (Dar Si Hmad)

Dar Si Hmad's mission is to promote "local culture and create sustainable initiatives through education, the integration and use of scientific ingenuity with the communities of Southwest Morocco" (Dar Si Hmad, 2016). Operating as a non-profit, Dar Si Hmad is funded primarily through private donations and organizations, and has an interest in expanding their recognition and donor base.

The projects that Dar Si Hmad manages include: fog collection, ethnographic schooling, and education pertaining to the recycling of water. They primarily focus on providing sustainable water

resources using fog collection techniques. Dar Si Hmad utilizes the dense fog of Aït Baamrane to provide better access to resources, allowing for increased quality of life to the region's inhabitants. The system currently distributes water to five villages, serving approximately 400 people (D'Amours, 2016). As Dar Si Hmad is the only fog harvesting project in North Africa, their capacity for growth and resources are limited (Dar Si Hmad 2016). One of the primary struggles Dar Si Hmad must manage is low staffing for a wide range of projects. Continuous issues of understaffing and managing a multitude of involved projects have made it difficult for Dar Si Hmad to expand their efforts. New collaboration with other disciplines and organizations will provide Dar Si Hmad with the necessary resources to manage the growth of their projects. The Conference of Parties offers the perfect setting to form such affiliations.

Conference of Parties

Conference of Party events, before serving as a platform to connect NGOs and other organizations, are held to address concerns of climate change. In 1995, the UN founded the Conferences of Parties, a gathering of the world's leaders to discuss and address the global issue of climate change. In the decade following its creation, the UN would recognize and propose various plans to battle climate change, such as the development of carbon sinks; restrictions on vehicle emissions; and the Clean Development Mechanism, which allows for developed nations to work and assist each other in reducing carbon emissions (UNFCCC COP6, 2001). The UN seeks to develop a successor to the Kyoto Protocol, and intends to implement it during COP22 in Marrakech, Morocco. Under a new plan, all developing nations can come to an agreement to combat the devastating effects and impacts of climate change (UNFCCC COP21, 2015).

The participation of civil society has been an important and defining feature of COP conferences. While non-government representatives may not participate in official delegation talks, the side events that occur are an outlet for many different causes, and give attendees the ability to partner with other organizations to whom they may otherwise never been exposed. Side events aim to "deepen thinking, strengthen debate, develop partnerships, formulate proposals, and promote knowledge sharing" to launch initiatives in favor of our climate (Side Events, 2016). Green Zone Side Events represent innovation and civil society, while Blue Zone Side Events are dedicated to the Moroccan Pavilion (Side Events, 2016).

Participants network with other organizations to gain new ideas, learn about scientific results, and participate in programs (Hjerpe & Linnér, 2010). Since the sixth COP, more than forty percent of participants at the conferences represent NGOs. By bringing together so many diverse organizations, there is a stronger civil society and media presence, which helps to raise public awareness of issues discussed at COP conferences (Hjerpe & Linnér, 2010).

Promoting the Science and Innovation of Dar Si Hmad at COP22

In November 2016, Dar Si Hmad will attend the COP22 conference as a participant in the Green Zone Side Events. As a way to engage observers in the convention process, Dar Si Hmad can communicate its objectives in a variety of ways. Through the use of guest speakers, side events, exhibits, and booths, all attendees will be given an opportunity to engage audience members. By putting forth several deliverables and takeaways at COP22, NGOs can attract the right attention in a chaotic environment. Executing an effective booth display will convey Dar Si Hmad's purpose at the conference, while simultaneously attracting potential stakeholders and partners.

A convenient, accessible booth display is crucial when attracting participants. Conveying key points quickly and easily gives viewers an idea of an NGO's message and leave a memorable impression. Proper organization, consistency, and accessibility will give the display a simple and purposeful presence.

Visual design makes effective use of images, charts, graphs, white space, font and other components of display. The best visual design relies on consistency and simplicity (Mendenhall, 2015). Engaging and efficient visual representations are useful to utilize in a booth display, as they are attention-grabbing and an easy way to extract information (Mendenhall, 2015).

Information graphics, or infographics, offer a multimodal medium that use visual relationships to make an argument (Mendenhall, 2015). The visual engages an audience, while the information presented provides knowledge that enables a clear understanding and imparts a memorable message onto the audience. Basic visualization allows for immediate detection and comprehension of notable patterns, trends, and outliers in the data. Additionally, visual representations such as video footage or still photos can offer a humanistic connection alongside the hard data and allow participants to connect with the display on an emotional level. This connection between hard science and its impacts on society is a theme Dar Si Hmad stresses in their work.

Social networking sites allow for the rapid dissemination and exchange of information, a necessity at a large public event such as COP22. Twitter, a short message service application, simplifies this exchange by not only sending real-time messages, but also by limiting the size of the messages, making the information easily digestible. COP22's Press and Communications team has developed a Twitter account to raise awareness and mobilize national and international actors (COP22 Digital, 2016). Organizations, specifically nonprofits, use Twitter to engage stakeholders through the use of various communication and interactivity tools specific to the message app (Lovejay, 2011). If nonprofit organizations, such as Dar Si Hmad, take the initiative to use Twitter to its fullest capacity, such as utilizing direct messages, retweets, public messages, and hashtags, these organizations can further adapt their relationship cultivation with stakeholders (Lovejay, 2011).

Water Dependence in Rural Morocco

The challenges facing Dar Si Hmad can be understood by examining how Morocco has changed in recent years and the region's resulting dependence on water. Morocco was once a land of springs. Water originated from the Atlas Mountains as rainfall and snow, filtering through layers of soil and rock to fill aquifers in the lowlands. This resource has played a significant role in regional livelihoods. Farming villages depend heavily on springs to irrigate crops and provide drinking water for community consumption. Over 300,000 square kilometers of land in Morocco are recorded as agricultural, a figure that translates to 68.7% of the total land in the country (Trading Economics, n.d.). Of that, however, 85% of the land used for agriculture depends on rainwater for its crop growth. While Morocco is nearly self-sufficient in food production, a reduction in rainfall has required increased importation of water during periods of drought (NationsEncyclopedia.org, 2008).

Morocco is a region in the world with sporadic weather patterns. Bordered by both the Sahara Desert and the Atlantic Ocean, the country experiences sub-Atlantic systems that have irregular patterns, making it difficult to predict the next rainfall or drought. As a part of the Palearctic Ecozone, Morocco experiences very little rainfall, an average of just 350 mm per year (World Bank, n.d). Unpredictable bursts of water from short periods of rain can overwhelm soil and agriculture, and fail to replenish groundwater. Without having reasonable models to predict precipitation, the balance between living comfortably and overusing water is precarious. Many of the springs in the North African region are "fossil aquifers," or aquifers that have been around for a countless number of years, storing water that has gone untapped for centuries (James, 2015). These reserves are being-drained at a rate faster than they can be replenished.

In a region highly susceptible to drought, the utilization of these aquifers depletes this important resource. As is the case in many rural villages in Morocco, there are few wells to provide water for the entirety of the population. If the well that provides life to a town recedes too far into the ground, residents will either be forced to relocate or walk far distances to functioning wells. As one researcher noted, villagers dug down more than 600 feet, and then "gave up" as the water level "kept dropping" (James, 2015).

Climate change has further affected Morocco's water resource projections and already unpredictable weather patterns. From 1967 to 2007, the average temperature of the planet rose by one degree Celsius. This, along with decreasing rainfall, resulted in a 33% drop in precipitation within the same period (Badran, Baker & Collins, 2012). Long periods of drought and irregular bursts of rainfall have drastically affected the region. In 2014, the Aït Baamrane region of Morocco faced a serious flood that destroyed much of the area's agriculture and irrigation systems (Morocco World News, 2014). Since this flood, villagers are still struggling to perform daily tasks as they once did. Sporadic droughts and flooding heightened by climate change demonstrate the difficulty in having an unstable supply of water, proving the need for alternate forms of water collection in the region.

Fog Properties and Fog Collection

As groundwater stores have become depleted, a new source of water for villages in the Sidi Ifni region must be found. While the arid Moroccan coast is characterized as a desert, with annual precipitation of less than 150 mm, the region is often blanketed in fog. In Sidi Ifni, fog is present on average 43 days per year. In the Anti-Atlas Mountains, 30 km inland, that number jumps to 161 days (Marzol, 2008).

Fog is a cloud with physical contact to the earth's surface, having droplet diameters ranging between 1 μm and ~40 μm (Klemm, 2012). Meteorologists more commonly use the definition that fog occurs when the horizontal visibility is less than 1000 m (Eugster, 2008).

There are seven types of fog that can be distinguished, typically named for their location and formation process: radiation fog, sea fog, steam fog, advection fog, coastal fog, valley fog, and mountain fog (Eugster, 2008). The types of fog and their modes of formation most important to this project are:

Advection Fog: a steady wind that moves formed fog upwind of the site of production.

Coastal Fog: typically an advection fog where the land surface is warmer than the ocean surface, and sea fog is transported from the ocean to the coast.

Mountain Fog: a cloud that moves over a land surface becomes fog when it is intercepted by mountainous obstacles (Eugster, 2008).

Because fog requires specific meteorological and geographical features to form, its presence is often unpredictable and infrequent.

Fog on the West Coast of Africa can be advected inland from formed sea fog, or during the winter, moist air advected from the sea may be trapped below a surface inversion layer to form valley fog (Oliver, 2002). Stratocumulus cloud formations are also common on the Atlantic coast of Morocco, and behave like fog when they hit the mountains. The cloud formation is connected to the Azores anticyclone and the subsistence thermal inversion layer off the coast of Morocco (Marzol,2010). Because of the unique climatological patterns that exist in this region, Aït Baamrane is well suited to a fog water collection project.

Water condensed from fog is found to be low in contaminants as well as minerals (Dodson, 2015). Important to the collected water is the chemical composition of the fog in the air before it strikes the collecting surface. Where fog water and rainwater were collected simultaneously, fog water is shown to contain higher concentrations of solutes because of the intense exposure of fog to near-surface emissions (Klemm, 2012). In the water collected by CloudFisher nets in Aït Baamrane, the water is colourless, clear, and odourless; has normal pH levels; and has a low conductivity due to low concentrations of chlorides, sulfates, and nitrates. The water also contains low concentrations of the heavy metals: chromium, copper, zinc, cadmium, nickel, and arsenic. These levels are well below the limits imposed by the European drinking water regulations (Aqualonis GmbH, nd.)

Emerging technologies are working to tap into fog as a sustainable water resource. Fog water collection has been practiced for many centuries using either water collected from trees, such as laurels and junipers, or constructing structures used to collect fog and dew (Fessehaye, 2014). One of the earliest documented fog collection experiments was conducted between 1901 and 1904 by Marloth on Table Mountain in Cape Town, South Africa. The experiment compared the amount of water collected by a rain gauge and a bunch of reeds suspended over a bucket – the rain gauge collecting 126 mm of water, the reeds collecting 2,028 mm (Oliver, 2002; Fessehaye, 2014). The reed method of collecting fog water became the

Image 4: Fog Water Condensing on Fog Net (Photo Credit: Kris Boudreau, 2015)

standard practice for measuring fog precipitation before the introduction of the Standard Fog Collector in 1994 by Robert Schemenauer (Fessehaye, 2014).

One of the first projects used to provide water from fog was pioneered in South Africa as a source for Air Force personnel. The fog collector was constructed from two large plastic screens situated perpendicular to prevailing winds, and collected an average of 31 m^3 of water per month between October 1969 and December 1970 (Fessehaye, 2014). Fog collection has since remained a mostly unchanged technology, its mechanism being relatively simple: fog is collected when water droplets impact the mesh surface. In most fog collection projects, a Raschel shade net material is used as the surface on which water condenses (Klemm, 2012). In a more recent fog net design by the German engineer Peter Trautwein, a Raschel weave has been shown ineffective, and other material options are being explored (Aqualonis

GmbH, nd.). The new designs are more resistant to wind damage, a leading cause of fog collector failure (Aqualonis CmbH, nd.; Fessehaye, 2014).

Dar Si Hmad's fog harvesting project is currently one of the largest collection and distribution systems in the world, and is the only one in North Africa. In 2013, after beginning meteorological research in 2006, Dar Si Hmad implemented the first phase of the project, using 600 m^2 of netting provided by FogQuest, a Canadian NGO. The nets, located at the peak of Mount Boutmezguida (1225 m a.s.l.) produced an average of 6,300 liters of fresh water per day (Dodson, 2015).

In the second phase of the project, six nets produced by Wassertiftung, a German water foundation, were installed. The new nets were experimental prototypes with an area of $9m^2$, with different netting materials in each of the six nets (Dodson, 2015). The new Cloudfisher nets, designed by Peter Trautwein, are designed to withstand wind speeds of up to 120 kph, making them more resilient and reducing the need for frequent maintenance (Aqualonis GmbH, nd.). These innovations are just the start, as Dar Si Hmad develops the "new design, the cloudfishers" (qtd. D'Amours, 2016). Currently, Dar Si Hmad utilizes 600 m^2 of the standard fog net design, but will expand to 1,600 m^2 with the new CloudFisher nets (qtd. D'Amours, 2016). This increase in surface area with the new nets will provide "more water and [require] less maintenance " due to their sturdiness (qtd. D'Amours, 2016.) The CloudFishers are shown below in Image 5.

Image 5: CloudFisher Pro Nets (Photo Credit: David Smallwood, 2016)

Technological advances have allowed people to tap into fog as a water resource, but the same process is used by the surrounding environment without the need for steel beams or special nettings. To clarify what this means, we will further explore the kinds of habitats that support fog harvesting.

Fog Habitats and Their Importance to Dar Si Hmad

Fog habitats are underappreciated resources for water harvesting. Plants have developed adaptations that allow them to condense water from fog, and use it as a source of water and nutrients. Collection of water by plants can even significantly contribute to the water balance of an entire ecosystem.

These regions are sustained primarily by the existence of fog. The most well known type of fog habitat is the cloud forest, "[a forest] affected by frequent and/or persistent ground level cloud" (Mulligan, 2005). Because frequent fog formation is highly dependent on meteorological patterns and corresponding geographical conditions, fog habitats are most often found at high elevations near oceans. High islands, for example, always have a cloud zone above a certain altitude; within this cloud zone fog forests usually exist (Shimzu, 1992).

Victoria Marzol, a leading fog scientist at the University of La Laguna, notes that the hydrologic existence of forests on Anaga Mountain in Tenerife can only be explained by taking the role of fog into account. The mountain forces trade winds to rise, cooling the air and causing water vapor condensation, creating fog to cover and move beyond the summits (Marzol, 2008). A similar example exists on Reunion Island in the southwestern Indian Ocean: the mountain range disturbs the eastern trade-wind circulation, and a subsistence inversion layer prevents the movement of clouds, causing them to collect. The fog is intercepted by the vegetation and contributes to the cloud forest water balance (Gabriel, 2008).

