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Investigation Root Cause Analysis

PANGEA is an adaptable greenhouse that harvests food, water, and energy. The concept has grown from being an outdoor hydroponic garden resting atop a steel drum to a commercial-grade greenhouse adaptable to its environment. Like the hydroponic garden, the greenhouse utilizes water and energy capture technologies to sustain itself, whether it be to regulate or produce ideal interior conditions. Through investigation root cause analysis, it was determined that an outdoor system shared many flaws from the exposure to shifts in climatic conditions to poor engineering and design. The thesis has changed, whereas urban food production is no longer the focal point. Increases in global surface temperatures and erratic, intensified weather patterns have significantly impacted farmers (urban and rural), communities, and city-state infrastructure throughout the United States. The mission is to increase food production through adaptive conservation design altering interior conditions based on the outer climate to lessen electrical and water utility consumption. By adapting to the irregularities in our weather patterns, this greenhouse will be able to produce the necessities for life and mitigate the risk of anthropogenic emissions. This paper's objective is to analyze current and future hazards, inefficiencies, and vulnerabilities then detail how each will be addressed.

Pangea – Greenhouse

INVESTIGATION ROOT CAUSE ANALYSIS

PANGEA – OUTDOOR HYDROPONIC GARDEN SYSTEM

Garden Bed & Utility Box

Multiple hazards observed in the original design for the hydroponic system. For starters, the garden bed resting atop the steel drum was splitting and collapsing upon itself causing it to break and fall into the steel drum full of water. This action threatens human and plant-life from electrical shock to diminishing yields. In the first attempt, the garden bed's two primary pieces of plastic, an inner and outer ring, were glued with water-soluble epoxy. For the second attempt, two holes were drilled and inserted with threaded rods epoxied into position. This second attempt performed better than the first but was still unsuccessful. Two alternative solutions are given either a) redesign the plastic garden bed with stronger supports or b) utilize new materials that can adapt to changes in water level. Solution A is much more time intensive and costly; it is also a more rigid structure. Solution B can be completed at a fraction of the cost and time of Solution A. Solution B employs conventional pool noodles and vinyl fabric to form a ring. Agricultural mesh will be sewn into the pool noodles and up plant capacity two-fold whereas the previous design permitted eight plants to be grown, the new design can double or triple this amount.

Figure 1 – Garden Bed breaking

Figure 2 – Garden Bed and Utility Box

Vertical Axis Wind Turbine (VAWT)

The new design for the garden bed forces the VAWT to be repositioned. Originally the VAWT rested rigidly fixed on the steel drum, but now it must be relocated. Circular plates and vinyl fabric are used to create a new utility box. A clamping mechanism allows the VAWT to be vertically raised or lowered based on the current location, obstructions, and wind speeds. Vinyl is a waterproof and durable material that can reduce electro conductivity and risk of water damage as this fabric is protecting an inverter, battery, motor, air pump, etc. The human hazards involved with operating the garden and striking into the VAWT while it's in operation have now been addressed but must be developed, executed, and tested. Power utilities and electronics are placed further away from the water, which reduces the risk of electrical shock.

Water Reservoir

The stainless-steel drum and rods are made from stainless steel. Stainless steel holds up well in marine environments, but white rust and algae have been spotted on both the rod and drum. Algae and rust do not bode well when growing food for human consumption. Marine paint or coating and regular maintenance can be applied as mitigation and adaptive techniques but is not ideal for the use case of a self-sufficient outdoor hydroponic garden system. The questions that remain are, what vegetables or fruits, if any, are best suited for these conditions (rust and algae)? If not, then maybe corn or herbs will be best to grow, knowing that the biomass from corn and algae can be processed into alternative energy sources known as, biofuel. Replacing steel with clay could be the best alternative in the future.

