STUDENT RESEARCH REPORT – REEU PROGRAM 2023

Renewing Sustainable Practices at Holyoke Community College: Drafting a Preliminary Layout for a Self-Sufficient Permaculture Garden

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Abstract

In this comprehensive project, the focus is on revitalizing the Holyoke Community College (HCC) sustainability garden that once stood as a beacon of sustainability and community engagement. Through meticulous planning and community involvement, it aims to serve as a balanced and regenerative food production system, all-the-while enhancing biodiversity, fostering community development, and providing aesthetic appeal. The plan meticulously outlines objectives, strategies, and a timeline. Soil testing reveals the garden's sandy loam composition, conducive to a wide range of plant growth, while comprehensive analysis of organic matter, pH levels, and nutrient content ensures the viability of crops. The initiative embodies permaculture principles, education, and unity, reimagining the garden as a thriving hub that reconnects individuals with nature, promotes mental well-being, and establishes a legacy of ecological stewardship at HCC.

1 Background

Sustainability keys into three main components: environmental health, economic vitality, and social progress (Blue Bite, 2023). For a system to be sustainable, it must both prevent degradation of its natural resources and ensure generational success in an effort to provide equitable and viable solutions to the problems brought forth by globalization and industrialization. Permaculture, an approach to agricultural management that simulates patterns observed in nature, embraces these renewable behaviors by implementing ethical production, environmental preservation, and the restoration of compromised ecosystems for regenerative change (McLennon, et al).

Permaculture once flourished at the Holyoke Community College (HCC). Established by Professor Kathleen Maiolatesi in 2010, an intimate 2,000 square meters of land on its campus (Fig. 1) became home to a sustainability garden run solely by the passion of student volunteers, all of which were motivated to fulfill a single objective: to advocate for free, organic produce. By collaborating with cafeteria staff, culinary arts programs, and local urban agricultural organizations– such as Nuestras Raíces– a small extracurricular project became a transformative experience for its community, sustaining a steady food supply for both human and non-human (e.g., pollinator) consumers. Its biggest and most ambitious project, Freight Farms, was provided a total of $208,000 U.S. dollars in funds from the state through MassDevelopment as part of its Transformative Development Initiative, which aims to accelerate economic growth in its Gateway Cities. United in their love and respect for agriculture, Maiolatesi and her students supplied over 450 kilograms of produce city-wide in 2018. However, the COVID-19 pandemic, along with the subsequent removal of the sustainability program, led to the garden's discontinuation and subsequent decline. Invasive weeds, plant diseases, and litter plagued the area once home to a thriving commonwealth of agronomy, and, soon thereafter, everyone's hard work became a victim to the merciless hands of time. Seeing a piece of the HCC campus previously immersed in the mission of sustainability go to waste was disheartening. Having such an integral piece of the college and its culture fall through the cracks became our ultimate incentive to take action.

The goal of the present project was to draft a new, preliminary layout of a permaculture garden for HCC and, in doing so, we determine potential locations for fruits, vegetables, and flowers in two segregated portions of its land. Sustainable strategies were incorporated to enhance pollination, manage pests, and minimize costs, all practices that fall under the principles of permaculture.

Due to the garden's sudden downfall, there are no known records regarding its previous condition or history, such as soil health, pesticide/insecticide use, or biodiversity. As such, its restoration has become a multi-year commitment that integrates community service, networking, and research. This layout provides a general guide to spearhead the reinstitution of the HCC permaculture garden via four objectives: (1) to create a balanced and regenerative food production system, (2) enhance biodiversity, (3) support community development, and (4) provide aesthetic appeal.

