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METHODS OF COLLECTING AIR HUMIDITY FOR THE PURPOSE OF VALORIZATION FOR CROP IRRIGATION

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Abstract: Non-conventional water resources have emerged as means to meet or supplement irrigation demand for reforestation and agriculture in water scarce regions. Irrigation by condensation is an inexhaustible resource of water for irrigation, the combination of high relative humidity, the air temperature and the low temperature of water circulating through a closed loop system. Irrigation by condensation are designed primarily to arid and semi-arid areas, where groundwater is deep and fresh water sources are rare. Air humidity is a potential source of freshwater that is accessible everywhere and can be used for crop irrigation. This paper presents a review of atmospheric water harvesting used for the purpose of valorization for crop irrigation. The aim of this study is to present methods of collecting air humidity for the purpose of valorization for crop irrigation.
Keywords: humidity collecting, irrigation

INTRODUCTION

Climate change is a major challenge for agriculture, water resources and ensuring stability crops being key priorities in the policy of prevention and mitigation of extreme events. Despite the vast amount of water on the planet, most of it (97.5%) is in seas with high salt content, rendering it unsuitable for human consumption, while the rest is foundas fresh water (2.5%). Of this fresh water, 70% is frozen and about 30% exists in the form of moisture or underground aquifers (*Mendoza-Escamilla et al, 2019*).

Non-conventional water resources have emerged as means to meet or supplement irrigation demand for reforestation and agriculture in water scarce regions (*Tomaszkiewicz et al, 2017*).

Despite the significant value of the potentially extractable fresh water in the world few atmospheric water-harvesting systems are commercially operating currently. In general, any viable atmospheric water-harvesting technology must satisfy five primary criteria: it should be efficient, cheap, scalable, wide-band, and stable enough to operate for a whole year or at last a monsoon season (*Yaodong, 2018*). Although resultant yields are relatively small, dew positions itself as a viable water resources supplement because it occurs naturally and frequently in many locations globally, particularly in the absence of precipitation or when more traditional water sources are subject to depletion (*Tomaszkiewicz 2015*).

Irrigation by condensation is an inexhaustible resource of water for irrigation, the combination of high relative humidity, the air temperature and the low temperature of water circulating through a closed loop system. Irrigation by condensation are designed primarily to arid and semi-arid areas, where groundwater is deep and fresh water sources are rare (*Manea et al, 2016*). The aim of this study is to present methods of collecting air humidity for the purpose of valorization for crop irrigation.

MATERIALS AND METHODS

According to the forms of airborne water, the atmospheric water-harvesting technologies can be divided into two categories: fog water collectionand dew water collection (*Yaodonget al, 2018*). Atmospheric water can be harvested through passive methods or active methods. Passive methods are suitable for atmospheric humidity that has already condensed to liquid rain, dew or fog (*Nidalet et al, 2017*). One passive method of atmospheric moisture collection utilizes screens and meshes to hunt dew mist and fog droplets and deposit them into gutters that stream them into collection tanks (*Nidalet et al, 2017*).

Another method of passive atmospheric water harvesting involves chemical treatment of cotton fabrics to enable them to absorb considerable amounts of water from misty air that can be more than three times of their own weights (*Mendoza-Escamilla et al, 2019*).

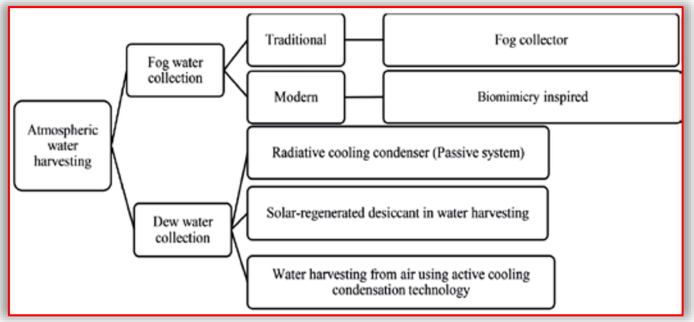

Figure 1. Atmospheric water harvesting technologies (Hasila et al, 2020)

Active harvesting of atmospheric humidity requires special dehumidifiers that condense atmospheric moisture to produce liquid water. Electromechanical / refrigerative dehumidifiers come with refrigerative coils, where moist atmospheric air is forced to pass through the cold coils. This causes the condensation of gaseous vapor into liquid water. This water is then streamed into collection tanks.

A more recent passive method of atmospheric moisture collection utilizes screens and meshes to hunt dew mist and fog droplets and deposit them into gutters that stream them into collection tanks *(Nidalet al, 2017)*.

