

10 Aquaponics as an exercise of integrated sustainability: Beyond social, environmental and economics

Jenny Leal Flórez

Grupo de Investigación en Sistemas Marinos y Costeros – GISMAC, Universidad de Antioquia, Campus Ciencias del Mar, Turbo, Urabá, Antioquia, Colombia

Center of Excellence in Marine Sciences (CEMarin), Bogotá, Colombia

Fabio E. Castaño Rivera

Grupo de Investigación en Sistemas Marinos y Costeros – GISMAC, Universidad de Antioquia, Campus Ciencias del Mar, Turbo, Urabá, Antioquia, Colombia

Mónica L. Álvarez Mateus

Universidad Cooperativa de Colombia, Campus Apartadó, Urabá, Antioquia, Colombia*

With editorial contributions from Claudia Wilke

10.1 Introduction

Despite having territory in two of the planet's great oceans, fishing and aquaculture in Colombia are not prioritized in the forefront of economic activities, unlike in other countries. Instead, they are largely perceived as "male" and low-income activities. Consequently, those engaged in these sectors

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lack sufficient support and union organization structure to actively participate in discussions and decisions regarding the country's development policies. Despite Colombia's geographical advantage of having over 50% of its territory covered by seas and rivers, there is a notable absence of clear, sustainable policies for managing its aquaculture and fishing resources. This deficiency is evident in the significant changes observed in the governing entities of the fishing and aquaculture sector over the last three decades, the declining allocation of budgetary resources to the sector, and the increasing degradation of water sources and associated ecosystems throughout the country (Leal-Flórez et al. 2017).

The Urabá subregion is a strategic area for port development, with high productive and trade potential. It is home to some of the best lands in the Antioquia department, which gave rise to banana production and exportation, an agro-industrial development that generated significant labor demand, as well as national and foreign investment (Gaviria and Muñoz 2007). However, Urabá is the second subregion with the highest percentage of displaced persons (20.3%) in Antioquia, as well as the highest forced land abandonment, accounting for 15.2% of the department's total, equivalent to 3,336.4 hectares (Gaviria and Muñoz 2007). This situation means that the vast majority of the population with agricultural occupation (including fishing and aquaculture), besides being considered vulnerable, has restricted access to lands of adequate size (minimum 5 hectares) to implement profitable land crops. In this context, the University of Antioquia, along with key partners such as ColombiaCONNECT and CEMarin, has undertaken the task of generating new knowledge to propose an agricultural model that, besides being highly productive and profitable, is inclusive, portable, comprehensive, sustainable, and applicable on small plots of land from 500 square meters onwards.

Additionally, this agricultural model is oriented towards technologies that ensure better water quality for aquaculture production, including systems such as water recirculation (RAS) and aquaponics. These technologies collectively operate with 90% less water than traditional systems to produce 1 kg of fish, capable of achieving high stocking densities exceeding 60 kg/m³. Moreover, the reduced water usage is a significant benefit for fish production: while traditional fish farming relies entirely on an external water source whose physical, chemical, and microbiological conditions are often largely beyond the system's control, with these closed-loop technologies, these external factors can be completely controlled (Bregnballe 2015).

Aquaponics presents technical qualities that suit the particular circumstances of coastal populations. This system combines fish and vegetable cultivation in artesian water recirculation systems, in sizes adjustable to the available space and in relatively short periods (12 to 15 months). The technical aspects related to production and health are resolved by working with species proven to be well-adapted for aquaculture production, and although implementation costs may be high, they are offset once economic equilibrium is reached due to tangible and intangible benefits of high value, such as: 1) requiring minimal personnel with adequate training for operation, 2) providing direct access to a more comprehensive food source (animal protein and high-nutrient vegetables), 3) combining fish and plant production, reducing harvest times and increasing productivity due to system conditions, 4) integrating production with other farm activities to combine with other

productive activities such as animal rearing fed by system products, which in turn return organic matter to the system, 5) exploring local and specialized external markets in clean production and fair trade, which typically pay higher prices to producers, and finally 6) the versatility of the model allows for experimentation with new species according to the requirements of target markets.