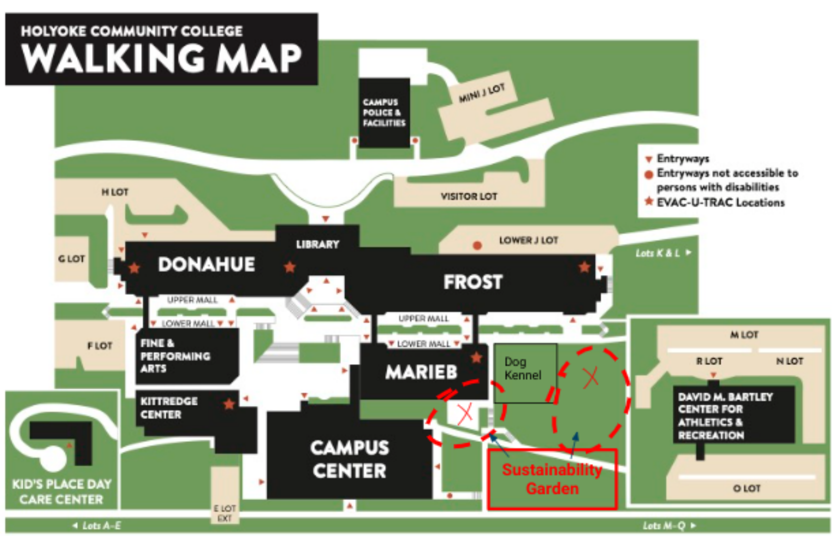


Figure 1. Holyoke Community College. A map detailing the campus of Holyoke Community College. Encircled is the general location of the permaculture garden.

1.1 Specific Project Objectives

Create a Balanced and Regenerative Food System

In the context of sustainability, creating balance means establishing a harmonious relationship between crop production and the natural world. Our plan is to bring together ecologically-friendly and productive agricultural strategies, aiming for both environmental reciprocity and greater food production capacity. For instance, this includes (but is not limited to): choosing hardier, insect pest- and disease-resistant crops with resilience against climate change, resulting in less product wasted and a greater prospect of yield; and avoiding highly demanding crops and/or synthetic fertilizers to prioritize the longevity of soil, produce, and consumer health.

As a result of these practices, the garden is expected to blossom into a regenerative system, holistic and free from the confines of wasteful management. We seek to garner tips from local permaculture gardens, such as UMass Amherst's, to further the probability of the garden's success. This objective will be quantifiable in bulk weight of yield every season.

Enhance Biodiversity

Increasing biodiversity is a means of providing ecosystem services by attracting (and retaining) a wide range of vertebrates, insects, and microorganisms to the ecosystem. To do so, we will implement an approach dubbed **'eco-stacking**,' which involves "combining, in an additive or synergistic manner, the beneficial services of functional biodiversity from all levels and types [where] different types of ecosystem service providers are fully integrated with the rest of the cropping system, including agronomic practices" (Hokkanen, 2017).

More information about Ecostacking!

Figure 2. A New Era. A before and after comparison of the garden from February 14, 2023 to August 10, 2023 after uprooting dead vegetation and removing trash.

Develop the Community
An integral drive behind this project is to reinspire a communal spirit around agriculture, as seen with Maiolatesi and her students. Our garden will be established on the grounds of a collective vision embraced by all HCC members by gathering insights, suggestions, and concerns via quantitative surveys. Given a significant gap between consumerism and agriculture, a permaculture garden also serves as an excellent conduit for educational enrichment for the wider public. We aspire to incorporate extracurricular and co-curricular activities, in addition to scholastic events, to expand others' understanding of agronomy and foster a deeper appreciation for the demanding aspects of food production. Overall, it will be managed by the community for the community, providing volunteer opportunities and paid internships through SAMP.

Provide Aesthetic Appeal
Through a marketing lens, evidence suggests that aesthetically pleasing surroundings have a positive impact on mental well-being and productivity, playing a crucial role in academic success (Foellmer et. al, 2021). Additionally, a thoughtfully designed and visually captivating campus commonly nurtures a sense of unity and pride among its student body, faculty, and staff. In turn, it fosters stronger connections and collaboration among individuals, creating an environment that encourages personal growth and intellectual advancement. Beautiful campuses stand as a testament to an institution's dedication to excellence, attracting exceptional talent from across the globe and elevating the reputation of a college. As the garden is located at the front of campus, its presence has the potential to greet visitors with a beautiful pop of color, as well as introduce potential undergraduates of possible extracurriculars upon the application season. Through surveys, we hope to prove that when students are immersed in a pleasing landscape, it completes two goals: ignites feelings of happiness, motivation, and active engagement, improving their well-being in a stressful environment; and, for freshmen, holds a persuasive merit to apply to Holyoke Community College (Fig. 2).

Figure 3. Cleanup Work. Laurel Carpenter, head of the Holyoke Community College Environmental department, weeding out invasive garlic mustard.

