PANGEA

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Abstract

Pangea is an outdoor hydroponic garden system that incorporates water collection with solar, and wind power capture technologies to sustain the garden and its immediate surroundings. There is a strong global interest to increase urban food production while reducing energy consumption to lessen stress on the modern food production system. Many popular urban innovations in food production eliminate the need for soil, land rotation, fertilizer, and pesticides. This proposal will explore traditional and modern practices in comparison to Pangea. Named after the hymn (Pange) of St. Thomas Aquinas and the supercontinent Pangea it is proposed that the Pangea system can address the global needs by bridging the gap between food, water, and energy. Pangea aims to be another tool for the quickly growing field of urban farming. The system will allow for the growing of food while conserving water and energy via water collection and conservation design, solar panels, and a vertical axis wind turbine. Currently, the yield of several crops corresponds to Pangea and a classic soil-filled garden bed of equal size located adjacent to the system. Data is also storing water use of each system and Pangea's renewable energy production.

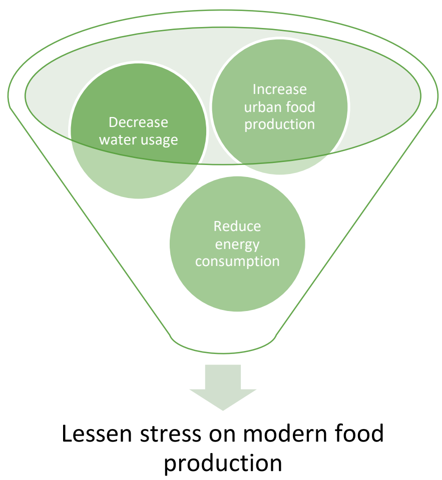

Figure 1. Mission Statement

Introduction

Future global population estimated to be 6.8 to 28.6 billion people by 2100 based on the four fertility scenario models. (Sachs, 2015). 68% of which in urban areas by 2050 (UN, 2018). Our population directly corresponds to general consumption rates from food, water, and energy. With increased populations, we know that food consumption rate will need to increase by 50% by 2050 (World Bank Institute, 2018). The case of our global population and consumption rates suggest a need to innovate the current agricultural and energy infrastructure. While growing food we need to enhance biodiversity and maintain economic gains which support a carbon neutral future.

In May 2018, the combined average global temperature over both land and ocean surfaces was 0.80 Celsius (NCDC/NOAA, 2018). Depending on future policies, Lord Nicholas Stern, known as the Stern Review of Climate Change, suggests a global temperature over 1 Celsius from the pre-industrial period can drastically impact food production for arid climates like the Sahel region (Sachs, 2015). Improper farming practice and regional change in conditions often lead to drylands making land infertile to grow on using classic soil-based farming techniques, otherwise associated as the process of desertification. The act of deforestation rhythmically transpires when the producer faces pressure for fertile land. The case of our global population, consumption rates, and an increase in average global temperatures stress a need to innovate the current agricultural and energy infrastructure atop existing, unaltered landmasses adaptable to its native region to enhance biodiversity and economic gains.

Henry Thoreau first sparked public discussion, questioning the effects of Industrialization and Urbanization through his literary work, Walden (Thoreau, 1854). Garrett Hardin extended Thoreau's observations publishing the Tragedy of the Commons, inferred that shared resources like water or air, humans tend to take more than their share and the commons becomes degraded (Hardin, 1968). Elinor Ostrom, who won the Nobel Prize in Economics in 2009 publishing, Governing the Commons, showed the only way to protect the commons is to have grass-roots and small scale stake-holders (Ostrom, 2015). ***Pangea's system supports urban food production while producing electricity and capturing water and solves the philosophical challenge of protecting a common through local stakeholders. The goal is to grow food efficiently where you live with urban hydroponic micro-grid farms backing sustainable development.***

Figure 2. Traditional Garden Bed –

8 bare root chandler strawberry plants grown in soil and peat moss with a 4-inch spread in 3 rows of 4 plants. Maintained by manual water and soil treatment. Photo shown after planting. Plants grown for 4 weeks

Figure 3. Pangea Garden Bed –

8 bare root chandler strawberry plants grown in hydroton and rockwool 4 inches apart. Water was treated with Ph down solution. This system is classified as a deep-water culture outdoor hydroponic system. Plants grown for 4 weeks.

