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Biomimicry in agrotechnology: Future solution of water problem for the agriculture industry?

Biomimicry in agrotechnology: Future solution of water problem for the agriculture industry?

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Abstract. Agriculture main issues are the reduction in water availability and the loss in water quality. If the population is increasing, the demand for food will increase, but the amount of water available to produce food does not increase. It would be a huge problem for the future. This study explores the alternative method in biomimicry to provide sufficient water supply for agriculture by reviewing challenges in agriculture and identifying biomimicry approach on previous research. The designers can use these technologies to solve water problems in agriculture, for example, Watercone and Warka Water. Both of these designs are inexpensive and can extracts gallons of fresh water from the air and designed to be environmental friendly by not causing any pollution or harm to the ground they are built on. By studying nature people learn to respect it and understand the importance of conservation, in other words, the more people, especially for designer, are aware of the potential of biomimicry. Biomimicry expected to be a promising approach, effective in improving well-being and its environmental efficiency at both agriculture and technology. Based on this study at the agriculture in particular, it is possible to see biomimicry as a driver to change urban environment.

1. Introduction

Population growth, growing demand for food, ever-increasing competition for water, decreased reliability of supply, climate change and climate instability and drought, decline in essential ecosystem services, competition for land use, evolving regulatory environments, and less participatory water resource governance are leading to increasing difficulties and challenges in managing water resources. The need for sustainable food supply for our global population and the need to protect the environment, both natural and man-made habitats and landscapes, have created an increased demand for integrated, participatory, and scalable solutions focusing on different levels of irrigation and water management, from field crops to catchment and basin scales. Meanwhile, challenges and issues related to water management for agriculture and food have been developed enormously over the last 30 years, and the task of active management of the components of the water cycle is becoming gradually important as their dynamics are essential to ensuring sustainable water usage, especially in agriculture and natural ecosystems. The key and the first challenge is to produce enough food for the growing population, closely linked to the challenges of agricultural water management, particularly irrigation management. This paper reviews the sum of design that used biomimicry concept for water management that can help agriculture industry on irrigated agriculture, mainly water management, and its contribution to food security and rural communities' welfare.

2. Agriculture and Water Scarcity

Agriculture is responsible for the largest water extraction and is considered the primary 'culprit' under real local scarcity conditions [1]. Water is essential to all socio-economic growth and the preservation of healthy ecosystems. As the population increases, groundwater and surface water for domestic, industrial and agricultural sectors exaggerated, leading to conflicts between the users and intense environmental pressures [2].

Water scarcity has a massive impact on food production. Water is the most crucial component of agricultural development. Water scarcity will reduce production and have a significant effect on food security worldwide. World agriculture uses about 70% of the fresh water withdrawn each year [3]. Just about 17 percent of the world's agricultural production irrigated, but this irrigated land provides 40 percent of its food supply [4]. Worldwide, the amount of irrigated land is steadily rising, even though salinization, waterlogging, and siltation continue to reduce productivity [5].

The water crisis's brutality has led the United Nations [2] to conclude that water shortage, not a deficiency in arable land, would be the most significant constraint to increased food production over the next few decades. For example, Australia is a significant food-producing and land-growing country, but the recent drought has significantly minimized its food and agricultural production [6]. Irrigation has helped increase agricultural yields and outputs in arid and semi-arid environments and stabilize food production and costs [6]. Globally, increased agricultural production is needed to reduce rural poverty and boost economic growth [6]. New investment in irrigation infrastructure and enhanced water management will reduce the effect of water scarcity [6].

The FAO (Food and Agriculture Organization) 2002 scenario of water scarcity argues that most Middle East and North Africa countries face acute water scarcity. Others, such as Pakistan, Mexico, South Africa, and large parts of China and India, face chronic water problems. In these countries, irrigated agriculture needs greater water demand. To overcome water issues, these countries must focus on the productive use of all water supplies (surface water, groundwater, and rainfall) and water allocation plans. Maximizing economic and social returns to limited water supplies and, at the same time, increasing the productivity of water in all sectors.