Fog forests are usually home to a diverse number of plants, many of which are endemic to the region or endangered. In Yoshikazu Shimzu's study of the Bonin Islands, of the 25 endangered species of interest to the study, all 25 were found in the areas of highest elevation, where the probability of fog occurrence was greater than in other areas (Shimzu, 1992). However, the endemism and reliance on fog makes fog habitats highly susceptible to climate change – both naturally occurring and human driven.

There is solid evidence of climate-driven range expansion, retreat, and extinction of species. For species reliant on fog, the tracking of suitable climatic conditions means altitudinal shifts in species presence (Rodriguez-Sánchez, 2008). In the Bonin Islands, the forest located below 100 m of altitude appears to be changing into a dry forest with different vegetation types from the forest located in the fog zone (Shimzu, 1992). Because of the restrictive altitudinal conditions required to produce cloud forests, they are isolated and restricted in spatial extent, and highly sensitive to land use and climate change (Mulligan, 2005).

While fog forests and habitats exist globally, the ones of most interest to the Dar Si Hmad fog collection program are on the Canary Islands. An interesting duality of fog phenomena exists between the Canary Islands and the project site in Aït Baamrane (Derhem, 2015). The two regions are both affected by the Azores Anticyclone off the coast of Morocco, however with opposite effects. The Moroccan fog model is very efficient from December to June, with a deficiency of water in July and August; and the Canary model, which behaves inversely (Marzol, 2010). The fog creates a unique ecosystem on the Islands, and is well documented by Victoria Marzol. The duality of weather patterns and vegetation observations suggests a similar phenomenon could occur atop Mount Boutmezguida, however no formal research has yet been conducted to support this hypothesis.

The existence of vegetation within zones of fog influence suggests that many of the plants on mountains within the arid Aït Baamrane region are sustained by naturally collected fog water. If this is indeed true, it could have an impact on the agriculture of the region, making previously unused land cultivatable. Consequently, Dar Si Hmad would like to expand their project to combine fog collection with tree growth. To better understand how fog impacts plant life, Dar Si Hmad has proposed conducting a botanical survey of the region, the purpose of which is to analyze all of the plant species on Mount Boutmezguida.

The fog collection project is located at an elevation of 1,225 m and the proposed tree project will be further down Mount Boutmezguida at an elevation of 670 m (Bargach, 2016).

A botanical survey collects and record all species of plants within a given region. Because cataloguing every square meter of a region would be prohibitively time consuming, botanical surveying methods can be used that expedite the process. There has been much debate as to the best method of collecting inventory within a region, given that some methods are less accurate than others.

One of the most common models for botanical sampling is a transect method, involving the examination of areas in close proximity to one another. A line is drawn across an environmental gradient, and the species touching this line are documented (Offwell Woodland & Wildlife Trust, 2004). These methods proved to be less effective due to the small sampling sizes used, and the nearness of one site to the next, limiting the overall area covered in surveying to one minute section (Stohlgren, 1998).

A subvariant of the transect method is the Daubenmire method, where a smaller area is used, but areas are not done in such close proximity to each other (Stohlgren, 1998). Using a larger plot area allows for more species to be documented in a survey. In order to accurately classify a species, reports from other similar regions will be used to compare plant types along with field guide books that categorize an array of species.

A more accurate method of plant species sampling that is nearly as time efficient as the transect method, is known as the Belt Transect Method. Line transects are drawn along ecological gradients, and

marked at specified intervals. At each interval, a quadrat is used, which gives a larger amount of data, allowing for the species richness of the area to be better determined (Offwell Woodland & Wildlife Trust, 2004). The Belt Transect Method allows for a broader recording of information than a normal transect and may also include having multiple people record the same location to ensure consistent results.

Details of the species include "a description of the biological setting, including plant community, topography, soils, potential habitat of target species, and an evaluation of environmental conditions, such as timing or quantifying of rainfall, which may influence the performance and expression of target species" (U.S. Fish and Wildlife Service, 1996). Upon analyzing different species found in a survey, a specific section is written for each plant. In this area, one is able to elaborate on the details listed above, including both physical and cultural descriptions of the vegetation and its uses in the wild and domestic realms. This allows for the species to be catalogued and reported.

By researching science communication and visual design, fog collection science, and fog habitats, the requisite knowledge was compiled to output deliverables that will help Dar Si Hmad promote themselves at COP22. The above information will serve to help us develop a methodology for achieving the project objective.

Chapter 3: Methodology

The goal of this project was to design engaging and interactive content for the upcoming COP22 presentation that effectively promotes the scientific aspects of Dar Si Hmad's work with fog water collection. We met this goal by accomplishing the following objectives:

- Establish a technical understanding of fog collection.
- Identify the impacts of fog on arid ecosystems.
- Develop creative ways to promote the efforts of Dar Si Hmad at COP22.

The methods by which we accomplish these objectives are outlined below:

Establish a technical understanding of fog collection

To meet objective 1, we gathered and synthesized articles and other information relevant to Dar Si Hmad's fog collection project. These articles consisted of media reports, interviews, research papers, and transcripts provided by Dar Si Hmad or located online. These formed the basis of our technical understanding of fog collection.

We also interviewed several members of Dar Si Hmad. Prior to traveling to Agadir and Sidi Ifni, our team met with Dar Si Hmad President, Dr. Aissa Derhem. In our meeting with Dr. Derhem, we discussed the basic fundamentals of where the fog project grew from, gaining background on why the particular region of Aït Bamraane was chosen as a land perfect for fog cultivation. After meeting with President Derhem, we traveled to Agadir to meet the rest of the Dar Si Hmad team (See Appendix A). In this informal setting, we had the opportunity to meet Salaheddine Ait Lakdoume. While meeting with Salaheddine, we asked more conceptual questions. Although no formal interview was held, we were able to gather more information that prepared us for our travel to Sidi Ifni.

In Sidi Ifni, to better grasp how the fog system delivered water to households, Hussein Sussan – the Dar Si Hmad water manager - gave us a tour of Mount Boutmezguida, stopping at homes and cisterns to show how water is piped to a household.

We met with the engineer behind the fog project, Mounir Abbar to get an explanation of the systems. With the aid of our translator, Souad Kadi, we asked questions about water collection and net design. We observed the pumping station, reservoirs, and water mixing stations, along with maps showing the paths that pipes take to reach each village. Having the ability to inquire about water production and distribution, we were able to further understand the supply side to the fog project.

To better understand the technology, we hiked Mount Boutmezguida along the water supply line to the nets at the top of the mountain. This gave us a first-hand look at the technology, providing a new dimension to our understanding of the project. We spent time observing the weave types on the old FogQuest nets, comparing them to the newly implemented CloudFisher nets. We also observed the catch basins and collection system used to track the amount of water collected by each net.

Identify the impacts of fog on arid ecosystems

To better understand the impact that fog has on the ecology of the Aït Baamrane region, we conducted a botanical survey of the region surrounding the fog nets. We identified two sample sites: one at the top of Mount Boutmezguida, and one at the base of the mountain. Mount Boutmezguida is located at the confluence of the Sahara Desert and the Atlantic Ocean, this junction creates unique climatological patterns responsible for the frequent presence of fog. The region around the mountain is considered a zone of special interest because of the unique ecosystem sustained due to the presence of fog. Conducting a botanical survey in conjunction with an extensive literature review allowed us to recognize the ecological impacts of fog on the region, as well as understand how the species present are used by the indigenous people.

The region of study for the botanical survey was chosen based on the wind direction and recommendations from Hussein Sussan, the water manager for Dar Si Hmad. The zone of special interest exists only above a certain altitude, where fog contributes to the local water balance. We used image analysis and a method of transect sampling to determine at what altitude this occurs. This will serve as a foundation for future reforestation projects sponsored by Dar Si Hmad.

A study of the top of Mount Boutmezguida was first conducted within the constraints of the green polygon as shown in Figure 2.

Figure 2: Botanical Survey Sites and Transect Lines (GoogleEarth, 2016)

Our team, with the help of a local resident Mr. Mohammed Sfourg, a fourth-generation beekeeper who knows the flora of the region, combed the area and identified 27 individual plant species. The names of the plants were recorded in a local Berber dialect and translated into their respective Latin names. According to Sfourg and Hussein, the plants discovered at the top were representative of the entire mountain: from the top, to the dried riverbed at the bottom.

Our botanical survey used a modification of a common sampling method, known as the Belt Transect method. For this method, we used 25 m transect lines and a 1 m^2 quadrat. The first transect started near the base of the CloudFisher nets, and extended 175 m along a 340˚ compass bearing. This transect line was not used during analysis, as the terrain became too difficult to continue surveying and the plant coverage near the top of the mountain was observed to be fairly homogenous.

To demonstrate the influence of fog on the water balance of the mountain, we moved to the base of Mount Boutmezguida to survey the transition zone. This extended from the road that led to Dar Si Hmad's well house (813 m above sea level) to 175 linear meters up the mountain (864 m a.s.l.). At the base, there is a dry riverbed, which contains Dar Si Hmad's primary drilled well. According to the Dar Si Hmad Water Manager, Hussein Sussan, the lower limit of fog influence is along this riverbed. Surveying the area around the riverbed will give the best representation of how fog affects the local ecosystem. Three transects

350 m in length - half above the riverbed, half below – were made perpendicular to the riverbed. At 25 m intervals along the transect a 1 m^2 quadrat was laid on the ground, and within each quadrat the vegetation coverage was estimated. A photograph of each quadrat was taken using an iPhone camera; and the GPS coordinates recorded using an iPhone App, Commander Compass v3.7.11. Samples of each unique plant species within the quadrat were preserved for later observation. The complete method and survey form can be found in Appendix B.

In addition to the transect study conducted at the base of the mountain, we explored the top of Mount Boutmezguida, completely canvassing the plot of land around the fog nets. This survey was conducted using the botanical knowledge of Mr. Sfourg, who is familiar with all of the species indigenous to the region. Our team searched the entire area for plant species, cataloguing an image of each species found, as well as the Berber name. These names were later translated into their respective Latin names with the help of Dr. Aissa Derhem.

Develop creative ways to promote the efforts of Dar Si Hmad at COP22

Our team was initially asked to create several visuals for the booth display. These deliverables included a poster relating fog science and its humanitarian impact, a Twitter Stream, and a slideshow, and contributed to our promotion of Dar Si Hmad's work. To successfully develop these deliverables, we completed the following methods:

Fog Science and Society Poster

To create a poster relating the technology behind the fog water project and the communities benefitted by the fog nets, we gathered and synthesized articles about Dar Si Hmad's project as outlined in our first objective. In addition to this technological information, we familiarized ourselves with the humanitarian aspects of this project. To do this, we read through several recorded interviews of Dar Si Hmad workers and members of the Aït Baamrane villages. These recorded interviews were supplied by Dar Si Hmad and outlined the Amazigh villagers' feelings about the fog project. These interviews provided our team with direct quotes and helped shape both the negative and positive impacts the fog net system has had on its beneficiaries. These articles and recorded interviews discussing fog science and the impact on the Aït Baamrane community generated the content that went into the poster design.

To strategically organize this content in an aesthetic way, we read books and tutorials discussing the basics of graphic design and visual representation. This list can be found in Appendix C. Effective visuals are imperative to a display. These readings and tutorials provided our team with ways to combine information and visuals in a way that is appealing and engaging to the audience. We spoke with experts in graphic design. Dr. Brenton Faber, a writing professor at WPI, who is skilled in graphic design and teaches

on the art of visual rhetoric. We interviewed Professor Faber to better understand key features of effective information graphics, or infographics. Through our graphic design research, we felt we could create an aesthetically appealing poster for Dar Si Hmad.

We examined several softwares to generate an effective poster design. We evaluated the softwares on the basis of ease of use, customizability, chart and graph functions, and overall visual appeal. The various softwares we looked at provided templates and suggestions for a possible layout of our poster. After weighing the pros and cons of the different softwares, we decided on the program Piktochart to formulate our fog science poster.

Twitter Stream

Social media has become a leading way of connecting people with similar interests or attending the same events. Dar Si Hmad plans on engaging new stakeholders and other COP22 participants using their Twitter, Instagram, and Facebook pages. We conducted a preliminary assessment of the Dar Si Hmad Twitter page to determine the level of engagement that would be possible with their existing account. This assessment was conducted by keyword analysis and number of interactions with each tweet.

To analyze the content and level of interaction with the twitter page, the number of likes and retweets for each tweet originating from the @DarSiHmad account (i.e. only original content, not retweeted from another account) were counted in the date range of 1 January 2016 to 14 September 2016 (176 tweets). The same 176 tweets were then analyzed for content.

All 176 tweets were converted into plain text and compiled into a Microsoft Word document. Each tweet contains the same links and words: Dar Si Hmad (account name), @DarSiHmad (twitter handle), Reply, Retweet, Like, and More. Using Microsoft Word Find and Replace, these words were removed from the plain text document. Each tweet also contains a date stamp, which were all removed manually (select and delete). The remaining plain text left only the content of the tweets. This content was uploaded to www.wordclouds.com to generate a word list with associated frequencies. All of the 176 tweets were also analyzed for number of interactions, counting retweets and likes.

To compose the tweets to be tweeted at COP22, we organized an itinerary for the conference and developed a relevant theme for each day. By researching Twitter communication and reading case studies about the use of Twitter at large conferences, we created tweets that used relevant hashtags, interesting content, and engaging messages to further engage audience members.

Slideshow

To create the slideshow, we took photographs of the fog water collection site in Aït Baamrane and incorporated photographs taken of the villages by previous WPI IQP teams and faculty. We selected images we thought to be most compelling, and organized them into thematic categories, including: villagers,

development, fog nets, and women as water managers. The photographs chosen for each category were compiled into two to three slideshows using Apple iMovie. The slideshows were exported as .mp4 format files, with two different resolutions: one for display on a large screen, and one for web sharing.

Chapter 4: Results and Analysis

Results

Fog Science

This section summarizes the results of extensive literature review and research. In this section we will include the data collected, and important scientific features relevant to the fog collection project.

Fog Data

- A cloud with physical contact to the earth's surface
- Droplet diameters between 1 μm and 40 μm
- Meteorological definition: horizontal visibility less than 1000 m

The seven types of fog and their mechanisms of formation are listed below in Table 1.