RESULTS

The usual method to collect fog water is placing a rectangular mesh perpendicular to the wind, which traps fog droplets. When exposed to a foggy environment, water droplets carried by the wind are pushed against the mesh and become trapped. After successive impacts, the droplets grow by coalescence until they are large enough to fall by gravity, and a gutter transports the water to a tank *(Yaodong et al, 2018)*. Research suggests that fog collectors work best in locations with frequent fog periods, such as coastal areas where water can be harvested as fog moves inland driven by the wind.

Figure 2. Fog collector (Domenet al, 2014)

The collection rate of a fog collector is determined by the fog liquid water content (LWC), the size distribution of fog droplets, the size and arrangement of the mesh mate- rial, and the wind speed.

The collection rate of a fog collector is determined by the fog liquid water content (LWC), the size distribution of fog droplets, the size and arrangement of the mesh material, and the wind speed.

The Raschel shade net material from the Chilean manufacturer Marienberg is used in most fog collector applications world-wide. The materials made of food-safe polyethylene and has a fiber width that is effective at collecting fog droplets *(Klemm et al, 2012)*.

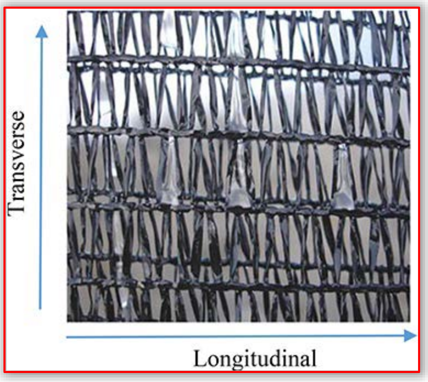

Figure 3. Raschel mesh (http://www.marienberg.cl)

Talaat A. Salem investigated the suitability of harvesting fog and rain water for irrigation using a pilot fog collector for water quantity, water quality and economic aspects. This study proved that fog harvesting is feasible in terms of water quantity, water quality and economy. But it recommends collection of fog at various locations and times, since both water quantity and water quality are variable in time and space *(Salem et al,2017)*.

Sabah A. Abdul-Wahab conducted Experiments using three fog collectors with different local materials: AC filter, green shade filter, and aluminium filter. The results indicated that the total fog water collected during the experimental period of 76 days by AC filter, green shade mesh, and aluminium shade mesh was 995.04, 879.93, and 752.58 L/m2, respectively. The ion concentrations were studied and found to meet World Health Organization drinking water standards. Water from the three fog collectors was found to be of good quality. The results indicated a significant linear association between the collected fog water and the wind speed and rainfall. It was found that fog water collection rates increased with increasing wind speed and rainfall *(Sabah et al, 2007)*.

— Dew Water Collection

There are two main types of dew condenser, the apparatus used to collect dew water, namely radiative (also called passive) and active condensers *(Khalil et al,2016)*. The technology behind radiative dew water collection system is relatively simple as it relies on exploiting the physical processes of dew formation, and no additional energy input is necessary. The technology behind radiative dew water collection system is relatively simple as it relies on exploiting the physical processes of dew formation, and no additional energy input is necessary *(Khalil et al,2016)*.

Figure 4. Dew condenser *(Daniel et al, 2009)*

Studies on passive cooling system include investigation on materials with low emissivity surfaces. Early study on the influence of condensing surface materials to the dew formation has been investigated for Bahrain climatic condition. Three materials: aluminium, glass and polyethylene foils were investigated as the condensation surfaces. From their study, aluminium surfaces were reported to have the highest amount of average dew collected at 3 kg/m2 per hour, followed by glass and polyethylene foils at 0.8 and 0.3 kg/m2 per hour, respectively *(Alnaser and Barakat 2000)*.

Sharan G. investigated three different types of condensing surface, galvanized iron sheet with emissivity 0.23 and thickness 1.5 mm, commercial aluminium sheet with emissivity of 0.09 and thickness 1.5 mm and PETB film (polyethylene mixed with 5% TiO_2 and 2% $BaSO_4$) UV stabilized.

From all the three surfaces being tested, the highest collection was in the PETB units (19.4 mm) followed by galvanized iron (15.6 mm) and aluminium- 9 mm *(Sharan, 2011)*.