2.1 Methods of water management

In order to resolve the growing issue, many have tried to explore more effective methods of water management. There are two practical methods that have been applied for this issue.

The first method is irrigation management. Irrigation is a method of transferring water to crops in order to maximize the volume of crops produced. Several irrigation systems in place do not utilize the water in the most effective way. This results in more water being used than is needed or in a shortage of water to ensure safe crops. According to [7], the irrigation management works to develop and maintain irrigation systems, such as groundwater irrigation, which are already in place and expand the irrigation areas to increase the quantity of crops produced.

Water management for rainfed agriculture is the second method. Rainfed agriculture is one of the most common forms of farming in developing countries. According to [8], 80 percent of the world's agricultural land is rainfed and "contributes about 58 percent to the global food basket". Some water conservation strategies for rainfed agriculture include the use of additional irrigation and water harvestings techniques, such as rainwater systems and weir or sand dams. These methods allow much-needed water to be used in areas where rainfall is erratic.

3. Biomimicry

Biomimicry is composed of two words: bios that mean life, and the other being mimesis, which means to imitate. Biomimicry is about learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs [7] .In biomimicry, nobody uses the organisms, and they only use the blueprints or the recipes from the organisms.

Biomimicry is a method that inspires nature as a guideline based on the development of sustainable technology. According to [8] the new paradigm of sustainable design has led to a broader improvement, where it uses organic materials and natural processes. Efforts to recreate the unnatural nature have inspired designers to deepen their knowledge of biomimicry.

3.1. Application of Biomimicry in Agriculture

Application of biomimicry concept in agriculture, by learning from prairies to grow food in resilient ways [7]. Looking at any natural environment, such as the prairie, we will see a unique food production system: efficient, resilient, self-enriching, and eventually sustainable [9]. Modern human farming practices are still beneficial, but only in the short term: irrigation, fertilizer, and pesticide inputs, on which current food crops are depleting and polluting increasingly scarce water and soil resources[10]. Some researchers have successfully revolutionized the conceptual foundations of modern agriculture by using natural grasslands as a model. They have shown that using deep-rooted plants that thrive year-to-year (perennials) in agricultural systems mimic stable natural ecosystems rather than the weedy crops common to many modern agricultural systems . This can produce equivalent yields of grain and also maintain and even improve the water and soil resources upon which all future agriculture depends.

3.1.1 Prospero: The Robot Farmer

Prospero is a functional prototype of the Autonomous Micro Planter (AMP), which uses swarm and game theory and is the first of four stages. It's supposed to deploy as a group or "swarm" The other three phases include autonomous robots that farm, harvest, and finally, a robot that can plant, cultivate, and harvest—autonomously going from one process to another [11]. The underbody sensor array helps the robot to know whether the seed has been planting in the region at optimum spacing and depth. The ability of Prospero is it can then dig a hole, plant a seed in a hole, and later cover the seed with soil and apply any pre-emergence fertilizers or herbicides along with the marking agent.

A swarm of small robots like Prospero will have the ability to farm inch by inch, inspect the soil before planting each seed, and choose the best variety for that spot [11]. This invention would increase each acre's productivity, allow less land converted to agriculture, feed more people, and provide a better quality of life for all these people because they would spend less of their money on food [11]. Prospero displays three key biomimicry traits, based on a personal favorite, the ant. The obvious biomimicry in Prospero’s design is the six legs, a highly stable locomotion method for rough agricultural fields. The more interesting one, though, is in the communication. The bots don’t record the spot at which they planted the seed digitally on a GIS type system, but physically, with a painted ‘pheromone’ marker (similar to ants and even dogs), which other bots can read.

3.1.2 Biomimetic Dew Harvesters

The Stenocara beetle lives in the extreme conditions of the Namib desert in Southern Africa [12]. Many articles described how the way this beetle collects the water is so vital to its survival. Recently, the study demonstrated that such insects could collect dew on their backs and not just fog as previously thought. This study is made possible by the wax nanostructure on the surface of the beetle’s elytra. These findings can improve the water yield of man-made dew condensers that mimic the nanostructure on the beetle’s back. In fact, by examining the features of this beetle’s back under an electron microscope, scientists established that it’s a perfect model for water trapping tents and building coverings or water condensers and engines.