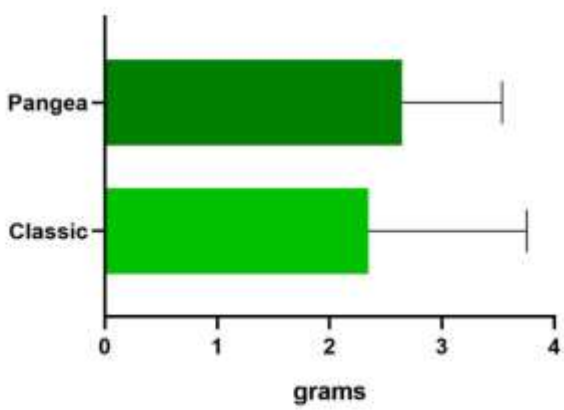

Figure 4: The shoot weight was recorded for each of the 8 plants grown in the classic and Pangea garden beds after 4 weeks. A t-test indicated no significant statistical difference between strawberries grown in either the classic or Pangea system (P=0.6).

1-MONTH (4 WEEKS)

GARDEN BED PRODUCTION	Classic Soil	Unit	PANGEA	Unit
WATER PRODUCED	-	Liters	48.02	Liters
WATER CONSUMED	69.00	Liters	246.03	Liters
WATER DIFFERENTIAL	(69.00)	Liters	(198.01)	Liters
ENERGY PRODUCED	-	kwh	4.04	kwh
ENERGY CONSUMED	-	kwh	3.99	kwh
ENERGY DIFFERENTIAL	-	kwh	0.05	kwh
PLANT WEIGHT	16.46	g	18.50	g
(SUM OF 8 PLANTS)				

Table 1: Water and energy differential for each system along with biomass

Methods

Plant Collection – 20 bareroot strawberry plants purchased from Wabash Feed & Garden Store.

T-Test – The shoot mass of the individual strawberry plants was weighted after 4 weeks in each system. Each plant was cut at the point where the root meets it stem. (Figure 2, 3, 4 and Table 1).

Building System – Local 3D printing consultation and services from Northworks Automation. Purchased steel drum from Bubbas Barrels in Tennessee. Local consultation and services of W.K. Hill Tent & Awning Co for solar canopy fabric. Other combined parts and resources assembled with CAD design and labor.

Analysis – The t-test and graphing were conducted by Prism graphpad.com.

Other Detection Methods – Raspberry Pi and Arduino Microcontrollers with a variety of sensors were used to develop programs to monitor, record, and automate other aspects and portions of this experiment.

Energy – Will measure usage based on annual sun hour averages for Houston, Texas, power ratings for solar panel and air pump, and conversions (Table 1).

Water – Measure flow rate of garden hose at University of Houston – Downtown in seconds and Houston, Texas rainfall by Wikipedia (Table 1).

Results

- The goal of creating a modular and portable energy-producing system was successful. The Pangea system generates solar and wind power (Figure 2).
- The system was able to collect rain water.
- The Pangea system was able to keep plants alive and there was no significant statistical difference between plants grown in the Pangea system and those grown in the classic garden bed ($P = 0.6$) (Figure 3).
- Measurements of energy and water use explained in depth in the results (Table 1).
- Future community engagement participants and potential customers have been identified (Figure 4 and 5).

Table 1 measures the water, energy, and plant differentials between a classic soil bed and Pangea hydroponic system. Pangea's stainless-steel drum is roughly 2.5' in diameter (0.762 m) or 4.91 SQFT (0.46 m^2). Houston annual rainfall averages are 49.77 inches (1264.8 mm) (Google, 2019).By multiplying, Pangea’s drum in m^2 to Houston’s annual rainfall this hydroponic system can accumulate roughly 152 gallons (576 liters) of rainwater per year. Dividing the annual gallons of rainwater by 12 representing months, we can estimate Pangea can produce 12.68 gallons (48.02 liters) per month. A classic soil-based garden bed is exposed to rainwater but unable to collect and reproduce water.

Both the classic soil bed and Pangea system consume water. Based on the time and rate in which water flows with two full turns from the UHD garden hose, it is known to take roughly 76.8 seconds to fill a 5-gallon bucket at a rate of 0.07 gallons per second. By converting gallons per second to liters per second, the water flow rate comes to be 0.25 liters p/second. The classic soil bed consumes 2.46 liters of water per day or 69 liters of water per month when multiplying flow rate (0.25) by time (10 seconds p/day). Since the classic soil bed consumes and does not produce water, the monthly water differential results in a negative 69 liters per month.