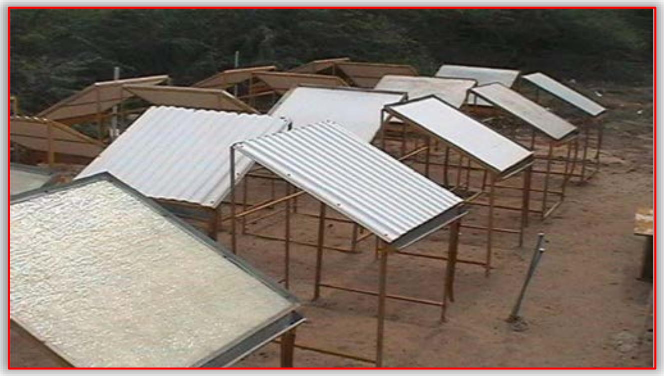

Figure 5. Different types of condenser surfaces (Sharan, 2011)

Active condensers typically require electrically powered compressors or vacuum pumps and the quantity of water harvested in directly related to the input energy *(Hasilaet al, 2020)*.

Compared to radiative condensers, active condensers are more efficient, with daily yields proven to be considerably higher *(Khalil et al, 2016)*.

The company Roots Up introduced a multifunctional greenhouse that allows farmers to grow food and collect water, named Ecodome. The greenhouse is an affordable technology that accumulates sufficient water reserves to provide year-round irrigation.

Figure 6. Ecodome-Dew Collector greenhouse (https://rootsup.com)

The greenhouse serves multiple purposes to suit different climatic conditions. It is designed to efficiently capture dew. The dome-like greenhouse is activated when temperatures increase in the noon sun, causing water to evaporate and rise. With the humidity contained, the top point of the structure catches this evaporation before it's able to escape into the atmosphere. As night falls, the greenhouse top is then opened by pulling the ropes attached to the latch, exposing the collected droplets to cool air. Those droplets then cool and condense, falling into a storage cistern. The collected water can then be used for watering plants. This system can be repeated each day, allowing plants to thrive while excess moisture is captured and saved for future use.

The Airdrop irrigation concept is a low-tech design that uses the simple process of condensation to harvest water from the air. Utilizing a turbine intake system, air is channeled underground through a network of piping that quickly cools the air to soil temperature. This process creates an environment of 100-percent humidity, from which water is then harvested. The collected water is stored in an underground tank, ready to be pumped out via sub-surface drip irrigation hosing. The Airdrop design also features an LCD screen displaying water levels, pressure strength, solar battery life and system health.

Figure 7. Airdrop irrigation design *(https://coolhunting.com/tech/airdrop)*

In 2016, INMA Bucharest developed the project "Intelligent technological system of condensation irrigation in greenhouses and solariums" which is intended for vegetable farms, especially those in areas threatened by desertification, to achieve a substantial saving of irrigation water. The field of use of the experimental model is the irrigation of vegetable crops in the open field or in protected environments (greenhouses, solariums), by capitalizing on the humidity in the soil and air, at a minimum installed energy power.

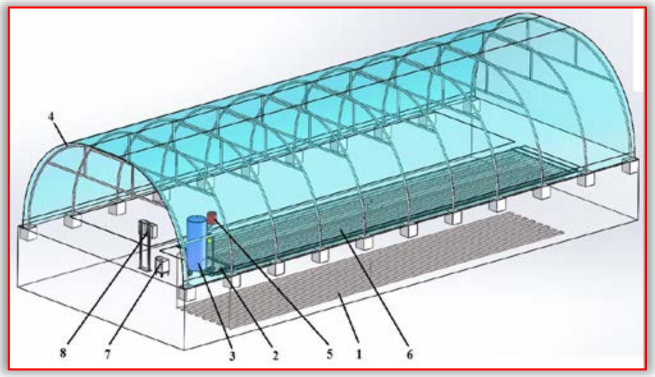

Figure 8. INMA's Intelligent technological system of condensation irrigation in greenhouses and solariums (Marin et al, 2017)

1-Temperature optimization installation in the area of plant roots; 2- Circulation pump; 3- Cold water tank; 4-Solarium with gothic vertical walls; 5- Expansion vessel; 6- Condensing system with copper pipes or with PHD pipes; 7- Water cooler; 8- Automation system

The system contains a condensing installation designed from a network with pipes, in version I of copper or in version II of PHD, mounted in a closed loop, which by recirculating the cold water inside them combined with the high relative humidity and the air temperature inside the solarium will use water resulting from condensation for the irrigation of the vegetable crop.

CONCLUSIONS

This study presented methods of collecting air humidity for the purpose of valorization for crop irrigation. According to the forms of airborne water, the atmospheric water-harvesting technologies can be divided into two categories: fog water collection and dew water collection.

Studies have shown that fog and dew harvesting is feasible in terms of water quantity, water quality, and economy. Researchers have demonstrated that atmospheric humidity collectors can be used for collecting water and use it for irrigation. It recommended that collection be made at various locations and times, since both water quantity and water quality are variable in time and space.

Water harvesting is a technology that has greatly evolve in the past decades but challenges remain to be optimized for efficiency and to ensure the delivery of water with a quality appropriate to its end use.

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