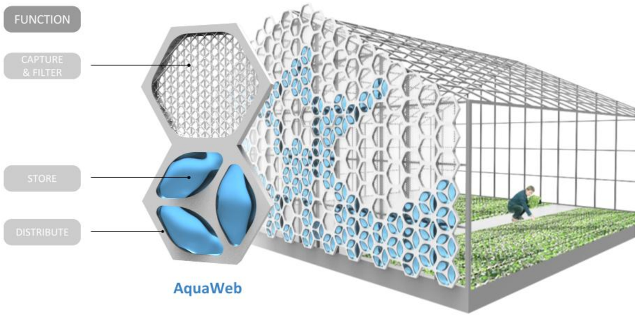

Figure 1. This diagram of the AquaWeb demonstrates how water is captured and utilized to grow food. Source: https://inhabitat.com/nexloop-unveils-water-management-system-inspired-by-spiders-fungi-bees-and-plants/system-aquaweb/

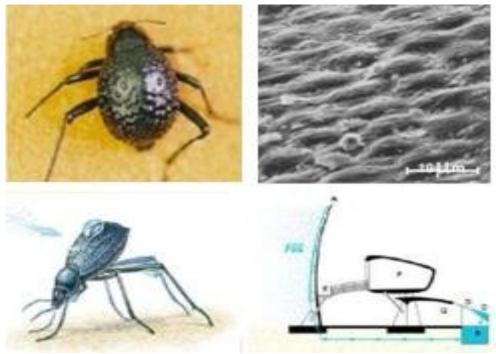

Figure 2. Illustration of Namib Beetle harvesting water vapor. Source: https://asknature.org/strategy/water-vapor-harvesting/#jp-carousel-8302

3.2 Application of Biomimicry in Agriculture Industry for Water Problem Solution

Based on previous, some of the agriculture already applied biomimicry concept in their field. However, the main problem faced by agriculture is water. By 2050, the world's population will projecting to rise to 9 billion, leading to water shortages that could affect half the world [9]. For example, some animal species that live in deserts have developed survival capabilities to deal with water scarcity. New technologies and biomimicry can provide solutions for easy, reliable, and affordable water collection and purification.

In the desert, where there is scarce water and few living things to be found, some animals have the most incredible designs to survive. Finding water in certain areas of the desert is a long trip. However, even when people found water, that doesn't mean it's safe because it can be polluted. Many solutions are emerging, but they must be quick, not expensive, and easy to maintain and implement [13]. New technologies and biomimicry are constant solutions to collect and purify water fast, efficiently, and affordable. Biomimicry is an engineering strategy that aims to find sustainable solutions to human problems by imitating nature's patterns and techniques. The purpose is to work on creating goods that are well-adapted based on long experience in nature. In reality, nature has already solved many of the problems that we face. The following paragraph will discuss some of the latest developments or designs in water technology that may have some answers to our water-related issues.

3.2.1 Sustainable water filtration

Often the problem is the lack of clean water and the ability to clean it. Sustainable water filtration systems can differentiate life and death in areas with access to polluted water. We often found many low-tech methods that use trees, tree seeds, ashes, or manure. Some purifiers are much easier, and use only the sun. Amongst them: Eliodomestico and the Watercone [14] .