In addition to the above, being a dual-purpose production scheme (fish and plants), family economy diversifies, favoring economic inflows and improving cash flow, which is the greatest obstacle to the survival of small-scale agricultural enterprises. Furthermore, aquaponics is twice as productive per square meter as traditional agriculture, being an organic production system highly efficient in water usage, technically viable, and above all, environmentally sustainable.

In the Urabá region, women find it more difficult to access employment compared to men. In the Subregion Urabá Development Profile developed by the University of Antioquia (2020), the female unemployment rate for 2019 was with 24.2% double the size of males, similar to the data reported in the socio-economic report of the Urabá Chamber of Commerce (2020), where the female unemployment rate is 15% while the male rate is 8.4%. This situation becomes alarming when considering that, as a consequence of the country's armed conflict, many women in Urabá have lost their partners, children, or other loved ones, suffering from various types of violence that have emotionally scarred them without the opportunity to heal as they must assume leadership roles within their families.

With all this in mind, and drawing from over 15 years of participatory work with coastal communities advocating for the conservation and sustainable use of the region's natural resources, the University of Antioquia, in partnership with ColombiaCONNECT, CEMarin, and other local institutions such as SENA, has established an integrated sustainability laboratory at the Tulenapa campus in Carepa. This space focuses on training for the implementation of aquaponics as a tool that not only provides technical education but also offers psycho-social support for the empowerment of vulnerable populations (e.g., victims of Colombia's armed conflict), with a special emphasis on single mothers who see aquaponics as an opportunity for business and personal growth.

For this purpose, the laboratory is equipped with an aquaponic system consisting of six fish tanks, each with a capacity of 4 m³, capable of producing 180 kg of fish monthly, and five hydroponic beds measuring 20 m² each for vegetable production. Additionally, being located within the facilities of the Tulenapa campus, which also serves as a field station for the University of Antioquia, provides not only suitable spaces for academic activities such as classes, conferences, and meetings but also accommodations and recreational areas. All of this allows the laboratory to be an appropriate venue for technical training and support in various aspects.

Taking into account the circumstances of single mothers, the integrated sustainability laboratory facilitates a part-time work schedule in blocks, one in the morning and one in the afternoon, allowing these women to continue attending to their household duties. Additionally, the laboratory provides not only technical training in all aspects related to aquaponics but also psycho-social

support through activities that contribute to participatory empowerment, understanding of teamwork, common good, and tolerance of failure, among others, enabling women to overcome personal and familial obstacles. This psycho-social support is understood as an approach to the "processes that influence people's social relationships and are in turn influenced by social circumstances and involve sub-processes of a cognitive, emotional, and motivational nature that have behavioral consequences" (Montero 2004). Therefore, it is in these sub-processes where the provided support is focused, which has also served as a means to create appropriate spaces for strengthening the socio-emotional fabric, where some women have experienced deep intrapersonal processes, such as healing traumatic events at the family and personal levels caused by the armed conflict and all its implications, such as displacement and forced disappearance. These traumatic experiences have been framed by sexual, psychological, and physical violations, as well as unresolved grief, which in most cases, pose possible obstacles to personal development and improving quality of life.

10.2 Achievements

In the midst of the pandemic in 2021, when universities in Colombia had not yet opened to the public for in-person activities, we began setting up the integrated sustainability laboratory at the agroecological studies headquarters of the University of Antioquia, known as Tulenapa, located in the municipality of Carepa in the Urabá region. In addition to the inherent difficulties of remote learning, which was entirely new to us, we faced an unexpected increase in prices due not only to the pandemic but also to a series of social conflicts that arose at both national and global levels, the failure of commitments from the municipality of Turbo, which was an initial ally of the laboratory, and the consequences of a persistent La Niña phenomenon that subjected us to almost four consecutive years of rainfall.

Our first significant achievement is that we persisted and successfully launched the laboratory, managing not only to emulate similar conditions to those encountered by coastal communities in their environment but also to involve a group of five women. Although the group is small due to all the mentioned difficulties, they showed great interest in our proposal.