TYPES OF FOG AND FORMATION CONDITIONS

1	Radiation Fog	Common when cold air accumulates during the night, or longer periods in winter.
2	Sea Fog	Humid air cools over a cold ocean surface, condensing water vapor to fog.
3	Steam Fog	Cold air with a low vapor saturation capacity flows over warm water that evaporates water faster than the cold air can hold it.
4	Advection Fog	A steady wind moves a formed fog layer upwind of its formation site
5	Coastal Fog	Advection fog that has been transported from the ocean.
6	Valley Fog	A radiation fog that forms in a mountain valley.
7	Mountain Fog	A cloud moves over a land surface at a given height and is intercepted by an orographic obstacle (e.g. a mountain).

Table 1: Types of Fog and Formation Mechanism (Eugster 2008)

The various types of fog referenced in the table above, are graphically depicted below in Figure 3.

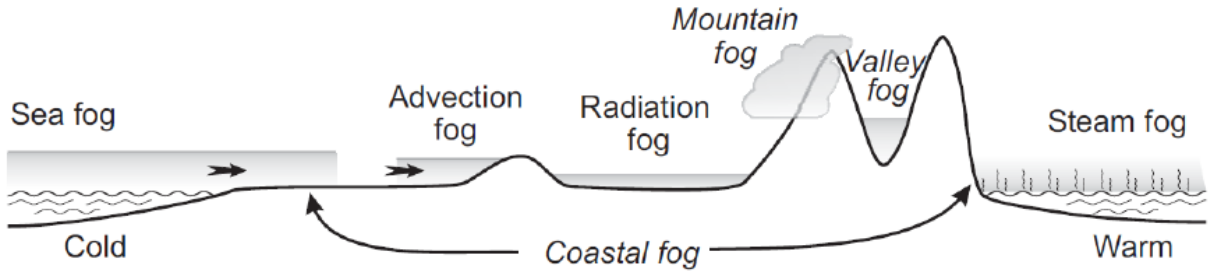


Figure 3: Fog Types and Formation Locations (Eugster, 2008)

Weather Patterns

The unique, localized weather patterns of the Aït Baamrane region are requisite to the formation of fog. Being at the confluence of the Sahara Desert and the Atlantic Ocean creates the perfect preconditions for frequent fog development. Figure 4 depicts the proximity of Mount Boutmezguida to the Atlantic Ocean, and the formation of mountain fog.

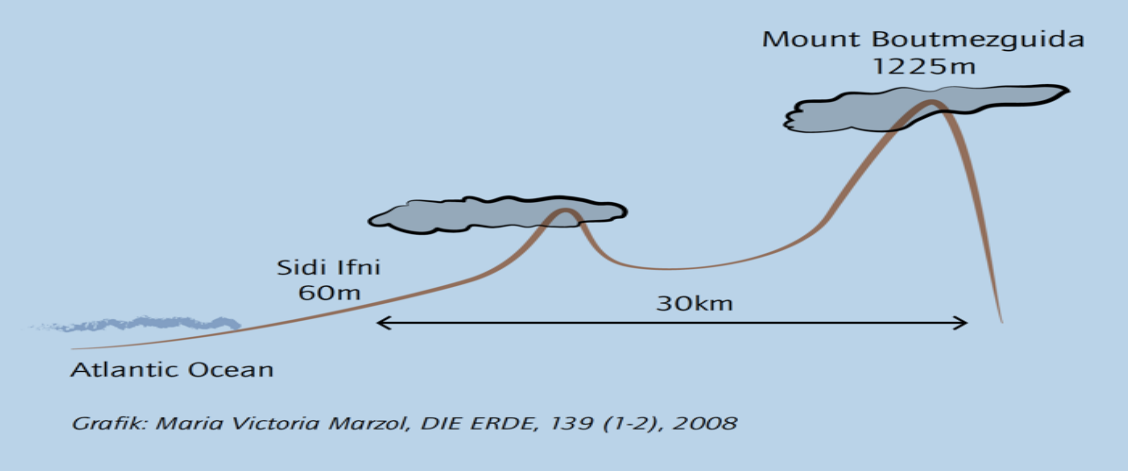


Figure 4: Proximity of Boutmezguida to Atlantic Ocean (Marzol, 2008)

A permanent subsistence inversion layer exists over the region, trapping clouds below a certain elevation, which varies with season.

Stratocumulus clouds are formed over the Atlantic coast of Morocco, getting trapped under the inversion layer and advected over land, where they are intercepted by the mountains.

The cloud formation is caused by the Azores Anticyclone and Canary Cold Current present off the Moroccan Coast. As seen in the image above, the particle rich air is blown 30 km inland to Mount Boutmezguida. The mountain intercepts the clouds, causing them to become fog. Statistical data relating to fog in the region are shown below in Table 2.

Weather and Fog Statistical Data for Aït Baamrane	
National Annual Rainfall	350 mm
Regional Annual Rainfall	152 mm
Fog Days Annually on Mt. Boutmezguida	161
Fog Season	September – June
Wind Speed at top of Mt. Boutmezguida	120+ km/h
Boutmezguida Water Needs to Support Humans and Livestock per Home	500 l/ day

Table 2: Weather Data for Aït Baamrane (Marzol, 2008)

Water Chemistry

The water collected by fog nets is found to be low in contaminants and minerals. The concentrations of important measurements gathered from extensive testing done by Aqualonis are shown below in Table 3, compared to WHO and EU water quality standards. The complete list with net type specific concentrations and pH levels can be shown in Appendix D.

Fog Water Quality			
	CloudFisher	WHO	EU
pH Levels	7.1-7.7		
TOC Concentrations	2.2/2.8 mg/ L		
Conductivity	83-99 S/cm		
Chloride Concentration	8.9-11 mg/L	250 mg/l	250 mg/l
Nitrate Concentration	5-6.4 mg/ L	50 mg/ l	N/A
Sulfate Concentration	11-12 mg/L	500 mg/l	250 mg/l

Table 3: Fog Water Quality Compared to WHO and EU Standards (Aqualonis GmbH, n.d)

Fog Collection: FogQuest vs CloudFisher

When initially testing to determine if Mount Boutmezguida was rich enough in fog, FogQuest, a Canadian NGO, implemented and tested netting. The Standard Fog Collector (SFC) was used to track the amount of water being pushed through the air. Having recorded a number high enough to meet criteria for fog collection, Dar Si Hmad was able to move forward with implementing nets, causing them to branch away from FogQuest and towards CloudFisher. A comparison of these brands can be seen below in Table 4.

Water Yield	
Collection Value to Implement Fog System (Daily Annual Average)	5 l m^{-2} day^{-1}
Standard Fog Collector (SFC) Area in Testing	1 m^2
SFC Efficiency	50%
SFC Boutmezguida Maximum Yield (2009)	10.5 l m^{-2} day^{-1}
CloudFisher Boutmezguida Maximum Yield	22 l m^{-2} day^{-1}
FogQuest Typical Production Rate	5 l m^{-2} day^{-1}

Table 4: Comparison of FogQuest and CloudFisher (Aqualonis GmbH, n.d; FogQuest)

One aspect that was greatly optimized in the CloudFisher fog net design was the net type. In previous FogQuest nets, only Raschel Dual-Layer nets were used, as shown in Figure 5.

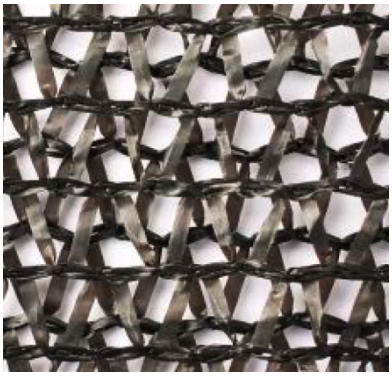


Figure 5: Raschel Net (Aqualonis GmbH, n.d)

In experiments conducted by Peter Trautwein at the Boutmezguida site, this proved to be the least effective net type. Two more experiments using new net weaves were conducted from November 2014 to June 2015, determining the most effective mesh type to be Spacer Fabric (Figure 6).

Figure 6: Spacer Fabric (Aqualonis GmbH, n.d)

To limit variables, the locations of the nets were changed and monitored, effectively removing wind direction as a factor on fog yield per mesh type. Results from these experiments show that woven mesh produces a lower water yield than monofilaments, the most effective being Spacer Fabric. Images of the nets used in the final trial of the experiment are shown below in Table 5.

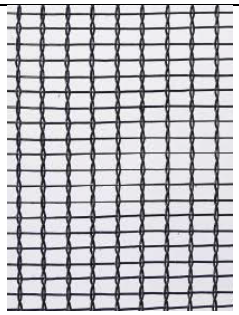
Netting Used in Phase Three of Cloudfisher Testing			
Hail Net High Density Polyethylene (HDPE)		Antigranizio 5x4 (HDPE)	
Spacer Fabric Polysulfone (PES)		Stainless Steel 1.5 x 5	
Dual Layer Hail Net (HDPE)		Stainless Steel 3x5	

Table 5: Nets used in Phase 3 of Cloudfisher Tests (Aqualonis GmbH, n.d)

Over the course of two and a half years, CloudFisher tested different types of netting on the top of Mount Boutmezguida. During this process, netting was changed as the phases continued. Nets that produced low yield in early phases were replaced with other mesh types in later trials. Overall, it was found that one mesh type, the Spacer Fabric, had the highest yield of water. From testing, it was determined that woven meshes yielded less water than monofilament fabrics. Due to this, testing focused on material used and dimensionality, comparing single layer and dual layer netting. Conclusively, dual layer netting and non-linear styles, such as the Dual Layer Hail Net and the Spacer Fabric were shown to have higher water yields.

A more comprehensive table of different types of nettings, along with their material properties can be found in Appendix E. This table includes weave types other than those tested by CloudFisher, but the types of material remain constant. To retain accuracy, the size of netting tested for each type was held constant, allowing only position to be a variable. In doing so, the phases were able to accurately determine

what mesh types were inferior and which remained most efficient. More extensive information about these experiments, including all trials can be found in Appendix F.

Botanical Survey

Using the same Belt Transect vegetation sampling method described in the Methodology Chapter, we collected samples from seven survey plots, along three transects with an approximately 300˚ bearing. The transects are shown below in Figure 7.

Figure 7: Sample Sites and Transect Lines on Boutmezguida (GoogleEarth, 2016)

The percent coverage of each plot was estimated using a coverage grid as shown on the Botanical Survey Form in Appendix B The coverage was plotted as a function of altitude, and a linear trend-line fitted to the data as shown in Figure 8

As shown in the model below, for elevations greater than 840 m a.s.l., plant coverage is on average 64%; whereas below 840 m a.s.l. the average coverage is only 9%.

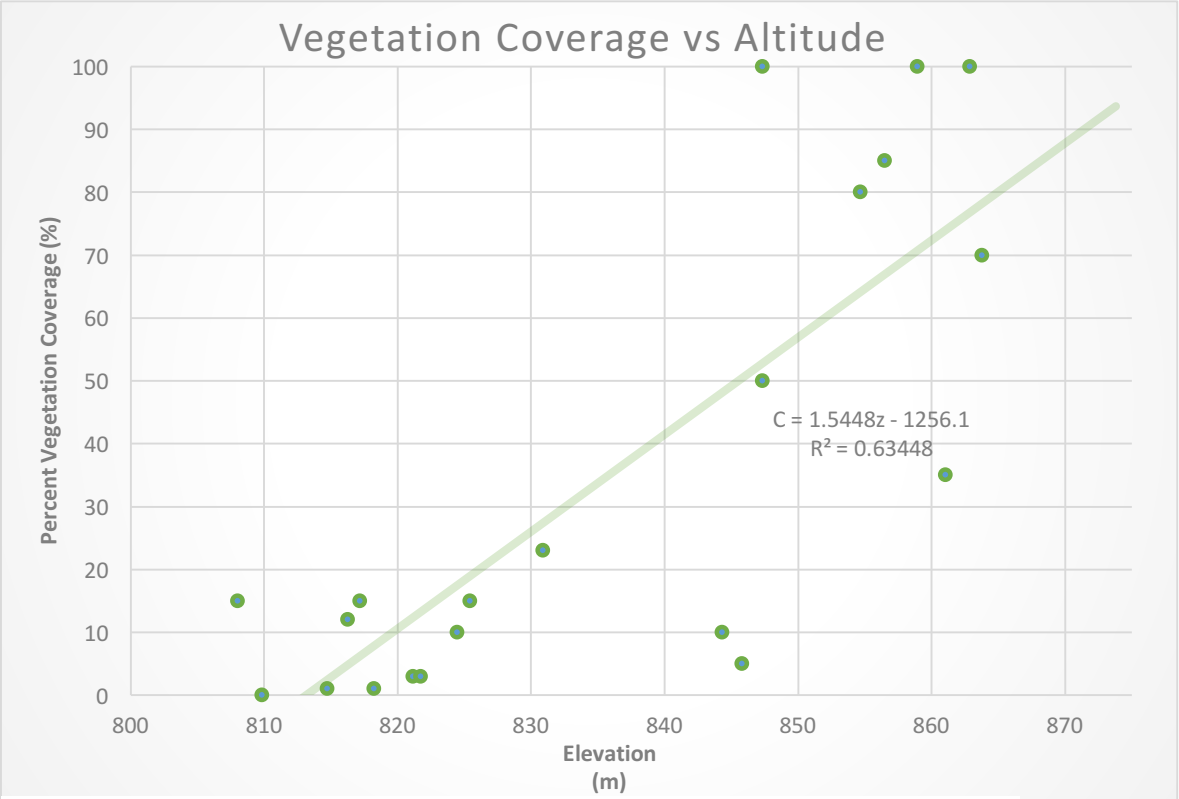


Figure 8: Vegetation Coverage vs Altitude (from survey data)

Where the physical study conducted was small, consisting of only 21 sample plots, covering an area of 2.15 hectares, it was supplemented with image analysis of the same region. To visualize the transition from the arid base of the mountain to the vegetation zone, we analyzed images from the base of the mountain for average color. An image of the mountain below the fog nets was taken, framed from the road at the base to the peak Figure 9.

Figure 9: Image Used for Image Analysis (Smallwood, 2016)

Using ImageJ, an image analysis software, the average color for 29 different rectangular selections was determined using the Average RGB plugin (Figure 10).