Figure 3 – PANGEA redesign with white rust present

Future Work and Thoughts

The goal is to harvest food, water, and energy. The hydroponic system is not limited by plants with taller grow heights anymore. Many plants used for biofuels are summer crops like Switchgrass, Sunflowers, and Soybeans and not sure if there is an all-season or winter crop equivalent. It would be best to find a plant that is edible and can be used as a source for biofuel. If not edible, then a C4 plant would be a great alternative so it can absorb the highest trace of CO^2 to mitigate anthropogenic emissions. The goal of harvesting food will be eliminated from future work when implementing a non-edible plant into the system. C4 plants absorb more CO^2 than trees, take up less space, reach maturity quicker, and can be harvested for both food and energy.

BACKGROUND INFORMATION

Weather patterns and behaviors share unknown risks from potential accidents to near misses. It can alter trade routes, influence industry, alter animal and human behaviors, force community relocation, and endanger citizens to extreme weather events like wildfires or flooding. This project plans to address all these potential incidents through adaptive conservational design harnessing what we define as bad weather and produce positive results. A lot of adaptive and mitigative techniques have been used to combat these incidents. From channeling existing waterways away of major cities to developing man-made island chains and deltas, however, these methods might cause more harm due to the limited information we have and the unknown natural reactions the Earth will demonstrate based on these man-made environmental engineering changes. Adaptability and mobility are the essential characteristics practiced for both the garden and greenhouse to minimize the human footprint and unaltered landmasses and ecosystems.

> ***"Preserving the biotic community will ultimately increase land use for humans by respecting both nature and humanity"* – Aldo Leopold**

PANGEA – GREENHOUSE

An aluminum frame, bolts, nuts, and klearspan-like fabric were used in the original design of the greenhouse. This greenhouse was a kit meant to be a temporary structure withstanding only 45 miles per hour winds. Due to these restrictions and location of the greenhouse being roughly 50 feet off the ground on a fourth story deck with limited obstructions, a bad weather forecast clocking wind gusts of 60 mph nearly threw this structure off the deck. Luckily, no harm was done and all the components inside the greenhouse were salvaged but this near miss could have resulted in accidents like property damage and human life. A much-needed incident and near miss forced constructive thought which resulted in the development of a mobile and adaptable greenhouse.

Figure 4 – Interior greenhouse prior to weather event

Figure 5 – Greenhouse after weather event

Bamboo, dowels, and twine will replace the aluminum frame, bolts, and nuts. This frame shares an equivalent tensile strength to steel and is less rigid then the metal counterparts. When exposed to high winds, this structure will stay intact and conform to its current environment. A trailer serves as the base foundation adding anchor weight and making this structure mobile and adaptable to multiple environments. Cabling and weighted ends are used to further secure the structure and withstand up to 120 mph winds which follows the USDA requirements for permanent greenhouse structures. The overall modular design can be redeveloped if further issues occur like what was demonstrated with the aluminum frame.

Figure 6 – Aluminum frame nuts and bolts

Figure 7 – Bamboo dowel pin and twine (zip-tie)

The canopy will be made of both klearspan (transparent fabric) and agricultural mesh. The agricultural mesh will serve as an evaporative cooling device to regulate interior greenhouse climate conditions and serve as a gutter system to collect rainwater. The klearspan will lower utility costs by receiving direct sunlight followed by supplemental lighting via grow lights for overcast days. Mylar will be used in the interior sparingly to redirect sunlight to maximize the amount of light for the plants needed to reach a stable cycle of photosynthesis.

