Earth Prize commentary

Problem:

The low-income communities in my local area struggle with food insecurity, water scarcity, and a lack of greywater management systems. A household of four generates an average of 50- 80 L of greywater daily from washing and bathing, 80% of which flows untreated into water bodies due to the lack of proper treatment infrastructure [1,2]. This leads to unsanitary conditions and breeding grounds for mosquitoes. Furthermore, natural wetlands, or nature's water purifiers, are depleted by urbanisation, resulting in inefficient and environmentally damaging food production systems in the city [3]. While aquaponics is being explored as a solution for urban farming, current systems often rely on complex and expensive filtration, making them inaccessible to low-income communities.

Proposed solution:

This project proposes to provide self-assembly open-loop media-based aquaponics kits that combine wetland biomimicry with aquaponics for sustainable urban food production to the low-income households in the local community. A multi-layer biofilter, mimicking natural wetlands, features gravel, vermicompost, sand, and Canna plants for water purification [4,5]. The dense roots of the canna plants absorb pollutants, release oxygen, and support beneficial microorganisms, effectively removing heavy metals and preventing water eutrophication [6]. The filtered water can be collected and reused for washing and cleaning purposes, as well as supplied to the connected fish tank. The fish tank contains tilapia fish, which are hardy, fast-growing fish that efficiently convert feed to biomass. Their nutrient-rich waste fertilises a connected grow bed in which some staple vegetables are grown, creating a closed-loop ecosystem. The omnivorous nature and temperature adaptability of the tilapia fish make them ideal for aquaponics [7].

This design mimics natural ecosystems, transforming greywater into a food production resource without chemical treatments. The system enables families to cultivate fresh produce while recycling water through an integrated, sustainable approach [8].

Implementation:

The project will be implemented in three strategic phases.

First Phase: System Assembly:

The system will comprise a multi-layered filtration system mimicking natural wetland ecosystems using soil, sand, gravel, and Canna plants. Greywater filtered through this biofilter will collect in a tank positioned beneath the biofilter, fitted with a 2-way outlet. The filtered water will be available for cleaning and washing purposes as well as for supply to the connected fish tank. A submersible pump in the fish tank will ensure optimal aeration and water circulation, facilitating efficient nutrient transfer and maintaining system sustainability. The nutrient-rich water from the fish tank, rich in nitrogenous fish waste, will then be supplied to a connected grow bed. The nutrient-rich water from the fish tank will act as an effective organic fertiliser to facilitate the growth and health of plants in the grow bed [7].

Second Phase: Community Integration:

Activities include recruiting and training high school students from the community in the installation and maintenance of the aquaponics systems, creating community awareness, obtaining installation permissions, establishing local partnerships, and distributing educational materials [9].

Third Phase: Monitoring:

Strategic monitoring will involve intermittent water quality, plant, and fish health assessments. Performance data and user feedback will drive system optimisation. A community WhatsApp group will facilitate issue reporting.

This phased approach ensures technical precision, community engagement, and adaptive management for sustainable implementation.

Financials:

The $12,500 prize money will be allocated across four key areas of the project to implement wetland-integrated media-based aquaponics systems in 100 households. Kit production will be allocated 40% of the total amount ($5,000), covering costs for fish tanks ($1,800), biofilter and water storage containers ($1,200), submersible pumps ($1,400), and moisture sensor kits ($600). Educational materials will comprise 20% of the total budget ($2,500), providing for video production and translation ($960), printed materials ($690), and installation training ($850). Support systems will require 25% of the budget ($3,125), including funding local hardware partnerships ($1,325), troubleshooting materials ($900), and water quality testing ($900). The remaining 15% ($1,875) of the budget will be allocated to support distribution through community demonstrations ($900), delivery logistics ($675), and quality control ($300). The allocation of the prize money has been carefully strategised and planned to ensure both quality equipment delivery and sustainable implementation through education and ongoing support, creating a replicable model for future scaling.

Long-term plan:

I have developed three comprehensive strategies to ensure the sustained growth of the project beyond the competition.

1. First, educational integration will be achieved through establishing partnerships with local schools and educational institutions. We'll develop a structured curriculum for six months comprising monthly workshops, informative workbooks, video tutorials, and an online knowledge base covering system maintenance, troubleshooting, and

best practices. This will ensure continued knowledge transfer even as project leaders transition.
2. Second, community support will be strengthened through strategic collaborations with local community leaders and partnerships with local hardware stores. These partnerships will create a reliable supply chain for replacement parts and system upgrades, while building local expertise in establishing and maintaining small-scale aquaponics systems. We'll establish a network of trained technicians within the community who can provide maintenance support and system improvements.
3. Third, the design of the system has been strategised to be economically viable through minimal operating costs, significant water conservation, and chemical-free water recycling and food production methods. The dual output of recycled water and food creates a compelling value proposition for households.