The Pangea system both consumers and produces water. It takes roughly 998.4 seconds to fill the 65-gallon (246.03 liters) stainless steel water drum at a rate of 0.07 gallons per second. It would take roughly 5-months to fill this same 65-gallon drum with rainwater based on Houston's annual rainfall averages. The water differential for the Pangea system returns a negative value of 198.01 liters for the first month of use. After six months of use, Pangea will return a positive water differential and produce 288.12 liters. The classic soil bed will continue recording a negative value adding 69 liters of water consumption per month, 414 liters after six months. Water evaporation not included in the calculations for the Pangea system.

The classic soil bed in this experiment neither produces nor consumes energy. Therefore, the energy differential for a classic soil bed is neutral. The energy consumption for powering the water utility was not factored. A Pangea system produces energy through a 50-watt solar panel and vertical axis wind turbine. Wind power production was not included in the table.

The maximum amount of power produced by the solar panel is 68.16 watts. Maximum power found by multiplying the area of the solar panel (0.341 m^2) by total irradiance (1000 w/m^2) and efficiency (20%). Dividing 68.16 watts by 1000 equals to 0.068 kilowatts (kW). Houston's annual sun hour average is 4.92 hours (TurbineGenerator, 2019). 0.335-kilowatt-hours is obtained by multiplying kilowatts to sun hours. When multiplying the hours in a day by days in a week, and weeks in a month, the total energy produced in a month is 4.04 kilowatt-hours.

The Pangea system utilizes a submersible dc powered air pump to create oxygen for the plant roots. This 12-volt, 0.46 amp rated pump requires 5.52 watts to operate. Diving the required watts by 1,000 equals to 0.0055 kilowatts. When multiplying the time in which the pump is powered on (24-hours) to kilowatts, the pump consumes 0.13 kilowatt-hours per day. When multiplying the hours in a day by days in a week, and weeks in a month, the total energy consumed in a month is 3.99 kilowatt-hours. The energy differential for the Pangea system is a positive 0.05 kilowatt-hours, assuming the Pangea system reaches its average sun hours.

8 bare root chandler strawberries were grown in both the classic and Pangea garden beds. 4-weeks after planting, the plants were uprooted to be measured. The shoot weight was recorded by weighing each plant from each system individually. A t-test indicated no significant statistical differences between strawberries grown either the classic or Pangea system. The p-value equals 0.6.

Discussion

The goal of this project was to build and evaluate the self-sufficient Pangea system. There was no significant statistical difference in plant growth comparing classic soil to Pangea while successfully reducing water consumption and producing water and energy. Growing food, water, and energy efficiently where you live is the next stepping stone in creating a sustainable solution for our growing urban environments.

Future Work

Future work includes human behavioral research, developing a metric database calculating the financial, environmental, and human costs and benefits, technological research and development, and commercialization.

- Modify Garden Bed
  - Consider straps connecting bed to drum
- Complete feed & draw solutions
  - Filter potable water
- Fine tune thin film solar panel
  - Consider enclosing garden bed with mesh overhang
    - Regulate temp – water drip technique
- Modify fan (turbine) blades
  - Consider higher placement above Garden Bed
  - Connect G3 timing belt to motor / motor to battery
- Minimize evaporation
  - Steel drum
  - White containers

Figure 5. Community Engagement

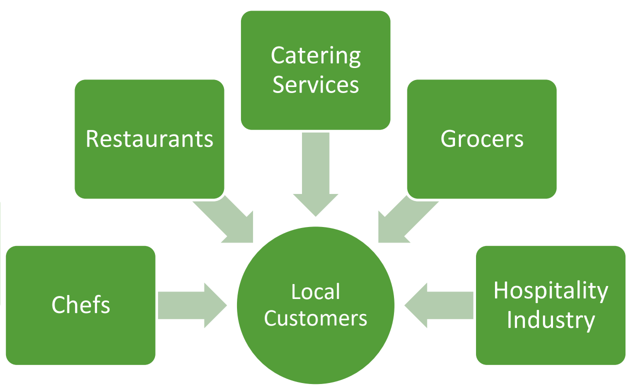

Figure 6. Potential Customers

Future Research

Human Behavior & Interaction

- Place PANGEA in highly dense foot-traffic area
  - Homeless Shelter
  - Local Foods
  - Whole Foods
  - City Centers
- Observe
  - Behavior
  - Interaction
- Conduct questionnaire amongst randomly selected participants

Taste Test & Microbial Life

- Grow 8 heads of lettuce in each system
  - PANGEA
  - Classic-Soil
  - Aquaponic Tank?
- Calculate weighted sum of lettuce in each system
- Grind lettuce and perform streak platting to determine microbial activity
- Heads of lettuce left over to examine taste from texture to consumption

Data Collection

- Refine table 1
  - Collect data in real time for Energy and Water differential

Acknowledgments

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