	Imperial	unit	Metric	unit		Metric	unit	Imperial	unit	Notes, Assumptions
Height of frame	70	in	1.778	m	Height	1.778	m			We use three dimensions and not the shape of the greenhouse, approximating it as a rectangular prism, overestimating the wind resistance.
Length of frame	72	in	1.829	m	Long horizontal	4.267	m			
Width of frame	168	in	4.267	m	Short horizontal	1.829	m			
Density of air			1.225	kg/m³	Collision area	7.5871	m²			We use long horizontal to get the larger estimate.
Max sustained wind speed	120	mph	53.6	m/s	Wind force	26746	N	6013	lbf	https://physics.stackexchange.com/questions/264524/force-of-water-hitting-a-wall
					Wind lever arm	0.889	m			The average height of wind force.
					Wind torque	23778	N·m			This is rotating the frame sideways, off its foundation.
Basic Anchor					Anchor torque	23778	N·m			Anchor is the force keeping the frame held down. It can be due to weight, or bolting, or welding, etc. This is assuming it is placed along the long horizontal edge of the frame.
					Anchor lever arm	1.829	m			
					Anchor force	13002	N	2923	lbf	
					Total anchor force	26003	N	5846	lbf	There has to be anchor on each side.
# of anchors			6	ct	Total force per anchor	4334	N	974	lbf	
Modified										https://www.trailersplus.com/Texas/Houston/6-Wide-Tandem-Utility-Trailers/trailer/4YMBU1824KT002020/
Trailer empty weight	1700	lbs	7562	N	Trailer anchor lever arm	1.0668	m			Anchor is the force keeping the frame held down. It can be due to weight, or bolting, or welding, etc. This is assuming it is placed along the long horizontal edge of the **trailer**.
Trailer short horiz	84	in	2.1336	m	Trailer anchor torque	8067	N·m			
Anchor lever arm	84	in	2.1336	m	Anchor torque	15710	N·m			
					Anchor force	7363	N	1655	lbf	
					Total anchor force	14727	N	3311	lbf	There has to be anchor on each side.
					Total weight	22289	N	5011	lbf	
# of anchors			4	ct	Total force per anchor	3682	N	828	lbf	

Figure 8 – Greenhouse Physics

How to with Bamboo

Bamboo is a building material with the intended use to replace wood collected from trees. Trees typically take ten or more years to reach full maturity, whereas bamboo can mature and be used within three to five years. Unlike trees, bamboo is naturally rot and pest resistant. Proper cure treatments, spitting of wood, and the usage of metal or other non-wood materials as a joint are all issues faced when building with bamboo. The failure to address these issues will cause near-misses or accidents and depending on the scenario can cause catastrophic damage.

Treating bamboo is an essential process toward ensuring the material will be long-lasting. It is strongly advised to cure bamboo twenty-four hours after harvest to guarantee it will last for a period of ten to one-hundred years. A 1-10 water compound ratio using boric acid and borax causes the bamboo to be stable, yet one might insist upon cutting the poles to size prior to administering the treatment. There are many methods to proper treatment techniques, but it is advised for a hobbyist to passively soak the bamboo for a week with the 1-10 water compound and let dry 7 to 14 days.

Each bamboo pole has nodes or notches along its stem. Between these two nodes are hollow where the pole will naturally crack. Cutting through one selected side of the bamboo with a table saw will mitigate the natural reaction of bamboo to split and control exactly where the crack forms. Again, it is advised to treat the bamboo after making this incision.

Figure 9 – bamboo passive soak for 1 week

Figure 10 – bamboo passive drying for 1 week

The strongest point of the pole is at each node. If you are building a structural frame for a greenhouse, it is advised to drill a hole and create a joint between two poles roughly two inches away from a node. The scraps found when cutting the poles to size can serve best as a dowel. By using the recycled scrap over another material like metal will ensure its structural integrity. Scrap can be used to create dowels which avoid the metal to crack the pole over time. When the dowel is placed parallel to the joining pole, twine or zip-ties will fasten the two poles together making for a reliable structure. Assuming the structure will be in limited contact with water when using fabric as a canopy, the only issue left to face is natural degradation and remembering to periodically fasten the joints.

CONCLUSION

These revisions of the current garden and greenhouse plan to reduce environmental and human risk. Conventional environmental engineering techniques meant to reduce human risk share unknown consequences. The garden is a precursor of how adaptable conservational design can harness the climate and environmental surroundings with a lower human footprint to unalter existing landmasses.