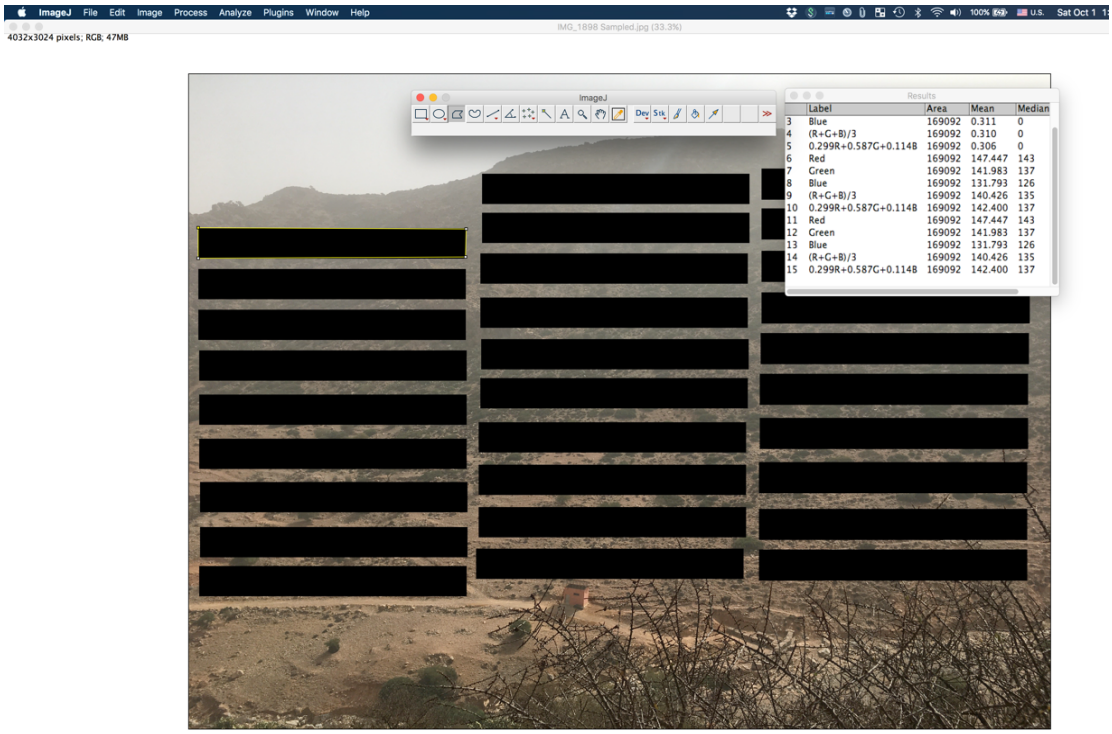


Figure 10: Selections in ImageJ for Sample Analysis (screenshot)

The average color of each rectangular selection was recorded as a Red, Green, and Blue value (RGB). The same 29 rectangles were drawn in Adobe Photoshop and filled with the average color of the corresponding rectangle in the analyzed image. The rectangles were slightly enlarged and connected, forming a color map of the original image. This was made transparent and overlaid onto the original image. The saturation of the image was increased to make the color map more visually appealing and better show the contrast between sample sites. The resulting image is a stylized representation of the data collected through image analysis and is shown below in Figure 11.

Figure 11: Stylized Average Colors of Sample Sites (Smallwood, 2016)

Note: This image is a stylized representation of the average color of the 29 sampled areas of the image analysis. It shows the transition from desert (orange colors) to vegetation coverage (green).

The RGB colors were further analyzed using Microsoft Excel. The ratio of green to red was plotted against elevation. As shown in Figure 12, as elevation increases, the ratio of green to red also increases for all three sample series. Where soil is primarily red, and vegetation coverage is primarily green, an increasing green to red ratio can be interpreted as an increasing ratio of plants to soil. This corresponds to the data collected with the physical vegetation survey, which also demonstrates increasing vegetation coverage with increasing elevation.

Figure 12: Ratio of Green to Red vs. Elevation (from image analysis)
Note: This chart shows the increasing ratio of Green colors to Red colors with increasing elevation from image analysis. This can be interpreted as increasing vegetation coverage with increasing elevation.

The region sampled was also found in GoogleEarth Pro (Figure 7), and a path drawn along the lower limit of visible vegetation coverage. The three transect sample lines from the botanical survey and elevation profile of the top of the mountain were also drawn in. The elevation profile of the vegetation line is shown below in Figure 13.

Figure 13: Elevation Profile of Vegetation Line

The average elevation of this line was calculated using a trapezoidal method of graphical integration and average value theorem: $\bar{Z} = \frac{1}{L}\Delta x(\frac{f(x_{i-1})+f(x_0)}{2})$. The average elevation of this line was calculated to be 833 m a.s.l. This elevation is consistent with the transition elevation approximated by the physical survey (840 m a.s.l.).

In addition to the analysis of the transition zone, we cataloged the species present on the top of Mount Boutmezguida. This collection documents the variety of plants we identified with Mohammed Sfourg. Photographs and labels of the species were compiled along with a complete list of what we found. The catalogue and associated pictures are located in Appendix G.

Deliverables

Through our extensive background research, interviews, and field work, we devised the following deliverables:

Fog Science and Society Poster

We developed a poster outlining the technology behind fog science, fog collection, and the societal implications of the project. This poster will be on display in Dar Si Hmad's booth at COP22. We researched several softwares to formulate this poster, and ultimately decided on Piktochart to complete the design. Table 6 below features the pros and cons of several softwares examined during the research process.

Software Comparison Chart			
Program	Pros	Cons	Utilized?
Piktochart	-Various infographic, poster, and presentation templates available -Various font options -Allows for chart and graph development -Online account accessible from various monitors -Very easy for non-designers -Many icons available	-Only partially appears in Explorer -Week long free trial	Yes (final poster, draft)
iMindMap	-More freedom for design	-Basic template -Week long free trial	Yes (draft)
Prezi	-Various presentation templates -free site	-Does not allow for PDF conversion -Does not allow for customization	No
Chart Chooser	-Allows for chart and graph development	-Does not allow for infographic design	No
Infogr.am	-Easy to use -Works in many browsers	-Few images/icons which makes it less visual	No
Easel.ly	-Less finicky than other programs -Works in many browsers	-Infographic must fit a specific theme -Does not recognize special characters	No
Dipity	-Allows for timeline development	-does not allow for chart and graph development	No

Table 6: Comparison of Visual Design Softwares

The content of our fog science poster encompasses the following six topics: Fog as a viable resource, the obstacles the fog project has faced thus far, the net design process, the future of fog harvesting, Dar Si Hmad's upcoming reforestation project, and the humanitarian impacts.

Our completed poster is shown below in Figure 14.

Figure 14: Final Poster Design

The outer region of the poster contains the first five topics listed above and largely focuses on the technical aspects of the fog project. The center focus of the poster contains the project's social aspects and how the beneficiaries of the project have been affected since the inauguration of system. Their feelings are depicted through several quotes taken from supplied interviews recorded by Dar Si Hmad. We chose to include a combination of photos, graphics, and text on the poster design, with a blue and black color scheme utilized throughout. Each of the topics is boxed off into its own section, with corresponding text to go along with each heading.

The design of the poster underwent several variations. The previous poster designs can be found in Appendix H.

Twitter

The Dar Si Hmad Twitter Page (@DarSiHmad) joined twitter in May 2013. As of 14 September 2016, the page has tweeted 551 times, is following 852 other accounts and is followed by 234 accounts. Of the 551 tweets, 169 have contained a photograph or video. The account's bio (biographical section) is: "Local non-profit in SW #Morocco utilizing innovative tech to provide #water & #education to rural communities. Also home to a dynamic Ethnographic Field School!"

Of the 176 @DarSiHmad tweets analyzed from 2016,, each tweet received on average: 0.5 Retweets and 0.64 Likes. The Mode and Median number of Likes and Retweets is 0. The maximum number of Likes was 5, the maximum number of Retweets was 3. The results of analysis of the content of each Tweet are shown below in Table 7.

Top 5 Words for @DarSiHmad		**Words Related to Fog Nets and COP22**	
Word	Uses	Word	Uses
Water	61	Water	61
RISE	46	Fog	29
Morocco	40	Water School	8
Fog	29	@COP22	4
School	25	#COP22	0

Table 7: Tweet Word Frequencies for @DarSiHmad

For our Twitter deliverable, we generated a stream of 36 tweets: 3 tweets per day for the 12 days of the conference. Each day focused on a different theme which we felt was relevant to both the conference and Dar Si Hmad's work. The entire stream can be found in Appendix I.

Slideshow

Photographs provided by previous WPI IQP teams and faculty, Dar Si Hmad, and our own photographs were compiled into the following thematic categories:

- Villagers
- Development
- Fog Nets
- Women as water managers

Sample images used in the slideshows are provided in Appendix J, along with a YouTube link to the fog net slideshow. The other slideshows could not be distributed per the request of our sponsor.

The compilations of photos feature a humanitarian focus. The photographs chosen for each category were compiled into two slideshows using Apple iMovie. Each photo is showcased on the slideshow for a period of seven seconds, and then fades out into the next photo. The slideshows will be put on a continuous loop, and will be featured within Dar Si Hmad's booth. The videos were exported into .mp4 file formats, two versions of each: one with a large resolution for display on large screens and one with a web compatible resolution.

Analysis

We feel the fog science poster, Twitter stream, slideshow, and botanical survey will effectively promote the scientific aspects of Dar Si Hmad's projects and formulate new affiliations with other organizations. This facilitated collaboration will give the NGO the necessary resources to continue the scope of their work. Through the progression of these deliverables, we discovered ways to effectively relate all components of Dar Si Hmad's work and communicate their message through our generated material. Dar Si Hmad is a unique and dynamic NGO with a large scope, and constantly aims to address and relate the scientific and social aspects of their project. In order to produce deliverables that capture Dar Si Hmad's work, our deliverables creatively relate these topics.

We also developed an understanding of our target audience and were mindful of how our they will interpret information. The theme of maintaining audience arose from the creation of the poster design, Twitter stream, and slideshow. When adapting each, the information was catered specifically to attendees at COP22. Information presented needed to be relevant, current, and engaging, while also maintaining a sense of visual appeal.

Our findings and results through the progression of this project have paralleled the background information from our literature review. Our research regarding Dar Si Hmad, their involvement and role at COP22, visual display and graphic design, the Aït Baamrane area, fog science and collection, and fog habitats and their importance have all proven relevant when developing this content for Dar Si Hmad. Due to this distinct parallel, the results gathered from research, interviews, and fieldwork did not surprise our team.

Our methods throughout this process have remained fairly consistent, with variations only occurring during the botanical survey. The first transect line was drawn on the top of the mountain, and we did not properly account for the topography of the region. After the seventh sample plot, our team reached a cliff face that had not been apparent on our maps, and we were forced to stop. It was at this point we moved to the bottom of the mountain to sample the transition zone.

The greatest challenges our team experienced occurred during the poster development process. Various posters were developed and sent to our sponsor and each draft required either new information or new portrayal of information. A majority of our redesigns transpired from email miscommunications. The concept for the final poster was rather abstract, focusing on "the open questions of fog science." Minute details about this topic are difficult to communicate through email, and as a result we resorted to a trial and error design process. Each iteration refined the content and design until we and our sponsor settled on a final product.

The poster will serve to tie together the elements of Dar Si Hmad's work that are already well founded with the new scientific material that our team produced. As seen in Figure 14 in the Results and Findings Chapter, scientific questions and knowledge are surrounding the humanitarian work done by Dar Si Hmad. For an NGO with a primary focus on human development, the core of their work is mainly humanitarian, achieved through the use of science and technology.

To promote their content, Dar Si Hmad hopes to engage other stakeholders and NGOs using their Twitter stream. Given the findings from our analysis of their Twitter page, they are not currently using the platform effectively to engage other users. As one of our deliverables, we developed a stream of 36 tweets: three tweets per day for the twelve days of the conference. We incorporated techniques for composing tweets that we have seen effective in our research, including using targeted hashtags, tweeting images and infographics, and linking other forms of social media.

In a meeting with one of Dar Si Hmad COP22 team leaders, Salaheddine Ait-Lakdoume, we discussed many of the options that could help them use their Twitter more effectively. One of the most notably lacking features of their twitter is the #COP22 hashtag. Hashtags give other users the ability to search all content related to a specific event, in this case COP22. They are going to make an effort to include #COP22 in addition to other conference specific hashtags to increase their visibility to other participants.

To again tie in technical information with humanitarian impacts, we developed slideshows to be displayed at the booth or tweeted out. The slideshows had different themes, including villagers, fog nets, and the Aït Baamrane villages. These montages had no content aside from images and quotes, but served to make an impression on the viewer. If a viewer saw an image that was particularly striking, perhaps they would engage with the staff at the booth – asking questions, or wanting to know more about the picture. Photographs serve to attract people in a purely humanitarian way, but the initial attraction to the booth will foster an engagement with other scientific aspects of the project.

The botanical survey presented an opportunity to tie in a scientific aspect of Dar Si Hmad's work not previously mentioned. The material we generated from this survey will further help Dar Si Hmad tie in their scientific work and display its resulting societal impacts. The survey was limited by time constraints and scale of the region of interest, but a careful selection of the region of study allowed us to determine an elevation above which fog significantly contributes to the water balance of the mountain. A physical study of three transects down the mountain and an image analysis of the same area shows that the lower limit of fog influence is 840 m above sea level. Knowledge of the location of this transition is important for Dar Si Hmad as they are soon beginning a reforestation project using fog water. With the new CloudFisher nets that are being installed in January, 2017, Dar Si Hmad will be faced with a surplus of water. The excess will be used to cultivate currently barren land.

A catalogue of species was of high interest for our sponsor for the upcoming reforestation project. In the preliminary survey conducted at the top of Mount Boutmezguida with the aid of Aissa Derhem and Mohammed Sfourg, a variety of plants were identified by the Berber name, and an attached picture. For plants with no readily available translation to a Latin name, they had to be visually compared to a field book. As some species were not included in the field book, or unknown by Sfourg, not every plant could be successfully identified. Additionally, of the thirty-two species initially discovered, later observation showed they were a different section of an already identified plant, as a result our list was reduced to twenty-seven unique species.

The plants catalogued on top of Mount Boutmezguida are products of the localized fog. Even without a systematic study, observation of the terrain from the top of the mountain shows a clear transition between desert and rich vegetation coverage. The catalogued species will also help Dar Si Hmad determine the type of vegetation they should be targeting for reforestation. By carefully selecting species, they can prevent the necessity of intensive upkeep or water demands, and potentially incorporate natural fog condensation.

From our analysis of results, we established themes and patterns present throughout Dar Si Hmad's work. The conclusions we drew from our results provided us with a framework from which we develop recommendations for Dar Si Hmad.

Chapter 5: Recommendations and Conclusion

Recommendations

Fog Project

We recommend that Dar Si Hmad utilize all media to provide access to the fog nets in Ait Baamrane. This can be done by:

- **Publishing all photos and slideshow material**: By utilizing the photos from the slideshow deliverable, Dar Si Hmad can more readily showcase their projects to their audience. By posting these photos on their website, blog, or other social media platforms, Dar Si Hmad will generate more interest in their project and overall work.
- **Scheduling interviews:** We recommend one member of the staff be assigned to manage media inquiries and arrange any potential visits or interviews with the team. Interviews will also encourage public interest.