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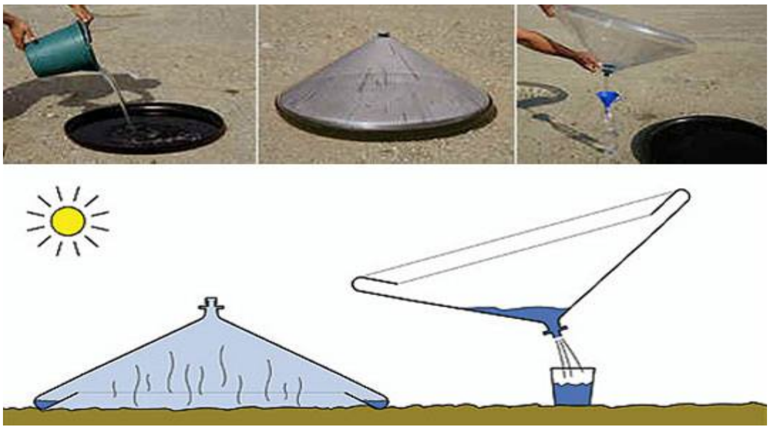

Figure 3. The Watercone is a solar powered water desalinator that takes salt or brackish water and generates freshwater. Source: https://www.pinterest.es/pin/238198267772861766/visual-search/

3.2.2 Wind turbine inspired by whale fin

Eole Water, a French-based company, is testing a wind turbine in the United Arab Emirates that claims it can generate hundreds of liters of drinking water a day from desert air. Tests on the outskirts of Abu Dhabi were able to generate 500 to 800L a day. The front limbs of whales are the largest appendages of any animal on earth, and it is the small bumps called tubercles found along the leading edge that give them their incredible acrobatic skills [15]. Scientists at Harvard found that these bumps change the distribution of pressure along the pectoral fin. Due to this variation, different fin stall areas with varying attack angles make sudden stalls easier to avoid. They concluded that this gives the whale "more freedom to attack at higher angles and the ability to predict its hydrodynamic limitations better."[7].

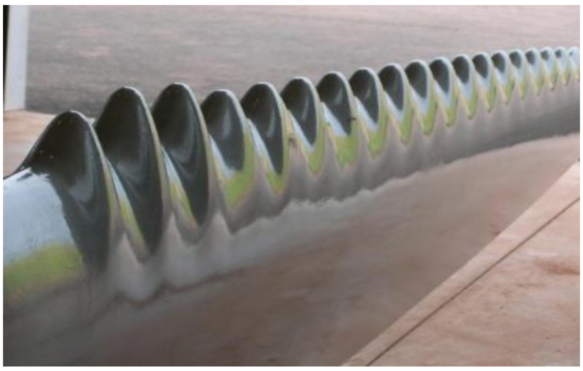

Figure 4. An example of the types of wind turbine blades that could increase renewable energy sources. Source: https://www.biosphereonline.com/wp-content/uploads/2019/01/whaleblade_x600.jpg

Figure 5. Wind Turbine blades inspired by Whalefin.Source:https://materialdistrict.com/article/humpback-whales-inspire-next-generation-wind-turbine-technology/humpback-whales-inspire-next-generation-wind-turbine-technology-1/

3.2.3 Warka water

Warka Water is a cheap and easy-to-assemble structure that can extract gallons of fresh water from the air. The innovation by Arturo Vittori, an industrial designer, and his colleague Andreas Vogler does not require complex gadgetry or engineering expertise. Instead, it relies on simple elements such as form and material and how they work together [16]. Each tower's rigid outer housing consists of lightweight and elastic Juncus stalks, woven in a pattern that provides stability in the face of strong wind gusts while still allowing air to pass through.

Figure 6. WarkaWater Towers Collect Drinking Water from Thin Air in Ethiopia. Source: https://media.wired.com/photos/593295e358b0d64bb35d2cf2/master/w_1600%2Cc_limit/warka6.jpg