1.2 Timeline

In January 2023, I (Karlie) took on an affirmative leadership position to revitalize the garden under the NSF STEM Scholarship. Weekly meetings with STEM Scholars, SAMP members, and the STEM Dean regarding interest, cleanup, restoration and renovation, legalities, finances and fundraising, and inventory followed for the entirety of the 2022 fall and winter semesters, where we revived the Sustainability Club and orchestrated a cleanup date for the garden on April 29, 2023 (Fig. 3).

In August 2023, the UMass Stockbridge Research and Extension Experiences for Undergraduates (REEU) internship became an opportunity to learn about new sustainable agricultural practices and create a layout of a new permaculture garden. We planned to remove weeds via sheet mulching, finish soil testing (e.g soil contaminants,) figure out where to get steady supply of inventory (e.g., seeds, mulch, soils), restore the outdoor greenhouse, begin setting up quantitative elements (e.g., IPM, surveys) and figure out funding for the fall 2023 semester. Once the cardboard and mulch decomposes by spring, we plan to begin planting and decorating the garden.

2 Plan to Plant

2.1 Community Suggestions

To create a successful project, we want to prioritize the college body and their opinions first and foremost. In early April of 2023, we partnered with Paige Edwards– a Student Ambassador and Mentorship Program (SAMP) member– to create a ten-question survey for students, faculty, and staff to fill out requesting feedback on what to add (either in sustainability practices or architecture/aesthetics), what to grow, what to be mindful of, and what to change. After two weeks, we received fifteen responses, six of which were staff and the remaining nine were students. The results are tabulated below (Table 1).

Table 1. **Permaculture Suggestions.** *A consensus of responses from Holyoke Community College students and staff regarding suggestions for future additions and modifications.*

Produce	Herbs	Flowers	Sustainable Practices	What to Add	What to Change
Green beans Tomatoes Lettuce Kale Spinach Cucumber Squash Carrots Mache Arugula Eggplant Scallions Garlic Paw Paws Roots yucca Native blueberries, raspberries, and elderberries Strawberries Grapes Watermelon	Dill Basil Cilantro Wheat grass Microgreens Rosemary Lemon balm Lavender Mint Chamomile Thyme Sage	Sunflowers Bee balm Lupine Penstemon Witch hazel Sweet Joe-Pye-weed Echinacea Hyssops Daisies Hastas Bulbs Native grasses for moths Plants recommended by the Massachusetts Pollinator Network	Native, pollinator-friendly areas Adding beauty with the use of native and non-invasive novel plants, ensuring accessibility for those seeking a sensory experience and peaceful environment Branches as trellises Making native plant "seed bombs" for community to dispense on and off campus Using a brush to apply pesticides rather than spray bottles (if pesticides are used) Eliminate plastic bag use	More seating, both in and out of shade Shelter with access to water, tables, and a bathroom Labyrinth for quiet meditation Bird houses/bird baths (blue birds!) Water area for turtles and other wildlife Fragrant treading area to walk on (herbs that release fragrance and can tolerate light walking, such as thyme, lemon-thyme, oregano, mint, rosemary, lavender, etc.) Wayfinding design implementation so visitors know how to use and navigate the space	Area above garden is a notorious smoking area No synthetic fertilizers Include more environmental projects to expose students to environmental awareness Improve pathways

2.2 Soil Testing

After collecting our responses, we collaborated with HCC lab technicians Mitchell Sadowski and Lindsey Dion along with environmental science undergraduate Carlos Robles prior to the REEU internship to run tests on the soil in late April of 2023. Our main goals were to assess its health through organic matter, pH, and nitrogen-phosphorus-potassium (NPK) adequacy, as well as its sand/silt/clay composition via a texture and soil sieve analysis. These data serve both as a precautionary and planning element: to determine which vegetation would harmonize best with the current soil nutrients and ground type, and scoping out any obstacles to tackle before the next spring.

When collecting for testing, we used a 0.5 meter soil sampler and selected random areas around each segment of the garden (e.g "pollinator" and "crop") and marked off their respective coordinates via MassGIS (ArcMAP, version 10.8) (Fig. 4). Each sample was approximately 0.18 meters deep and combined into separate buckets for each segment, (both sterilized), with a total of 24 areas tested in total (12 in "Pollinator," 12 in "Crop"). Both soil products were separately mixed via a gloved hand in the laboratory, where all foreign matter– sticks, roots, stones, etc.-- were removed, and left to dry overnight on newspapers.