Social Media Outreach

In order to maintain a public presence on social media, we encourage Dar Si Hmad to perform the following:

- **Post more frequently:** A Twitter page with no content, or infrequent posts will not generate engagement with other users.
- **Link all social media outlets:** Linking all forms of social media into one will maximize exposure and provide links to Dar Si Hmad's work. Linking social media accounts will also ensure that all forms of social media are consistently utilized.
- **Employ active hashtags:** Throughout the duration of the conference, we recommend Dar Si Hmad utilize engaging and current hashtags such as #ClimateChange, #WomensEmpowerment, and #COP22 to gain more public interest.
- **Continue social media presence after conference:** Even after the conference has ended, it is important that Dar Si Hmad continue to post on social media about any updates or new information. This will keep future partners interested and invested.

Botanical Survey

During our botanical survey, 27 different plant species were found and recorded. Some of the species were unknown and coud not be documented. As Dar Si Hmad looks to move forward with a reforestation project, we recommend they perform the following:

- **Compile a plant encylopedia:** This index will contain all plant species. We believe a working list that is easily readable and accessible will aid in further research. This index should include photographs of each plant, colloquial names, Latin names, and other descriptions.
- **Continue investigation and surveying:** Due to the limited amount of time in which we conducted our survey, we feel that further investigation, surveying, and soil analysis would benefit Dar Si Hmad in understanding the characteristics of the fog habitat.

General Organization

After working with resources in the Dar Si Hmad office, we encourage Dar Si Hmad to develop a better organizational system for their engineering data. This can be accomplished by:

- **Formatting all files consistently:** Ensuring unified formatting of files throughout will expedite the extraction of information and the ease of transfer between future partners.
- **Keeping all files in the same location:** This will also expedite the information sharing process, and will make the navigation of information easier, both for Dar Si Hmad staff and future partners.
- **Continuously updating information:** Updating information is critical to educating new partners. All current information should be readily available to those given access.

Conclusion

Dar Si Hmad has worked to elevate the scientific elements of their projects to facilitate collaboration with new stakeholders. Attending the 22nd Conference of Parties will provide Dar Si Hmad with an opportunity to engage with new NGOs, promote its projects, and attract potential new stakeholders and partners. By providing perspectives not previously available, our team explored untouched aspects of their previous research. The material and recommendations presented by our team will give Dar Si Hmad the necessary tools to gain better funding, new intellectual capital, and partnerships to help actualize their ideas.

Winning the UNFCCC Momentum for Change Award positions Dar Si Hmad to engage with a significant portion of the COP22 attendees, as their project will be specially highlighted. They won the award for their Fog Harvesting project, but that is just one of the many projects they are involved with. All of these programs have similar themes of education and human development, but rely on fog and water as the backbone.

Currently, the state of fog research has numerous projections. Dar Si Hmad wants to expand their fog harvesting project to other areas near the Aït Baamrane region, as well as incorporate a reforestation project using excess fog water. The fog net technology being used is cutting edge, developed by the German industrial engineer Peter Trautwein. With little more to be done in the field of passive fog collection technology, Dar Si Hmad can shift their focus to active fog collection and human investment. This route is something new stakeholders, researchers, and perhaps future IQP teams will have the opportunity to explore as attention around this project continues to grow. Attendance at COP22 will give them an opportunity to gain this support.

Garnering new partnerships and supporters requires effectively presenting their material at COP22. With heightened attention surrounding the upcoming conference and the NGO's recent UNFCCC Momentum for Change Award, Dar Si Hmad is in a terrific position to spread awareness about their sustainable and innovative fog harvesting system. Our team was fortunate enough to work with Dar Si Hmad during this pivotal time, and we are thrilled with the future prospects of this project and NGO. We hope that Dar Si Hmad can engage new stakeholders and achieve the necessary resources to continue their mission.

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Glossary

Advection Fog	A steady wind that moves formed fog upwind of the site of production.
Amazigh	Pronounced (Am-ah-zeer), ethnic group native to northern Africa, primarily Morocco and Algeria. Sometimes referred to as "Berbers".
Anaga Mountains	Mountain range in the northeastern part of the island of Tenerife in the Canary Islands
Anti-Atlas Mountains	Desert mountains of Morocco where the fog nets are stationed
Apple iMovie	Video editing software created by Apple that allows users to create videos, slideshows, and animated photos
Azores Anti-Cyclone	Large scale circulation of winds around the region between the Sahara Desert and the cold Atlantic winds that forms under high atmospheric pressure.
Bonin Islands	Archipelago of 30 subtropical islands south of Japan
Boutmezguida	Rural countryside of Morocco and location of fog-project that supplies water to local villages
Canary Current	Wind driven surface current created by major ocean currents that travels acriss the coast of Morocco and northern Africa
Canary Islands	Spanish archipelago off coast of northwestern Morocco composed of volcanic isles.
Carbon sinks	Devices constructed by a nation that absorbs carbon dioxide as a means to reduce carbon emissions in the air
Chart Chooser	Software that offers variety for chart and graph construction. Developed by JuiceAnalytics.
Clean Development Mechanism	Defined in article 12 of the Kyoto Protocol, allows a country with an emission-reduction requirement to implement an emission-reduction project in developing countries.
CloudFisher	New design of fog nets created by the Munich Re Foundation that drastically increases fog water collection volume and efficiency.
Coastal Fog	An advection fog where the land surface is warmer than the ocean surface, and sea fog is transported from the ocean to the coast.
Confluence	The meeting point of the cold Atlantic costal winds and the hot ecosystem of the Sahara Desert causing the formation of fog
COP22	Conference of Parties 22nd, climate change conference held by the United Nations to gather world leaders together and discuss means by which countries can reduce carbon emissions and combat climate change.
Dipity	Online digital time management software that allows users to organize information and other media into a visually structured manner
Easel.ly	Infographic software that offers the ability for users create visual media.
Fog forest	Dense concentration of plant life at an altitude above the normal ecological zone that forms by sustaining itself off of the water delivered by fog formation at the altitude.
FogQuest	Canada based NGO that provides access to fig nets and fog findings, was the world's first fog water collection based NGO

Hectares	Area of land equal to 10,000 square meters
iMindMap	Concept mapping software developed by OpenGenius Ltd
Infogr.am	Infographic software that offers variety of means to create visually representative media.
Kyoto Protocol	The first major agreement of the United Nations Framework Convention on Climate Change that established basic rules and implementation means to reduce carbon emissions
Median	The value found at the midpoint of a data set
Mind map	Diagram used to show the flow of ideas and relation of data into a visually organized manner
Mode	The most common occurring value in a data set
Mountain Fog	A cloud that moves over a land surface becomes fog when it is intercepted by mountainous obstacles
Munich Re Foundation	Germany based charity organization that is part of the German reinsurance company Munich Re
Munich Re	German financial reinsurance company based in Munich, Germany
NGO	Non-Governmental Organization
Palearctic Eco-zone	Ecological zone that consists of Europe, Asia, North Africa, and the northern Arabian Peninsula
Piktochart	Infographic software program used to create the poster for Dar Si Hamd at COP22 after determining the software offered the easiest use of tools
Plot sampling	Method of vegetation abundance estimation that involves using plots of land to estimate the average vegetative concentration.
Prezi	Privately developed cloud based presentation software that allows users to navigate through mapping information
Quadrat	A 1m x 1m square that is used to record and estimate the average vegetation coverage of a given area in a botanical survey
Sidi Ifni	City in the southwest of Morocco located on the coast, bordering the Atlantic Ocean. Serves as the location for the headquarters of Dar Si Hmad
Transect	A straight line path in which one records occurrences of species pertaining to the study
U.N.	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WasserStiftung	German for “water foundation”, it is the partner organization with Dar Si Hmad and provides the construction of the fog nets to Dar Si Hmad
www.wordclouds.com	Online resource that can automatically generate clouds of specific words and tags.

Appendices

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Appendix B	Botanical Survey Methodology
Appendix C	Readings for Infographic
Appendix D	Fog Water Quality Report
Appendix E	Mesh Types
Appendix F	Mesh Testing
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Appendix I	Twitter Stream
Appendix J	Slideshow Images and YouTube Links

Appendix A: Dar Si Hmad Staff

Dr. Jamila Bargach
- Director of Dar Si Hmad, manages financing and accounting
- Original founder of Dar Si Hmad
- Has been acting as correspondent with IQP team as liaison between Dar Si Hmad
- Has been providing updates and feedback for our work at the project site

Dr. Aissa Derhem
- Current President and one of the original founders of Dar Si Hmad
- Oversees all operations of Dar Si Hmad and provides feedback of findings for IQP team
- Provides scientific and local information on habitats, organisms, culture, and structure of the fog project

Abderahmane Ennassiri
- Driver for Dar Si Hmad
- Works on the maintenance of fog nets
- Provides insight into vulnerabilities of fog nets
- Allows for our team to visit the project site

Dr. Leslie Dodson
- ICTD Consultant, Director of Tifawin, Dar Si Hmad's U.S. branch
- Has worked with various news organizations before collaborating with Dar Si Hmad
- Provides further expose and information on Dar Si Hmad across the globe

Souad Kadi
- Project Coordinator and language instructor
- Provides access to Dar Si Hmad resources for IQP team
- Allows for IQP to transition easily in relation to Dar Si Hmad

Najib Kabir
- Project Translator and Cultural Facillitator
- Works as translator for team so information can be relayed properly and effectively
- Allows for proper understanding between locals and workers of Dar Si Hmad

Abdellah El Moutaouif
- Administrative and Accounting Officer
- Manages finances of Dar Si Hmad's projects funds and creates budget templates
- Graduated from Ibn Zohr Universsity and has been working non-profit finances since 2015

Khadija Changa
- Accountant and Administrative Assistant for Dar Si Hmad
- Holds degree in Business Administration

Salaheddine Ait Lakdoume
- Communication Manager and Project Coordinator for Dar Si Hmad
- Has spent ten years of experience working with non-profits
- Joined Dar Si Hmad in 2012

Hadda Buzguar
- Hospitality Manager and Chef for Dar Si Hmad
- Has been working in variety of hotels and enjoys sharing her culture with others
- Has been working for Dar Si Hmad since 2012 and ensures students and faculty enjoy their stay

Mounir Abbar

- Fog Project Water Technician
- Specializes in water treatment with 20 years of experience in coordinating between rural villages and Moroccan organizations
- Has been with Dra Si Hmad since 2012

Hassan Ansari

- Maintenance and Security Manager for Dar Si Hmad in Sidi Ifni
- Local of Sidi Ifni and helps introduce student to the people and culture of the town.

Hussein Sussan

- Fog Project Manager for Dar Si Hmad
- Has engaged with Aït Baamrane community in the creation of the fog-project since 2011
- Currently manages the fog project, working as liason with the homes and villages for the ethnographic school

Mohammed Sfourg

- Local Bled volunteer working alongside Dar Si Hmad
- Bee-keeper and designated plant expert

Appendix B: Botanical Survey Method

Purpose

The purpose of this survey is to:

- Identify plant species present on Mount Boutmezguida.
- Create species inventory with common names, Latin names, and uses.
- Determine vegetation coverage as a function of elevation.
- Determine influence of fog on plant species.

Materials

The materials required to complete this survey are:

- Topographic maps of the region
- GPS or Altimeter (or compass)
- 100 m measuring tape
- Transect Ropes
- PVC quadrat frames
- Camera
- Logbook

Method

Our survey used a method of sampling known as the Belt Transect Method. We have modified the standard procedure slightly to better suit our project's needs. Transect lines were made perpendicular to the dry riverbed at the base of Mount Boutmezguida. This river bed is approximately the point at which fog begins to interact with the ground surface, and thus will give the best representation of how fog affects the local ecosystem. Each transect was 350 m long, half above the river, half below. Samples were taken every 25 m for a total of 14 samples per transect. At each sample site a segment of each unique plant was taken and preserved for later observation.

In addition to the transect studies conducted at the base of the mountain, a more intensive study was conducted at the top of Mount Boutmezguida, completely canvassing the plot of land around the fog nets. This was conducted with the help of a local beekeeper (Mohammed Sfourg) who is familiar with all of the plants indigenous to the region. Our team searched the entire area for plant species, and catalogued each one observed.

Procedure

Starting at the edge of the river bed:

1. Mark the initial spot.
2. With one person holding a tape measure at the initial spot, the second moves along the compass bearing of the transect 25 m.
3. At 25 m, the point is marked, and the 1 m^2 quadrat is placed
4. Take a top down picture of the quadrat, including the quadrat number
5. Estimate the percent ground coverage, and shade in squares on sample sheet.
6. Account for all species within the quadrat.
7. Collect a sample of each species present in the quadrat
8. Mark the quadrat's coordinates and elevation using a GPS.
9. Begin a new 25 m transect at the end of the previous transect, maintaining the same compass bearing.

Results

Each quadrat sampling will generate the following data: species present, vegetation coverage, coordinates, and altitude.

The species present will be compared to a list provided by Dar Si Hmad, and the uses of each plant will be documented.

The vegetation coverage will be plotted against altitude, and will hopefully show the predicted correlation between increasing altitude and increasing vegetation coverage. This can also be analyzed as a function of fog presence, given sufficient data already exists.

BOTANICAL SURVEY FORM

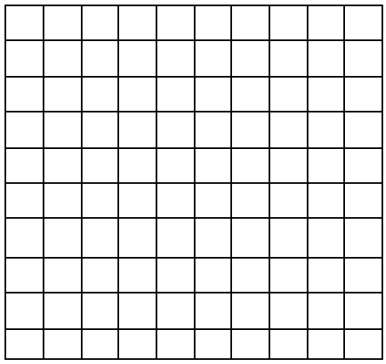
Survey Site_____

Surveyor Initials_____

Coordinates_____

Altitude _____

Shade Ground Coverage



Estimated Coverage %_____

Tree Present at Survey Point?

YES NO

(If YES, use tree supplement form)

Photograph Taken?

YES NO

Species Present

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Continue on Back if Necessary)

Botanical survey form used to record data.

Appendix C: Readings for Infographics

Books:

- *Information Graphic*s by Sandra Rendgen
- *Infographics: The Power of Visual Storytelling* by Jason Lankow

Infographics:

- Minard's Visualization of Napoleon's 1812 March
- Piktochart.com's Top 10 Best Infographics of 2015

Interviews:

- Professor Brenton Faber (WPI, Humanities and Arts Department)

PDFs:

- *Recipe for an Infographic* by Debbie Abilock and Connie Williams
- *Designing Research: Using Infographics to Teach Design Thinking in Composition* by Annie S. Mendenhall

Websites:

- coolors.co – Color Palate Design
- Piktochart.com

ANALYSIS OF FOG WATER

Relevant values compared to threshold values under the German Drinking Water Ordinance (DWO) of 21 May 2001 and the standards of the WHO.