Successful early adopters will serve as community demonstrators, naturally promoting system adoption and creating a self-sustaining growth model that extends well beyond the competition's timeframe [10].

Stakeholders:

Local hardware stores providing system components and maintenance support, environmental organisations offering expertise in sustainable practices, and textile-based organisations facilitating liaisons and knowledge transfer will form an important support network. Technical expertise sourced through collaborations with sustainable agriculture and water recycling experts, organisations studying the impact of textile industry effluents, and wetland conservationists will be crucial in optimising the performance of the system for wider dissemination and environmental impact.

The project involves diverse stakeholders across varied sectors. The primary beneficiaries include low-income urban households seeking food security, schools implementing educational gardens, community gardens promoting local food production, and textile industries aiming to implement responsible greywater management and water recycling practices.

The customer base encompasses low-income communities struggling with food insecurity and water scarcity, individual households interested in sustainable food production, educational institutions incorporating hands-on learning experiences, community organisations promoting food security, small-scale farmers seeking efficient water use and dual crop-fish production systems, and textile industries that would benefit from reduced water costs and better environmental compliance.

Communication plan:

According to the communication plan of the project, both digital and in-person media will be used to maximise community engagement and participation. While Instagram and Facebook will be leveraged to showcase system installations, share success stories, and provide maintenance tips, a dedicated YouTube channel will host tutorial videos and troubleshooting guides, and a WhatsApp group will facilitate real-time support.

Monthly in-person hands-on workshops and public demonstrations will be conducted at community centres and partner educational institutions. Quarterly open houses will be organised through community liaisons at successful installation sites, allowing potential adopters to interact with experienced users.

The use of open-access databases, free social media platforms, community spaces for in-person workshops, and driving knowledge dissemination through shared success stories, testimonials from early adopters, and partnerships with environmental organisations and textile industries makes the marketing endeavours very cost-effective.

This multi-channel approach will ensure wide dissemination while building a supportive community around sustainable urban farming and greywater management.

Impacts:

The GreytoGrow system will recycle and conserve 50-80 litres of greywater daily per household. The system aims to reduce freshwater consumption by 30-40%, with a goal to save 5000+ litres of water monthly at the community level.

The system targets a 50-60% increase in crop yields compared to traditional farming, while ensuring crop variety, nutritional diversity, and accessible nutrition. GreytoGrow will facilitate food security for low-income urban communities by measuring household food expenditure reduction and crop productivity.

Community engagement focusing on system adoption and knowledge transfer is at the core of the impact and success of the GreytoGrow system. The project aims to expand beyond 100 households, maintaining a retention rate of over 85% in the first year. This goal will be achieved by training 20+ community members as technicians, thereby creating a local support network for system maintenance and technical support and creating partnerships with local hardware stores. A community WhatsApp group will provide ongoing support and maintenance assistance, thereby ensuring system effectiveness and retention.

Reduced consumption of freshwater and prevention of discharge of untreated greywater will contribute to ecological improvements, thereby ensuring substantial environmental impact. The implementation of the system in textile industries promises to further enhance the environmental impact. GreytoGrow aims to ensure sustainable urban ecosystem management by incorporating detailed environmental tracking modules into its operations.

The economic impact of the system will be assessed by tracking household savings from reduced water and food bills. The project targets a system return on investment (ROI) within 18 months, while creating local employment through maintenance networks. This approach addresses economic disparities and provides an innovative solution to urban resource management challenges.

We have actively identified and evaluated the potential negative impacts of the GreytoGrow project, leading to the adoption of proactive measures for their alleviation. Environmental concerns include the risk of system failures causing localised flooding or water contamination due to improper maintenance. Robust training programs, regular maintenance checks, and the establishment of local support networks, including technicians, and WhatsApp collaboration groups with simple instructions for troubleshooting, will effectively address these concerns.

Inappropriate plant selection could introduce invasive species to local ecosystems. Carefully curated lists of native plants and training for choosing appropriate species and responsible plant management will empower the community members to mitigate this concern.

Technological inequalities may exacerbate existing socioeconomic disparities within communities. This will be mitigated through tiered support models, ensuring equitable access and community workshops that will ensure equal knowledge sharing and spread of skills among all members, particularly pairing experienced users with newcomers.

Health considerations include the risk of creating mosquito breeding grounds at implementation sites. Submersible pumps that circulate water, the incorporation of natural mosquito deterrents, and educating users about proper water management and circulation techniques will address this concern. Improper greywater handling poses contamination risks, which will be addressed through strict safety protocols, the use of appropriate personal protective equipment, comprehensive waste-handling procedures, and regular water quality testing.