Figure 4. Geographic Information System Map of Holyoke Community College's Garden. *A tentative layout of the permaculture garden on MassGIS. Yellow represents available, yet unutilized land, whereas orange is the space planning to be used. The top section (or the pollinator garden)'s dark green coordinate points delineates where soil was tested, with the neon being previously identified perennials. The bottom section (or the crop garden)'s points represent only soil testing sites.*

3 Soil Data

We initiated a series of tests to determine if the recommended plants would fit well with the current garden's soil condition after prior collection.

Tests	Method	Pollinator	Crop
Organic Matter (%)	Dried soil bunsen burned in weighted crucibles, before desiccated and reweighed to calculate mass difference. (The burnt off soil content equates to the amount of organic matter, which is presented as a percent measurement.)	0.777%	1.52%
pH	Dried soil mixed with demineralized water measured with an EXTECH pH meter.	6.2	6.4
Nitrate Nitrogen (NO_3 - N)	Extracted from the soil via demineralized water and associated nutrient extraction powder pillow; diluted and added into a sample cell with contents of reagents before measured in spectrophotometer.	39 ppm N NO_3 - S	39 ppm N NO_3 - S
Phosphorus (P)	Identical to nitrate nitrogen.	1.2 ppm P A/F S	1.2 ppm P A/F S
Potassium (K)	Identical to nitrate nitrogen.	56 ppm K A/F S	56 ppm K A/F S

Table 2. Conducted Tests on Soil Properties. *Prior tests run on the soil of the permaculture garden, including a brief synopsis of methodology and the results of each section (pollinator and crop). Ppm = parts per million.*

3.1 Organic Matter

Organic matter pertains to substances within the natural environment originating from living organisms or their byproducts, primarily composed of carbon compounds. These substances are generally abundant in carbon and encompass various elements like hydrogen, oxygen, nitrogen, and smaller proportions of other elements. The forms of organic matter vary, encompassing fresh remains of plants and animals to decayed matter like humus; the stable, dark component of soil created through the gradual breakdown of organic substances (not to be confused with the delicious chickpea dish) (Collins et. al, 2019).

The significance of organic matter lies in its pivotal role in the operation of ecosystems and the health of soil. Within soil, it enriches fertility by supplying vital nutrients and enhancing soil composition, moisture retention, and drainage. Moreover, organic matter serves as a fuel source for microorganisms in the soil, cultivating biological processes that sustain plant development and the cycling of nutrients. In the realm of agriculture, organic matter is commonly introduced to soils as compost, manure, or other decomposed materials from plants and animals. This practice augments the nutrient profile of the soil, stimulates microbial activity, and contributes to ecologically sound and sustainable soil management (Table 2) (Gasch & Dejong-Hughes, 2019).

3.2 pH

Soil pH is a measure of the acidity or alkalinity of soil, indicating the concentration of hydrogen ions (H+) in the soil solution. It follows a pH scale which ranges from 0 to 14, with 7 being considered neutral. A pH value below 7 indicates acidic soil, while a pH value above 7 indicates alkaline (basic) soil (Table 3) (UMass Extension, 2021).

Soil pH is an important factor in determining the availability of nutrients for plants. As an example, nitrogen, phosphorus, and potassium are more readily available in slightly acidic to neutral soils (pH around 6 to 7), while others like iron, manganese, and zinc are more available in slightly acidic to mildly alkaline soils (pH around 6 to 8). Furthermore, it influences various soil properties, including microbial activity, nutrient cycling, and the solubility of minerals. Certain plants have specific preferences, so understanding and adjusting soil pH can be crucial for optimizing plant growth and health. However, it's important to manage in an agricultural environment as high pH levels can be detrimental; extremely acidic soils (pH below 4.5) or extremely alkaline soils (pH above 9) can limit nutrient availability and create conditions where certain toxic elements become more soluble (Jensen, 2010).