Parameter	Unit	Limit WHO	Limit DWO	Hail net	Spacer fabric	Enkamat	Slubbed fabric	Raschel net	Shade net
pH value	-	-	6,5-9,5	8,5	7,7	7,2	7,2	7,2	7,1
Conductivity (20°C)	µS/cm	-	2790 (25°C)	84,0	83,0	89,0	99,0	88,0	93,0
Chloride	mg/l	-	250,0	9,5	9,9	9,7	11,0	8,9	10,0
Sulphate	mg/l	-	250,0	11,0	11,0	12,0	12,0	11,0	12,0
Nitrate	mg/l	50,0	50,0	5,0	-	6,4	6,4	6,1	6,3
Ammonium-N	mg/l	-	0,65	1,1	1,5	1,2	1,2	1,8	1,9
Iron	mg/l	-	0,2	0,0084	0,014	0,0083	0,0044	0,016	0,013
Manganese	mg/l	0,4	0,05	0,012	0,011	0,067	0,0083	0,013	0,012
Lead	mg/l	0,01	0,01	0,00015	0,0002	0,000094	<0,00005	0,00014	0,00013
Arsenic	mg/l	0,01	0,01	0,00033	0,00037	0,00042	0,0083	0,00043	0,00045
Chromium total	mg/l	0,05	0,05	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005
Copper	mg/l	2,0	2,0	0,003	0,0049	0,0042	0,0029	0,002	0,0077
Zinc	mg/l	-	-	0,064	0,065	0,097	0,066	0,079	0,071
Cadmium	mg/l	0,003	0,003	0,000095	0,00011	0,000092	0,000052	0,00008	0,000091
Nickel	mg/l	0,07	0,02	0,0013	0,0012	0,0016	0,00092	0,0014	0,0012
Uranium	µg/l	15,0	10,0	0,013	0,013	0,01	0,012	0,033	0,024
Calcium	mg/l	-	-	3,1	2,9	3,6	5,7	4,0	4,3
Magnesium	mg/l	-	-	0,99	0,92	1,0	1,1	1,1	1,1
Total organic carbon	mg/l	-	-	2,4	2,8	2,4	2,3	2,2	2,6

UNIVERSITE CADI AYYAD
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MARRAKECH

جامعة القاضي عياض
كلية العلوم والتقنيات
مراكش

Tableau II *Résultats des analyses physico-chimiques des eaux de forage et de Brouillard (Projet Collecte de brouillard Sidi Ifni)*

Référence échantillon	*Eau de forage*	*Eau de brouillard*	*Norme Marocaine Eau Potable NM 03.7.001*
Paramètre analysés			
pH au laboratoire	7,58	7,96	6,5<pH<8,5
Conductivité à 20 °C, µS / cm	140	30,00	2500
Matières en suspension (MES), mg/l	0,28	0,08	
Oxydabilité au KMnO4, mg O2/l	20	0,14	5
Ammonium (NH4), mg/l	1,5	0,05	0,5
Bicarbonates (HCO_3), mg/l	56	6	
Chlorures (Cl^-), mg/l	124,17	3,25	750
Nitrates (NO3) mg/l	38,00	32,00	50
Nitrites (NO2), mg/l	1,03	0,29	0,5
Sulfates (SO_4^{2-}), mg/l	219	9,10	400
Phosphore (P), mg/l	0,1	0,1	
Sélénium (Se), mg/l	<0.0010	<0.0010	0,01
Calcium (Ca), mg/l	99	14	
Aluminium (Al), mg/l	<0.0010	<0.0010	0,2
Sodium (Na), mg/l	190	19	
Potassium (K), mg/l	7	0,51	
Crome (Cr) mg/l	<0.0010	<0.0010	0,05
Nickel (Ni), mg/l	<0.0010	<0.0010	0,02
Molybdène (Mo), mg/l	<0.0010	<0.0010	
Fer (Fe), mg/l	<0,09	<0,09	0,3
Baryum (Ba), mg/l	<0,003	<0,003	
Plomb (Pb), mg/l	<0.0010	<0.0010	0,01
Cobalt (Co), mg/l	<0,003	<0,003	
Cuivre (Cu), mg/l	<0.0010	<0.0010	2
Cadmium (Cd), mg/l	<0.0010	<0.0010	0,003
Zinc (Zn), mg/l	<0.0010	<0.0010	3
Manganèse (Mn), mg/l	<0.0010	<0.0010	5
Magnésium (Mg), mg/l	49	2	
Argent(Ag), mg/l	<0.0010	<0.0010	
Arsenic (As), mg/l	<0.0010	<0.0010	0,01
Bore, mg/ l	<0.0010	<0.0010	0,3

Marrkech, le 6 février 2015

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FACULTE DES SCIENCES ET TECHNIQUES Marrakech
Département des Sciences Chimiques

Appendix E: Fog Net Mesh Types

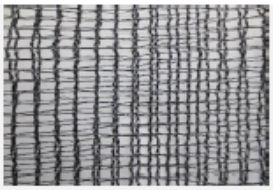
Hagelschutz		*HDPE*	*Black color and a silk mesh. Tested two-layered.*
Stabilizing grid (not a mesh used for fog harvesting)		*HDPE*	*Black color. Put behind the meshes to stabilize the construction.*

Table 2: Different 3D mesh types and their properties.

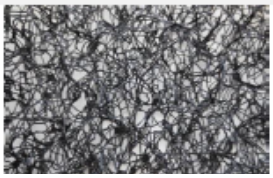
Mesh type	*Picture*	*Material*	*Description*
ITV		*Polysulfone (PES)*	*Has a hexagonal structure. Thickness 1 cm.*
Enkamat		*Aliphatic polyamide (PA6)*	*Mesh with high stiffness. Thickness 1 cm.*

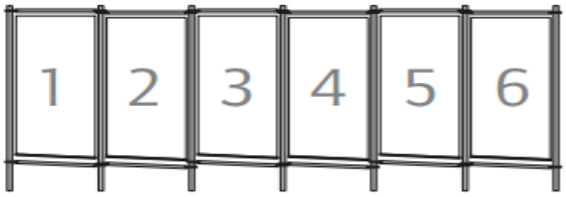
Table 1: Different 2D mesh types, the stabilizing grid and their properties.

Mesh type	*Picture*	*Material*	*Description*
Schattier		*High-density Polyethylene (HDPE)*	*Green color and silk mesh*
Raschel		*Polypropylene (PP)*	*Black color. Silk mesh and normally used for fog harvesting.*

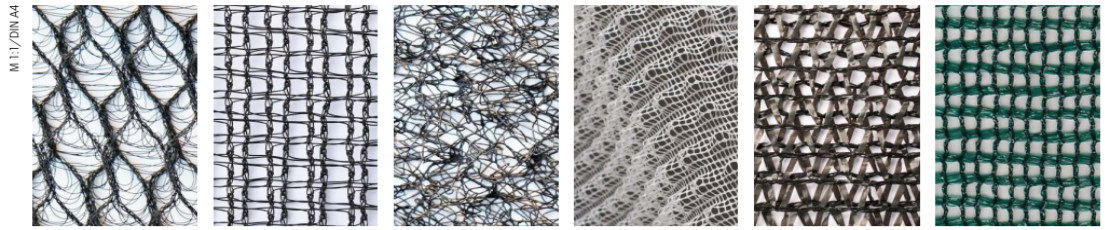
Appendix F: Phases of Mesh Testing

MESH TYPES
FIRST TEST PHASE: NOV 2013 - JUNE 2014

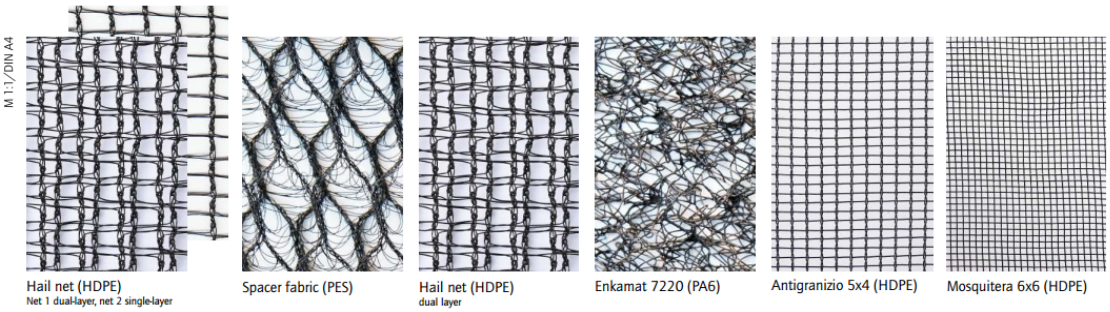
Fabric type	Nov. 2013	March 2014	May 2014
	Position	Position	Position
Shade net	1	5	3
Raschel net	2	4	1
Slubbed fabric	3	6	2
Enkamat	4	1	5
Spacer fabric	5	3	6
Hail net	6	2	4



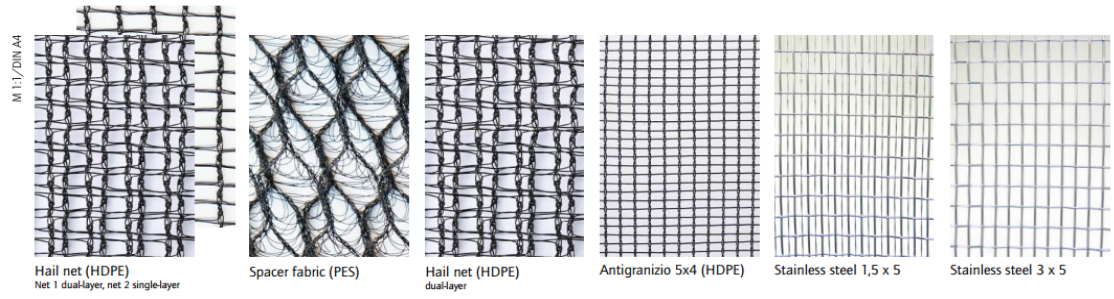
Phase One Fog Nets



Phase Two Fog Nets



Phase Three Fog Nets



Appendix G: Plant Species Found on Mount Boutmezguida

Species	Common Name	Description	Matrix Cell
Astragalus balearicus	Ach-ffoud	Dense green ground shrub composed of small elliptical leaves on thin spiny branches. Blooms with white-maroon colored flowers. Found in dry arid climates	16
Centaurea pungens	Tassenante	Herb thistle plant with long, white spiny formed from bracts along its stem. Top of herb will bloom into a bright violet flower	12
Ceratonia siliqua	Tikida	Flowering evergreen shrub with medium sized green oval shaped leaves. Known for producing edible long brown seed pods. Native to Mediterranean region.	26
Chamaerops humilis	Tiznirt	Small clustered ground palm found at high altitudes in Morocco. Composed of long linear leaves growing lowly on the ground in high temperatures.	9
Cistus salviifolius	Irgel	Bushy shrub that grows in dry hills and open woodlands with snow white five pedal flowers with golden ovaries. Recognized by its hairy ovate shaped crenated leaves.	21
Diplotaxis harra	Lkerkaz	Tall, thin stemmed flowering plant with yellow blossoms of four pedals. Has elliptical serrate shaped leaves.	4
Euphorbia echinus	Tikiwt	Species of cacti with densely packed multiple branches that grows in full sun. The species is a succulent and is known for its very spicy flavored milk. Recognized by the dual spines running down the crests of the stalks and usually consisting of 5 to 7 crests per stalk.	24
Lavandula angustifolia	Timzzira	Species of lavender native to Morocco. Noted for its pleasant scent and purple colored densely packed blossoms.	2
Marrubium desserti	Ifzi	Green shrub species with hairy stalks and small pale pink flowers that can be eaten by herbivores.	8
Olea europea	Azmmour	Known as an ancestor to the olive tree, the plant can be found in dry arid regions. The plant produces the edible fruit of the olive and can be found across the Mediterranean.	10

Ornithogalum umbellatum	No Berber Name	Species of flowering plant recognizable by its six pedaled ghost white flowers, blond colored anthers, and bright yellow pitils.	13
Pistacia lentiscus	Tidkt	Evergreen shrub of the pistachio genus featuring thin red stalks and smooth elliptical leaves	6
Quercus rotundifolia	Abouham	Slow growing evergreen tree that is capable of producing acorns. Recognizable for its spiny, oval shaped leaves and acorn nuts. Commonly used for animal feed.	11
Senecio anteuphorbium	Achbarto	Large species of cacti capable of growing up to 5 feet in height. Features long upright stalks in clustered bunches. Stalks are very long, narrow and terminate in a thistle pedaled cream colored flower.	15
Solanum nigrum	*Solanum nigrum*	Sparsely packed plant with large serated deltoid shaped leaves. Recognizable for the black berries it produces.	27
Thymus vulgaris	Azoukemni	Commonly known as thyme, an evergreen shrub with grey-green smooth ovate leaves. The plant produces a noticeably strong aroma and will produce cluster of violent colored flowers.	25

1 (Unknown)

2 (Lavandula angustifolia)

3 (Unknown)

4 (*Diplotaxis harra*)

5 (Unknown)

6 (Pistacia lentiscus)

7 (Unknown)

8 (Marrubium desserti)

9 (Chamaerops humilis)

10 (Olea europea)

11 (*Quercus rotundifolia*)

12 (Centaurea pungens)

13 (Ornithogalum umbellatum)

14 (Unknown)

15 (Senecio anteuphorbium)

16 (*Astragalus balearicus*)

17 (Unknown)

18 (Unknown)

19 (Unknown)

20 (Uncertain)

21 (Cistus salviifolius)

22 (Unknown)

23 (Unknown)

24 (Euphorbia echinus)

Appendix H: Fog Science Poster Variations

This is the final poster design for Dar Si Hmad. It describes the following topics: Fog as a viable resource, the current obstacles facing fog collection, the future of fog collection, the design process, and Dar Si Hmad's upcoming reforestation project. Fog as a viable resource discusses the inception of the fog project and why Mount Boutmezguida is an ideal area for fog collection. The obstacles address current arguments against fog collection, such as the unreliability of the fog patterns and the problems with storing water over long periods of time. The future of fog harvesting discusses the two paths the project can take fro here: continued research and future project management. The design process graphic depicts an image comparing and contrasting the amount of water collected from the old fogquest nets to the new CloudFisher nets, with CloudFisher collecting nearly 4.5 times the amount of water as the fogquest nets. The reforestation section discusses Dar Si Hmad's upcoming project and their plans to redistribute water throughout the area. This infographic was created on Piktochart.

BRINGING SCIENCE AND SOCIETY TOGETHER

Fog As a Viable Resource

It started out as a simple idea.