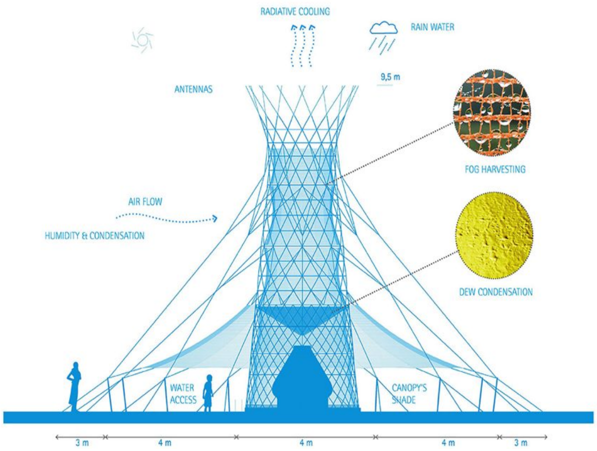

Figure 7. Warka Tower is a vertical structure designed to harvest potable water from air, giving an alternative water source to rural populations. Source:https://media.wired.com/photos/593295e358b0d64bb35d2cf2/master/w_1600%2Cc_limit/warka6.jpg

A mesh net made of nylon or polypropylene, which recalls a large Chinese lantern, hangs inside, catching droplets of dew forming along the surface. When the cold air condenses, the droplets roll down to the bottom of the tower. Water in the container will then passes through a tube that acts as a faucet, taking the water to those waiting on the ground.

3.2.4 Sietch Nevada (An Oasis in the Desert)

Frank Herbert's design a seminal sci-fi classic Dune, where is set primarily in the dystopian desert world of Arrakis. Water has become a form of currency and is the basis for a futuristic idea of urban design in America's arid interior in Sietch Nevada. Crafted by Matsys Designs, the project envisages a drought-stricken future in which water-hoarding communities are force to combat constant drought and 'water wars.' [17]. Sietch Nevada, an underground city of tunnels and caves, stores water in aquifers underneath the honeycomb-structured dwelling areas and tunnels that serve as both transport and irrigation channels. The underground city draws power from above, collecting surface water, extracting electricity from renewable sources, and increasing food using urban agriculture and aquaculture techniques [18].

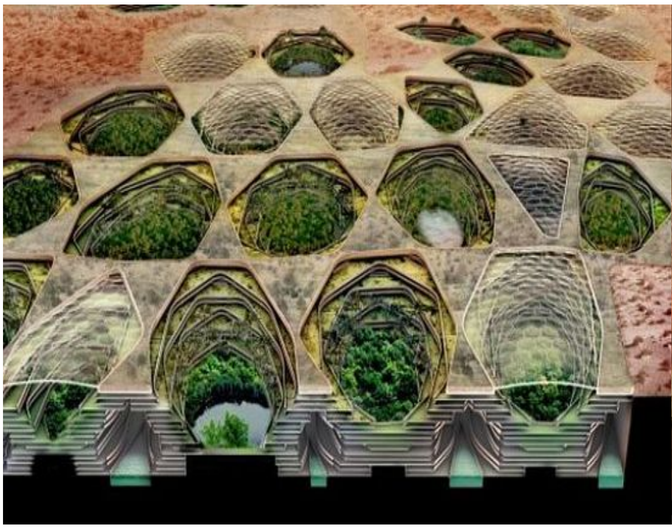

Figure 8. Illustration idea of Sietch Nevada. Source:https://designbuzz.com/wpcontent/uploads/2012/07/sietch-nevada_ZAFMG_58.jpg

Figure 9. The underground city features numerous residential and commercial cavern structures, connected with a network of waterways and storage canals. Source: https://designbuzz.com/wp-content/uploads/2012/07/sietch-nevada-02_jlCvY_22980.jpg

4. Results and Discussion

More than one solution design to minimize or overcome the water shortage problem that the world is facing today. Any action is necessary and must take into account. Our world is currently facing a crisis of insufficient water supplies, and if the situation continues to evolve without drastic alterations, the consequences would be detrimental. Water cone is one of unexpensive and efficient to collect the water. The product consists of a transparent plastic cone, which produces a greenhouse effect. This float-able cone is either set onto still water, wet ground, the ocean or on the river, water poured into a black pan, which is place underneath the cone. The cone's material consists of polycarbonate, UV-resistant, long-lasting (daily use for five years), non-toxic, non-flammable, and 100% recyclable. It is very durable, easy to transport (they stack easily), inexpensive to produce, and low-tech enough to be used even if no other infrastructure is present.