Table 3. Soil pH References. A table detailing pH ranges and their respected acidic/alkalinity levels.

pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
Intensely acidic	Moderately acidic	Slightly acidic	Balance between acidic and alkalotic	Slightly alkalotic	Moderately alkalotic

3.3 NPK

a. Chemical Analysis of Nitrate Nitrogen (NO_3 - N)

Nitrogen can occur in the soil via ammonium, nitrate, nitrite, nitrogen gas, and organically bound nitrogen. Organic nitrogen isn't usable by plants, so it becomes oxidized to usable compounds such as nitrate nitrogen by microorganisms. It stimulates plant growth and aids in the utilization of phosphorus, potassium, and other miscellaneous elements within the soil, which indicates its presence is good for soil fertility (Killpack et. al, 2020).

b. Chemical Analysis of Phosphorus (P)

Phosphorus is usually present in soil in small amounts, quickly exhausted, and must be replenished. It's typically organically bound, derived from plant or animal detritus or as inorganic phosphate complexes. Its most readily available form is inorganic orthophosphate, and is required for seed formation, root development, and plant maturity. A plant's health is dependent on its sufficiency, especially those with flowers as it is dependent on the nutrient for color, fragrance, and size of blooms (Prasad & Chakraborty, 2019).

c. Chemical Analysis of Potassium (K)

Potassium is a general tonic for all plants. It promotes stamina and sturdy growth, strengthens stems and stalks, and increases plant winter hardiness. It improves the quality of plant yield and is required for the production and movement of sugars and starches along the xylem and phloem. (Liesche & Patrick, 2017). Sometimes referred to as potash (K_2O), potassium may be added to the soil by applying granite dust, potash rock, or wood ashes. Availability of potassium for plant consumption is influenced by the presence of other elements such as calcium, nitrogen, and phosphorus in the soil (Table 4) (Schoessow, 2020).

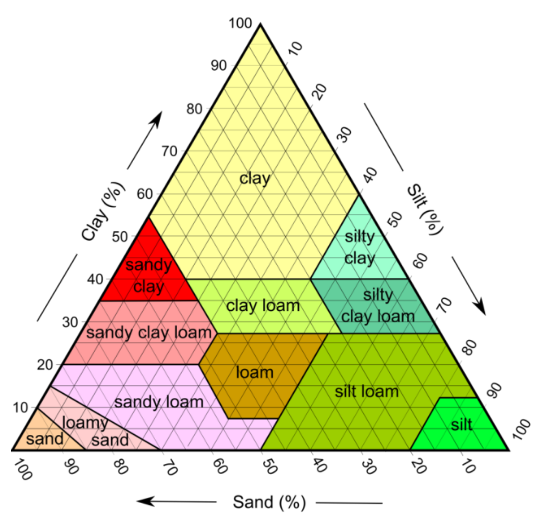
Table 4. Soil Nitrogen, Phosphorus and Potassium Reference Levels. Range of part per million (ppm) levels of nitrogen, phosphorus, and potassium commonly found in the soil.

Soil Test	Low	Acceptable	Optimum	High	Very High
Nitrate-N (ppm)	0 - 39	40 - 99	100 - 179	180 - 280	280+
Phosphorus (ppm)	0 - 3	4 - 7	8 - 13	14 - 19	20+
Potassium (ppm)	0 - 59	60 - 149	150 - 249	250 - 350	350+

3.4 Texture

Soil texture is determined by its percentages of sand, silt, and clay. Its resulting structure (platy, prismatic, columnar, blocky, single-grained, or granular) affects the penetration and drainage of water, as well as its aeration characteristics. Depending on the porosity of the soil, texture is also a huge contributing factor to water usage (Fig. 5) (Easton & Bock, 2016).

Sediment Type	Method	Sediment (mL)	% Equation	Result
Sand	Combine soil, distilled water, and a texture dispersing reagent in a soil separation tube, shaking for 2 minutes; let stand for 30 seconds.	14.5 mL	mLs in A x 100 / total volume of soil (mLs)	**78.125%**
Silt	Carefully pour liquid of the first soil separation tube into a separate, identical tube, and allow it to sit undisturbed for 30 minutes for sediment to accumulate.	3.5 mL	% silt = mLs in B x 100 / total volume of soil (mLs	**21.875%**
Clay	Determined by adding calculated volume percents of the two tubes, then subtracting from 100.	N/A	% clay = 100 - (% sand + % silt)	**0 (>1%)**



Ben Eagle; Soil Texture: Sand, Silt and Clay.

Figure 5. Classification Data and Triangle. *The table (left) details the sediments (sand, silt and clay) that form texture, as well as its respective equations to find specific percentages of their presence within the soil. The classification triangle (right) is used to find the type of soil based off of the recorded percentages.*

Indicated by the diagram, the soil texture at the HCC permaculture garden is **sandy loam.** Loamy soils provide the most suitability for plant growth due to the ability to balance out aeration and water retention. The clay fraction of the soil was nullified to 0 during the calculative process, signifying an inaccuracy in the dormancy periods. However, there is still clay suspended in the liquid at >1%.