The second achievement was that this group of women remained steadfast throughout the waiting period until the laboratory reached economic equilibrium, allowing fish and vegetable production to cover the operating expenses of the system to initiate the long-awaited stage of job creation, which would directly benefit these women.

A third achievement, perhaps one of the most important, is that through psycho-social support work, these women gained greater awareness of their emotional wounds and scars, as well as the possibilities for personal growth that they themselves could create, allowing them to envision ways to overcome the pains and sorrows accumulated from many years of violence. This is one of the many ways to achieve peace.

The fourth achievement, another significant one, is that in addition to the mentioned group of women, the Federation of Artisanal Fishermen and Aqua culturists of the Gulf of Urabá-Darién (FEDEPESGUDA) was also involved, exchanging technical experiences with the project staff.

10.3 Lessons learned

In addition to the unforeseen circumstances already mentioned, one of them drastically affected the continuity of the project and the economic impact expected to have on the group of participating women: in February 2023, an external human error caused the sudden death of over 80% of the fish during the initial stage of achieving economic self-sustainability, resulting in the loss of the achieved balance both economically and biologically within the system. Since there was not enough savings to deal with the emergency, this forced the project to close to the public and cease activities with the group of women, as their economic situation required immediate financial support that the project could no longer provide.

Although this accident seemed to have ended the laboratory, the relationships established with FEDEPESGUDA allowed production and technical training activities to continue until harvesting all existing fish and vegetables in December 2024, thanks to the voluntary work of several of its members.

Several lessons can be derived from the achievements and difficulties:

- Sustainability can be called integrated when it includes not only the traditional three pillars (environmental, social, and economic) but also a fourth, which is cross-cutting and sometimes imperceptible: the emotional aspect, concerning the individual as the sum of body, mind, and soul. If humans are not strengthened internally, spiritually and emotionally, it is difficult for them to achieve true interaction with their community (social), their physical environment (environmental), and the economic system, so that any process they undertake can be sustained harmoniously over time.
- The integrated sustainability laboratory aims to emulate conditions similar to those experienced by people in participating communities, which are typically located in places with little or no access to technologies. However, it is undeniable that current technological advancements can allow for the choice of some simple and inexpensive ways to automate the monitoring of physical, chemical, and biological variables and include remote alarms that would have allowed better preparation to address the human error that caused the fish mortality mentioned. So, a new challenge for the laboratory, in addition to researching new cultivable species, is innovation with technologies that adapt to the conditions experienced by single mothers and their communities.
- While the economic pillar is crucial in sustainability, the experience gained from empowering the group of women and the unwavering commitment of the communities teaches us that the pillars of emotional, social, and environmental aspects are fundamental and form the basis for ensuring economic sustainability.

10.4 Final considerations

While Colombia has made progress in ensuring gender equality, it is important to note that there is still inequality faced by women compared to men in multidimensional challenges throughout the life cycle, and these are exacerbated according to the characteristics and conditions of the territory and the different social groups to which the woman belongs (CONPES 2022). For this reason, it is important to continue implementing and strengthening through experiences of integrated growth, such as the project at hand, because it provides solutions to multidimensional problems in economic, psychological, educational, social, and environmental aspects, while also contributing to the achievement of Sustainable Development Goals 2 (zero hunger, food security, and sovereignty), 5 (gender equality), 13 (water action), and 14 (life below water), among others.

This project not only contributes to the achievement of sustainable development goals but also contributes to strengthening state policy whose legislative agenda seeks to strengthen women's rights mainly in employment opportunities, entrepreneurship, and educational access. This means that women have the opportunity to generate more economic income (CONPES 2022), which in turn allows for the enhancement of means or forms to meet fundamental basic needs, such as survival, protection, understanding, affection, creation, participation, and freedom (Neef et al. 2006). It is important to note that in this laboratory, in relation to the psychosocial component, the fundamental basic needs of the participating women are not seen as deficiencies but as potentialities through which women have the possibility to undergo processes of unlearning and relearning that allow the transformation of their realities, thus contributing to the construction of peace, not only at the individual level but also at the level of their family group, their community, and the environment in which they interact.

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