Economic concerns focus on maintenance costs becoming burdensome for low-income users. Local partnerships between community participants and hardware stores will lower expenses while maintaining sustainable operations. Programs that promote community tool sharing and bulk purchase of replacement parts will further reduce costs. The initial learning curve might discourage continued use, so graduated implementation phases with early successes will build confidence and commitment.

Proactive identification of the potential negative impacts and appropriate interventions will minimise risks while maximising positive environmental and social outcomes of the project.

Scaling potential:

The scaling strategy for the GreytoGrow system leverages the modular design and community-centred approach of the project to expand impact beyond initial implementation. Detailed implementation blueprints will be adapted for diverse housing configurations, and regional demonstration sites will be developed that will serve as training hubs. Community cooperative ownership models will be developed and promoted for shared systems in dense urban environments. Strategic partnerships with municipal water authorities will integrate systems into urban planning initiatives. Furthermore, alliances with textile industries in regions facing similar water management challenges will provide additional implementation pathways.

Technology enhancement will follow an open-source design approach, encouraging community-led modifications based on a robust feedback loop. Simplified do-it-yourself versions requiring minimal tools and peer-training models will improve accessibility while encouraging maximum retention of the system. Knowledge exchange between community members will create a self-sustaining ecosystem of innovation.

Institutional integration will be pursued through standardised curricula for technical schools and agricultural extension programs. Partnerships with government agencies will be leveraged to incorporate the system into housing improvement programs. Additionally, policy advocacy initiatives will be explored to promote greywater reuse regulations and incentives. Certification programs for system installers and maintenance technicians will ensure quality control during expansion.

The procedural simplicity of GreytoGrow makes it approachable for new users, while its modular nature enables adaptation to various contexts while maintaining core functionality. Emphasis on knowledge transfer through open educational resources and creation of self-sustaining economic models will allow the system to scale organically, while addressing specific regional challenges of water scarcity and food security.

References:

1. Jain, A. (2021) The State of India's Urban Wetlands and Why They Need to Be Protected Urgently. *Down to Earth*. [Online] URL: https://www.downtoearth.org.in/environment/the-state-of-india-s-urban-wetlands-and-why-they-need-to-be-protected-urgently-78456 (Accessed: January 31, 2025).
2. Katukiza, A.Y., Ronteltap, M., Niwagaba, C.B., Kansiime, F., Lens, P.N.L. (2014) Grey water treatment in urban slums by a filtration system: Optimisation of the filtration medium. Journal of Environmental Management, 146, pp.131-141.
3. Freight Farms (2023) Agriculture Is the World's Greatest Water User and Polluter. *Freight Farms*. [Online] URL: https://www.freightfarms.com/blog/agriculture-water-usage-pollution (Accessed: January 31, 2025).
4. Licata, M., Virga, G., Leto, C., Farruggia, D., Bellone, Y., Iacuzzi, N. (2022) Constructed wetlands as nature-based solution for sustainable wastewater management in urban areas: a critical assessment by experimental studies and literature. Acta Horticulturae, 1345, pp.173-180.
5. Stefanakis, A. (2019) The role of constructed wetlands as green infrastructure for sustainable urban water management. Sustainability, 11(24), pp.6981.
6. Li, Y., Cheng, C., Li, X. (2021) Research Progress on Water Purification Efficiency of Multiplant Combination in Constructed Wetland. IOP Conference Series Earth and Environmental Science, 632(5), pp.052051.
7. Tiwow, V.M.A., Adrianton, N., Abram, P.H., Arafah, S. (2019) Bakasang Fermentation of Tilapia Fish (Oreochromis Mossambicus) Waste for Production of Liquid Organic Fertilizer (LOF). Journal of Physics Conference Series, 1242(1), pp.012018.
8. Raut, N., Kashyap, S.R. (2021) Assessment of water reuse potential of wastewater treatment systems used in Mumbai, India. *International Research Journal on Advanced Science Hub*, 3(Special Issue ICEST), pp.12-19.
9. EPICS in IEEE (2019) San Jose State University - Sustainability Education through Aquaponics. [Online] URL: https://epics.ieee.org/blogs/san-jose-state-university-sustainability-education-through-aquaponics/ (Accessed: January 31, 2025).
10. Nsanzimana, J., Nsengiyumva, I., Nshimiyimana, I., Mukeshimana, M.A. (2023) Assessment on the impacts of urbanization on Wetland. Case Study City of Kigali. Global Scientific Journal, 11(11), pp.1325-1327.