3.5 Soil Sieve Analysis

Soil sieve analysis is a technique used in agriculture to assess the particle size distribution of a soil sample to best understand soil structure, drainage characteristics, and permeability, as the distribution of sediment affects soil fertility, water-holding capacity, and root penetration.

Table 5. Soil Particle Sizes and Percentages. A classification of soil components, in addition to particle size, weight, and percentage in the prepared sample. Mm = millimeter (one thousandth of a meter); µm = micron (one millionth of a meter).

Approximate classification	Sieve #	Inches	mm	µm	Grams	Percentage
pebbles, gravel	4	0.187	4.75	4,750	1.7	0.017%
gravel	10	0.0787	2	2,000	5.5	0.055%
very coarse sand	18	0.0394	1	1,000	10.4	0.104%
coarse sand	35	0.0197	0.5	500	21.7	0.217%
fine sand	60	0.0098	0.250	250	23.3	0.233%
very fine sand	140	0.0041	0.106	106	18.0	0.18%
silt, clay	270	0.0021	0.053	53	8.5	0.85%
pan					7.8	0.078%

The data collected presents a comprehensive profile of the growing conditions at the HCC permaculture garden space. Sandy loam is known for its balanced texture, providing both effective drainage and adequate moisture retention; for this soil type, a composition of 0.777% to 1.52% organic matter content is a modest presence, with an average of 1-3% (Magdoff & van Es, 2021). The slightly acidic to neutral pH range of 6.2-6.4 aligns well with many plants' preferences, ensuring optimal nutrient uptake and efficient utilization. Nitrate nitrogen levels at 39 ppm indicate a moderate supply of an essential nutrient for plant growth, while phosphorus at 1.2 ppm and potassium at 56 ppm further contribute to the well-rounded nutrient content of the soil. Overall, these conditions offer a conducive environment for a diverse range of plants, facilitating their establishment and healthy development.

Many of the produce and flowers recommended in the survey fall within that respectable range, save for eggplants (which prefers richer soils), paw paws, roots yuccas (both which are adapted to poor, sandy soils), sweet joe-pye-weeds, and hostas (both which favor soils that are moist rather than excessively well-draining like sandy loam) (Drost 2023), (Ames, 2018). A portion of the garden will be solely dedicated to insectary plants– such as native flowers and grasses, including (but is not limited to): sunflowers, bee balm, lupine, penstemon, witch hazel, echinacea, hyssops, daisies and bulb flowers– to provide an abundance of nectar and pollen resources throughout the year, which will in turn create a beneficiary cycle of pollinators, predators, and parasitoids. In the future, we intend to do a count of soil fungi, bacteria, and microorganisms (e.g nematodes) within the soil via culturing, DNA extraction, and microscopy under the guidance of a microbiologist, as well as do a count of plant species and their roles– e.g food/nectar/refuge/**insectary plants**, general biodiversity support, **trap crops**, etc– after establishing steady growth within the garden. This is the bulk of the experimental aspect of my project, with quantifiable data available in visual/passive recordings such as wildlife visitors, sticky cards, and pest traps.

More information about insectary plants!

More information about trap cropping!

4 Expected Outcomes

In the envisioned future of the HCC Permaculture Garden, the reinstated program stands as a testament to sustainability, education, and community engagement. It will emerge as more than just a green space; anchored by the principles of synergy, the garden will serve as a hub to reconnect students back to nature with its showcase of harmonious balance between productive crops and the surrounding ecosystem. By involving students, faculty, and staff in its development, the garden will cultivate unity among the college members, embodying the legacy of its originator Professor Maiolatesi. As a source of education and inspiration, we will successfully contribute to bridging the gap between consumerism and agriculture, propelling a deeper understanding of food production and fostering a culture of sustainable practices. Furthermore, it will have a positive impact on mental well-being, creating a conducive environment for academic success and personal growth.

The timeline for the garden's future is clear: it will remain a dynamic force, nurturing a thriving ecosystem, offering educational opportunities, and contributing to the broader goal of sustainability, with the HCC campus transformed into a living example of regenerative practices and community engagement.

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