The Boutmezguida region creates the perfect fog harvesting climate. Antennas at the top of the mountain were seen condensingwater and forming droplets. This observation led to the theory that fog water could be mass harvested.

Reliable access to freshwater provides many benefits to the rural communities in this area. In this arid region, fog-water collection has been a life-altering adaptation.

The Obstacles

-Fog collection requires specific environmental conditions, limiting implementation to specific regions

-Water must be stored in large quantities for dry season use.

-Strong winds and snow fall can result in structural failure.

-Water yield is difficult to predict.

-There are few commercial producers of mesh currently in operation.

Often times the journey has been quite difficult...

"There were a lot of conflicts. Tons of conflicts"

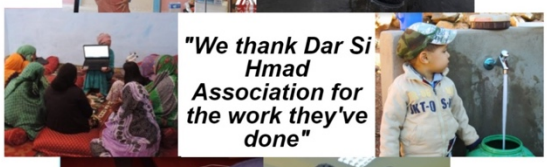
"Nobody thought about the social dimension"

"There's a lot of unspoken assumptions about how things should be"

"They were skeptical, they were dismissive"

Dar Si Hmad

"Life in the villages has become better for our generation"



"We thank Dar Si Hmad Association for the work they've done"

"This is a gift"

"We worked together"

"We don't suffer anymore"

"I love being educated"

"The life of my daughter is better now"

The Future of Fog Harvesting

Continued Research

In order to address some of the obstacles that fog harvesting faces, further research surrounding the project must be collected. This research could help outline future uses of fog water, more efficient net and mesh designs, canalizations of water to the villages, and a more cost-effective approach to implementation and distribution.

Furthermore, research could help expose new condensation techniques for fog of a smaller particle size, thus expanding the regions where fog water can be harvested.

Project Management

Along with the scientific research that allows for the most efficient implementation possible, the management of the system is important to maintain.

This maintenance includes the relation between the technical and social aspects of the project. It is necessary to continuously re-evaluate the components of the system, such as:

-the reliability of the nets
-the piping of water into villages
-the social impacts on the benefiting communities

The Design Process

Fogquest Nets vs. CloudFisher Nets

Original Net Design

5 Liters/sqm collected per day

CloudFisher Design

22 Liters/sqm collected per day

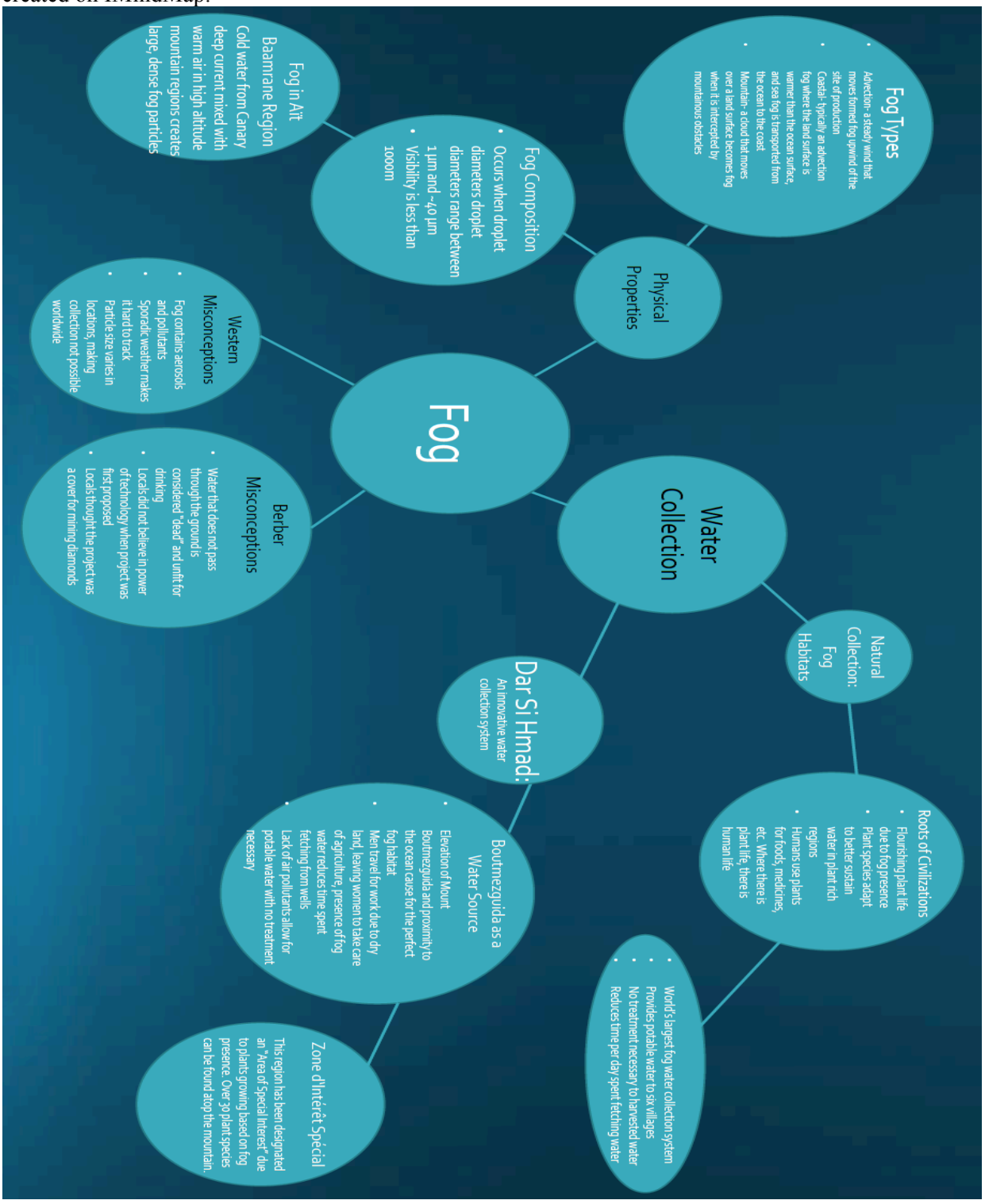
4.5 X MORE WATER COLLECTED WITH NEW CLOUDFISHER NETS

Dar Si Hmad's Reforestation Project

With a greaternumberof nets in use, excess water will be collected. Dar Si Hmad plans to use this excess water to start testing for a reforestation process, beginningOctober 2016. This projectwill examine what new plant life can grow in the area.

The project has a unique opportunity to restore natural vegetation and support agriculturalpractices throughthe sourcing of clear water for craps and livestock.

The next image is an original draft of the poster design. This style is slightly different than the final poster design, with information represnted in the form of a mind map. This image relates all portions of the work performed by our team, work performed by Dar Si Hmad, fog science, fog collection, societal impacts, and why Boutmezguida is an ideal location for fog collection. This style of poster relates the entire scope of work, but does not convey all relevant information that Dar Si Hmad requested. This poster was created on IMindMap.



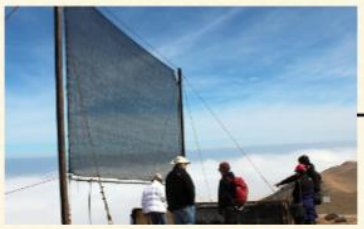
This is the first draft of the poster presented to Dar Si Hmad, in the style of an infographic. This infographic displays the science and mechanics behind the nets, but does not address the open questions surrounding fog as the new poster does. It contains several drawings created in AutoCAD depicting the mechanical features of the nets. Below those images, the monthly fog collection is shown in graph form. It goes into detail explaining the dry summer months and the use of reservoirs when fog collection is low. To the left of the graph are several photos depicting the societal influence the nets have had on the Ait Baamrane community. Below these photos, the same graphic from the final poster design appears in this draft, depicting the difference in water collection between the fogquest net versus the new and more efficient CloudFisher nets. In the lower right corner there is a photo of Morocco, along with graphs and images showing the elevation of Mount Boutmezguida and the path the water takes down the mountain. While visually appealing, this poster does not discuss the necessary information requested by Dar Si Hmad. This infographic was created on Piktochart.

FOG COLLECTION

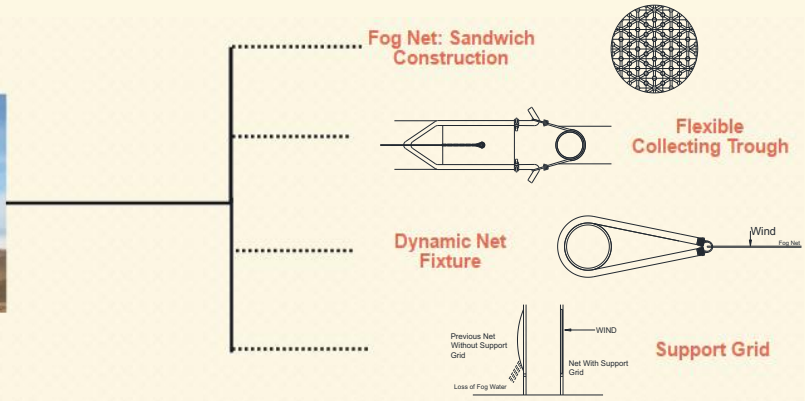
Natural Wells of the Sky

Dar Si Hmad's fog harvesting project is currently one of the **largest** collection and distribution systems in the world, and is the **only** one in North Africa.

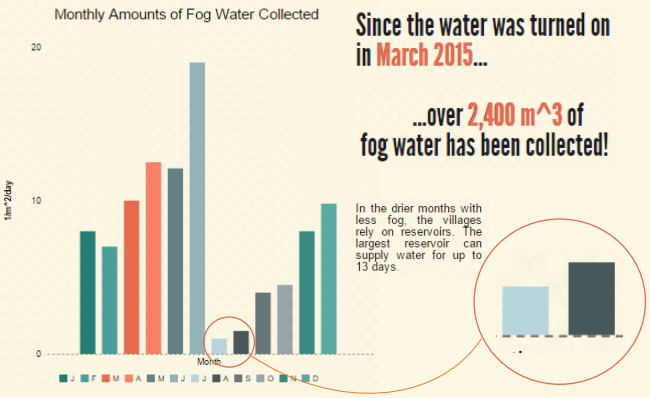
SECURE SUPPLY OF DRINKING WATER



High Quality Drinking Water
Meets WHO Standards
Provides Water For Agriculture and Forestry



WANT TO SEE THE IMPACTS?



Since the water was turned on in **March 2015**...

...over **2,400 m^3** of fog water has been collected!

In the drier months with less fog, the villages rely on reservoirs. The largest reservoir can supply water for up to 13 days.

Original Net Design

5 Liters/sqm collected per day

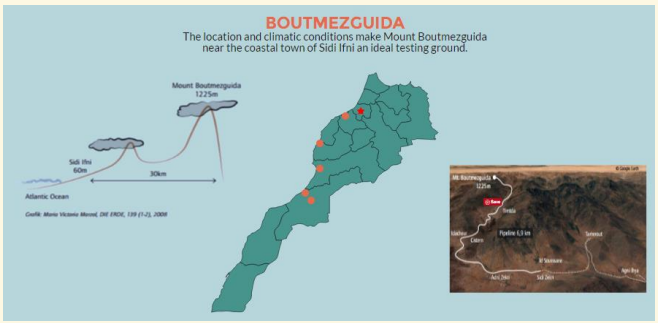
New CloudFisher Design

22 Liters/sqm collected per day

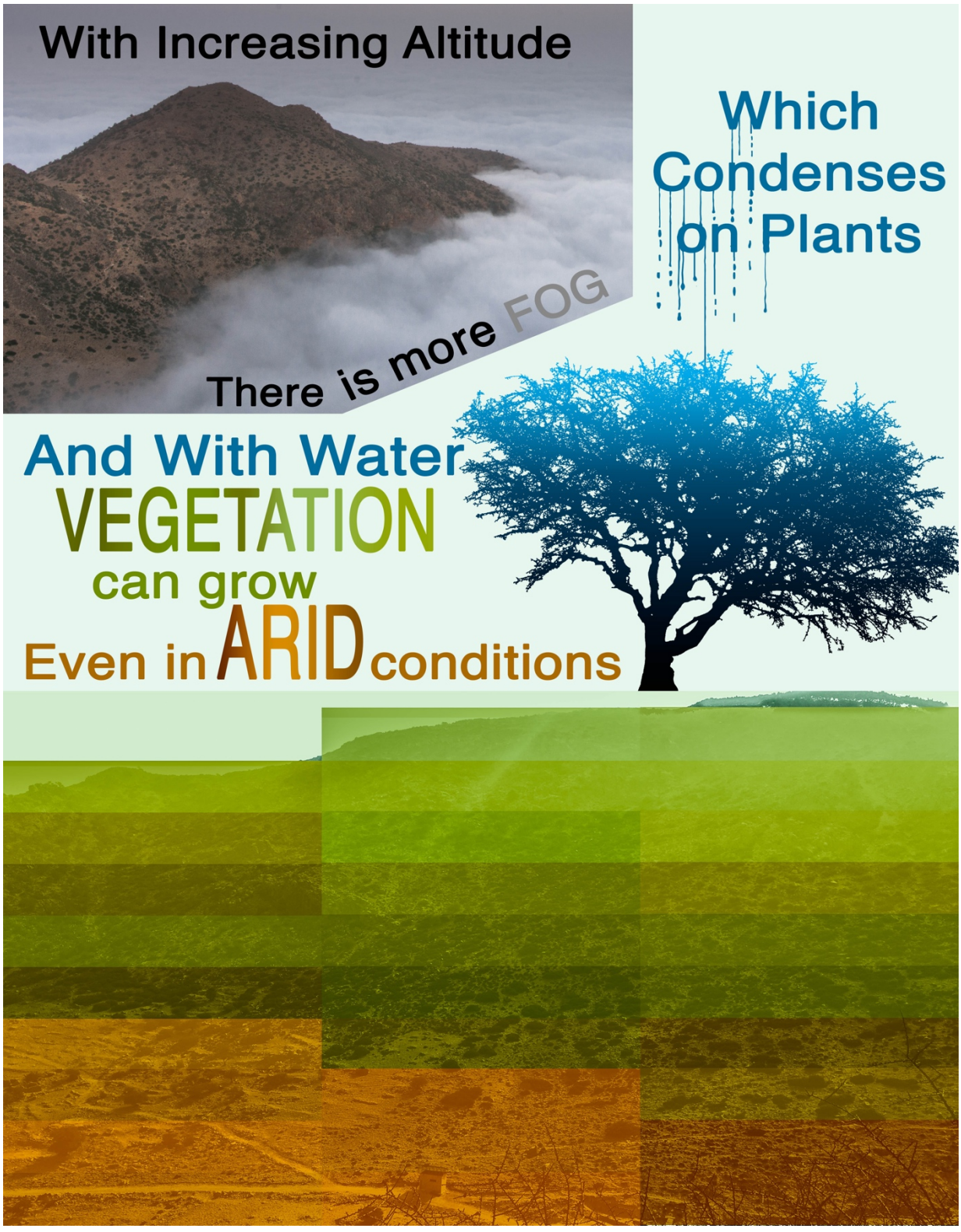
4.5 X MORE Water Collected With New CloudFisher Nets