Warka Water almost the same as the water cone but on a big scale. Made from a lightweight wooden tower that is quick and cheap to build without any power tools, it harvests water from the atmosphere via condensation. It had been designed to be environmental friendly by not causing any pollution or harm to the ground they built. The Warka Water team hopes the towers will also benefit the environment by providing water for irrigation, reforestation, and ecosystem regeneration. The former problem regarding water use essentially comes down to the question, “How precisely should we recreate natural systems in agriculture?”. Should we try to copy natural systems in all possible detail, or is incorporating certain organisms or natural substances for their agrosystemic function enough to have ecologically ad humanly safe agriculture? It is interesting to assess these eco-system design approaches from the recently emerging biomimicry perspective. Researchers draw on natural solutions to engineering problems to devise sustainable technologies [7] [19]. Since the design looks upon natural ecosystems for their designs and has sustainability as the main goal, both had described accurately as biomimetic approaches.

The inspiration and ideas offered by ask nature facilitate the creation of radically innovative, sustainable products and services worldwide. How are we going to feed nine billion in 2050? Nature has the answers to that. Biomimicry is the best method for developing more resilient food systems [20]. Whether dealing with waste, growing methods, pest control, packaging, conservation and distribution, soil quality, or climate change, there are countless strategies for addressing food and agriculture problems in creative ways. And nature does this while helping the ecosystem and minimizing water consumption, energy use, and waste. Biomimicry is working with food and conservation experts to seek solutions inspired by nature to strengthen our food systems [21]. From 2019 to 2022, our Global Design Challenge will unite thousands of students and practitioners worldwide to solve food challenges. Our goal: to demonstrate how modeling nature can provide viable solutions to reduce hunger and address the challenges of the industry while at the same time creating conditions conducive to all life. Step over genetic engineering; biomimicry seems to be the best bet to tackle global hunger. Biomimicry word is composed of two words, one being bios that means life and the other being mimesis, which means to imitate. Biomimicry is about learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs [7]. In biomimicry, nobody uses the organisms, and they only use the blueprints or the recipes from the organisms.

Biomimicry is a method that inspires nature as a guideline based on the development of sustainable technology. According to [18], the new paradigm of sustainable design has led to a wider improvement, where it uses organic materials and natural processes. Efforts to recreate the unnatural nature have inspired designers to deepen their knowledge of biomimicry.

5. Conclusion

Although there are various types of application of biomimicry in order to solve water scarcity in agriculture, the types which inexpensive and environmental friendly are the best to be applied. The applications such as Warka water and sustainable water filtration (Watercone) have the features that helps extracts gallons of fresh water from the air, low-tech and designed to be environmental friendly by not causing any pollution or harm to the ground they are built on. Warka water relies on simple elements such as form and material and how they work together. It used a mesh net made of nylon or polypropylene, which recalls a large Chinese lantern, hangs inside, catching droplets of dew forming along the surface. On the other hand, Watercone use low-tech method which purify the water by using the sun. However, there are also limitation associated with the farmers. The most critical limitation is some farmers need to be supported with appropriate policies, the right mix of public and private investments, and access to knowledge and resources for producing more and better with less water. We should provide a technical study about managing the proper method of this innovative technology. Hence, farmers can deal with climate variability and build on improved land. The sustainable intensification of food production, with more efficient water management systems adapted to climate variability and local circumstances, can help increase water productivity and raise on-farm incomes.

Biomimicry is comprehensive: it provides innovative solutions to environmental problems and answers to sustainability dilemma, but it is an ideology, too. By studying nature, people learn to respect it and understand the importance of conservation; in other words, the more people, especially the organizations and people in design, can apply these innovations inspired by nature, i.e., biomimicry strategies in their design. They will become aware of biomimicry's potential; the more they want to protect biodiversity, every loss of species is a potential loss for new sustainable and profitable innovation. Adopting this ideology may affect the way we see ourselves in the world ‘s order.

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