BOUTMEZGUIDA

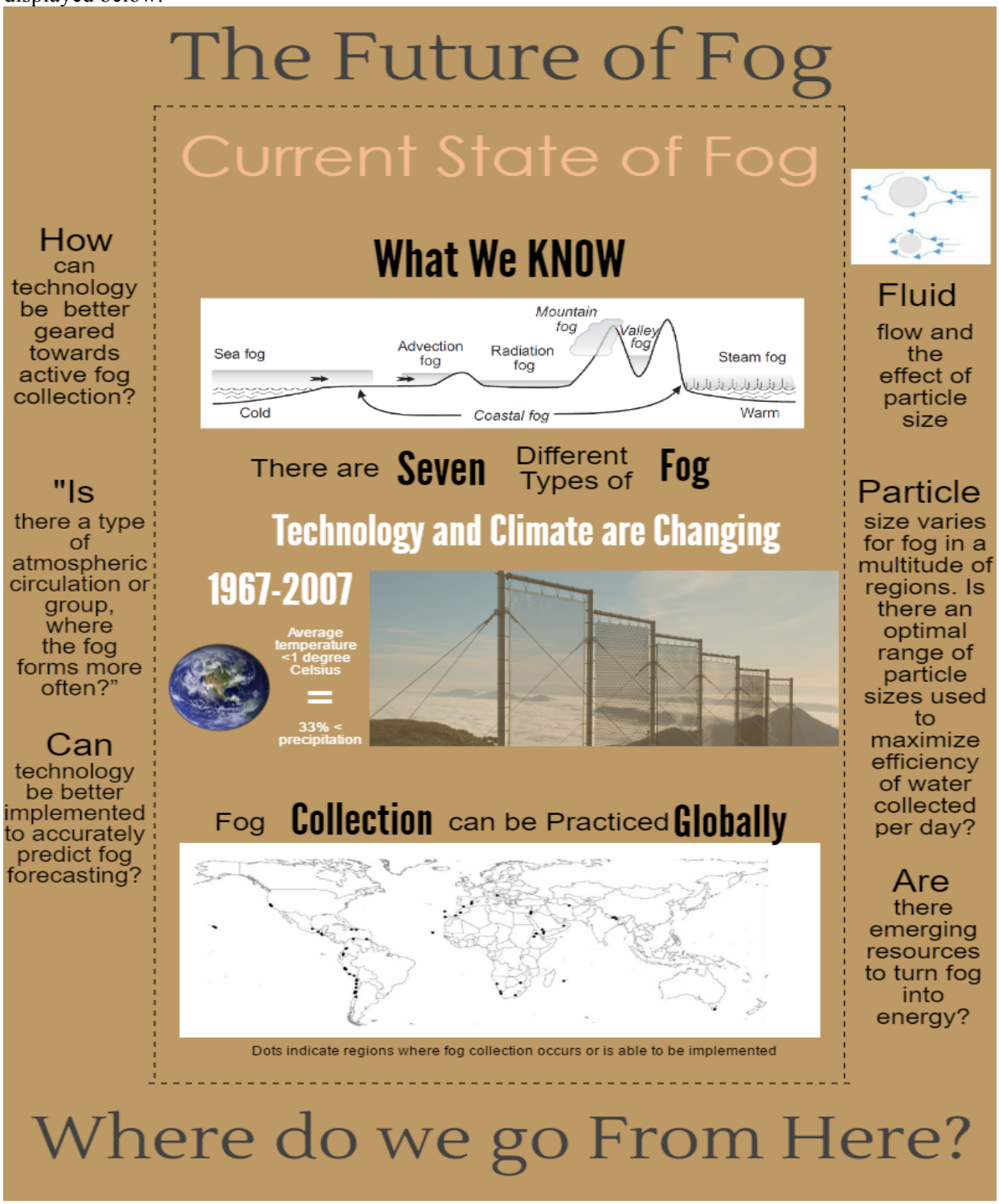
The location and climatic conditions make Mount Boutmezguida near the coastal town of Sidi Ifni an ideal testing ground.



The next poster design is an initial design of a botanical survey infographic. It was created using Adobe Photoshop, and implements the visualization of vegetation transition created earlier.



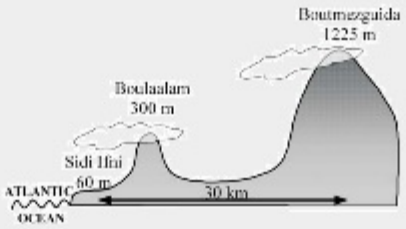
Other posters were designed highlighting only the "broad questions relating to fog science." These are displayed below.



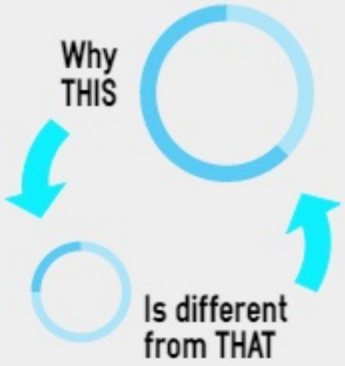
ALL ABOUT FOG

What Is Fog?

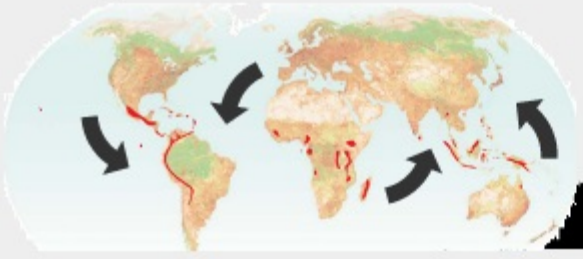
FOG TRENDS

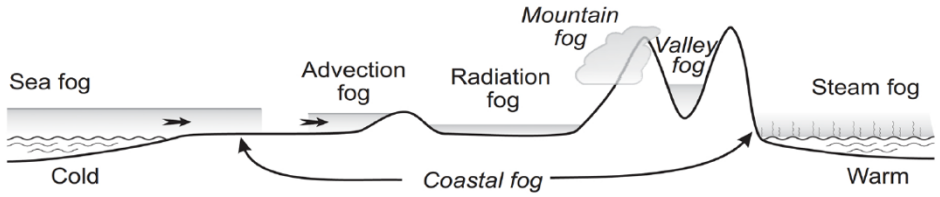


The Importance of Particle Size



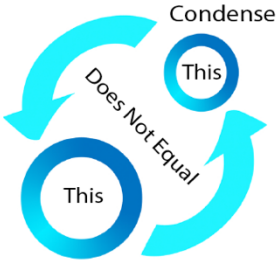
Moving to Other Areas of the World





Why Particle Size Matters

Sea fog CANNOT Condense



Mountain Fog CAN

LARGE Drops Easily Consense

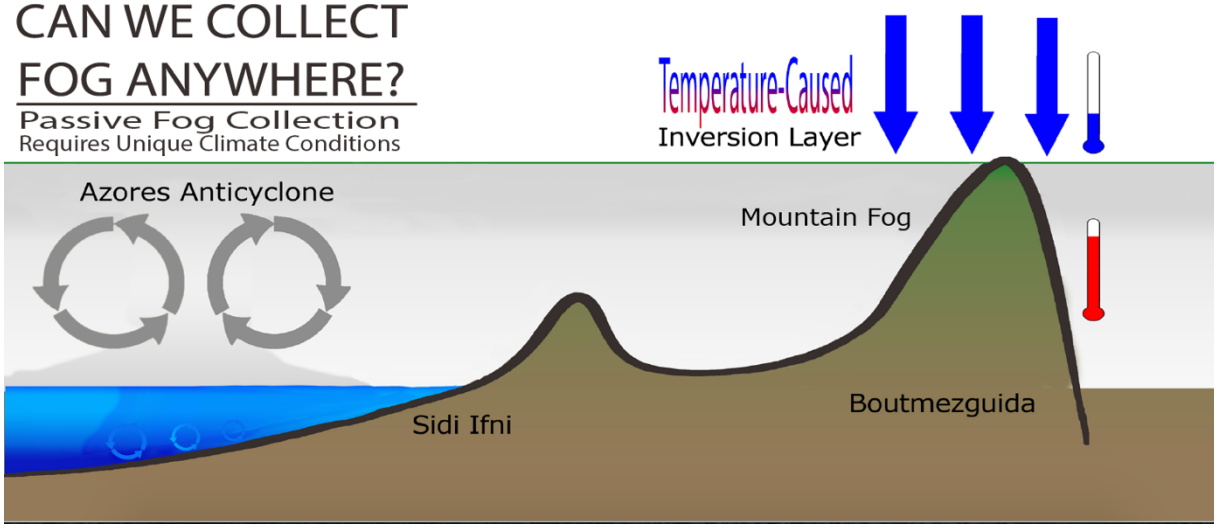
Can SMALL fog be condensed?

YES

But requires ENERGY input

CAN WE COLLECT FOG ANYWHERE?

Passive Fog Collection
Requires Unique Climate Conditions

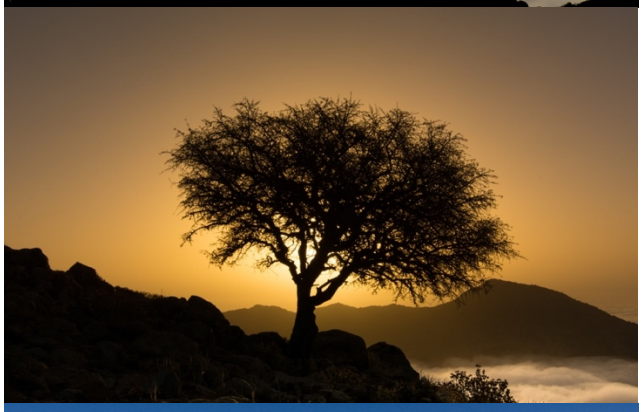


Appendix I: Twitter Stream

COP 22 Twitter Stream			
Day	Theme	Tweet	Content
1	Opening Day	1	Dar Si Hmad is beyond excited to be at #COP22, stop by to see our projects and ask questions! We look forward to meeing you!
		2	The entire staff is honored to be recognized as one of 13 UNFCCC Momentum for Change award winners. Come check out our project! #COP22
		3	We want to answer your questions! Tweet @darsihmad with #DSHquestion and we'll respond! #COP22 #Q&A
		4	Follow us on Instagram (@darsihmad) and like us on Facebook for even more content! #COP22 www.instagram.com/darsihmad www.facebook.com/darsihmad/
2	Meet DSH	1	Stop by our booth to meet (names/handles)! #COP22
		2	Come see our photo montages of the fog net collection system and its impacts! #COP22
		3	Stop by and ask about our UNFCCC Momentum for Change Award winning fog project! #COP22
3	How climate change has affected Aït Baamrane Region/Morocco	1	The Ait Baamrane region receives less than 200 mm of rainfall per year. Here's what we're doing about it #COP22 #ClimateChange
		2	Too much water can be a bad thing: in 2014 Aït Baamrane was devastated by a flood, destroying water and agriculture resources #COP22
		3	Our project provides a stable supply of water in a region with such sporadic weather patterns! #climatechange #COP22
4	Fog Nets	1	We have plenty of #fog in Aït Baamrane-check out this infographic about how we turn it into drinkable water #COP22
		2	In January we will add 1,600 m3 of CloudFisher Nets, tripling our water yield! Here's why they're better #COP22
		3	Ask us questions about Fog Collection! Tweet @DarSiHmad with #fogquestion and we'll respond! #COP22

5	Women's Empowerment	1	Check out our award-winning Women's Empowerment project! #COP22
		2	Without having to walk hours to wells, women can get jobs, and girls can got to school #womensempowerment #COP22
		3	Stop by our booth to hear more about women's work in Argan Co-Operatives! #womensempowerment #COP22
6	IQP Team	1	The @WPI IQP team spent two weeks exploring Mt. Boutmezguida, gathering data, and conducting a botanical survey for DSH #COP22
		2	The @WPI team studied the scientific background of fog collection. Here's our final poster! #COP22
		3	Everything is related! The @WPI team's mind map shows how science relates to human development #COP22 #MomentumForChange
7	Vegetation/Plants	1	Fog gives life to plants unique to the region! Check out how fog coverage causes vegetation growth #COP22
		2	Argan trees + prickly pears are vital to the economy of Aït Baamrane. Our fog-water reforestation project will promote their growth #COP22
		3	Fun fact: Over 32 plant species can be found in the fog zone of Mount Boutmezguida. Fog gives life! #COP22
8	Did you know?	1	Did you know that fog water is so pure that it exceeds all WHO drinking water standards? #COP22
		2	Did you know fog collection dates back to ancient tribes? #COP22
		3	Did you know more families are returning to the Aït Baamrane region because of our project? #COP22
9	Roundtable Event	1	Excited to generate new ideas and discussion at today's roundtable event! @UNFCCC #COP22
		2	Lots of great collaboration going on here @UNFCCC # roundtable #COP22
		3	Thrilled to have been a part of this great conversation today! @UNFCCC #roundtable #COP22
10	Momentum for Change Award	1	We are so humbled to have been awarded the Lighthouse Momentum for Change Award by the UNFCCC! #COP22
		2	Momentum for Change's 3 focus areas are: #WomenForResults #ClimateFriendlyInvestment #ICTSolutions
		3	Congratulations to the other 13 winners of this award! Let's make change happen #COP22
11	DSH Future Goals	1	Fog Reforestation Project
		2	Installing more Nets, expanding zone of coverage
		3	Proud to be partnered with @Weltwassertag @WPI @BeccaFarnum and many others! Collaboration is key to progress #COP22
12	Closing Day	1	Final day of #COP22! If you haven't had the chance to check us out, stop by our booth or tweet @darsihamd
		2	Inspired to promote climate change awareness along with so many other amazing organizations! #climatechange #COP22
		3	Thank you to everyone who has helped promote Dar Si Hmad! #COP22 was incredible, and we're proud to be part of such an important mission!

Appendix J: Sample Images for Slideshow



Examples of images used in the slideshows developed for Dar Si Hmad. (Photographs by, or provided by Kristin Boudreau and edited by David Smallwood)

The Fog Net Slideshow can be found at: https://www.youtube.com/watch?v=VfVjKeb_wp0&feature=youtu.be