



Erasmus+

# Aquaponics Manual

and other sustainable production methods

Erasmus+ Project 101015987



**FISH**

Farmers  
Innovation  
Science  
Hub



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## 1. Erasmus+ FISH Project and This Manual

This manual is a guide designed to improve the sustainable production of plants and fish. It is the result of collaboration among the various entities that participated in the ERASMUS+ KA210 FISH Project.

In this manual, you will find theoretical and practical content to help you improve agricultural and livestock production and complement it with fish farming. It can be read in its entirety or in sections, prioritizing ease of use. It is intended for all types of people, whether they have a personal interest and want to start these initiatives for their own consumption or from a professional perspective, whether as a producer or as part of an educational institution linked to sustainability.

### 1.1. Erasmus+ Project: FISH – Farmers Innovation Science Hub.

**Farmers Innovation Science Hub (FISH)** is an ERASMUS+ KA210 project whose main objective is to promote environmental sustainability and food security by improving resource efficiency—primarily water—through the implementation of new techniques that combine traditional methods with modern techniques and technologies (hydroponics, aquaponics, electronic sensors, etc.).

In this way, the project seeks to enhance plant production alongside fish cultivation through the following objectives:

- ✓ Promote learning opportunities and the development of knowledge and skills among adults.
- ✓ Provide practical tools to improve the cultivation of plants and fish.
- ✓ Contribute to environmental protection and conservation.
- ✓ Increase the resilience of people and communities by implementing sustainable production systems that improve food security.

Through a series of pedagogical resources and tools, the project aims to develop and strengthen a set of “green skills” to improve sustainable production of plants and fish while optimising resources.

Accordingly, the project strives for better adaptation and a stronger fight against climate change and drought, while also fostering community development thanks to the synergies and collaborations that are generated.

The project is aimed at adults residing in the European Union, with a preference for Spain, Portugal and Italy.

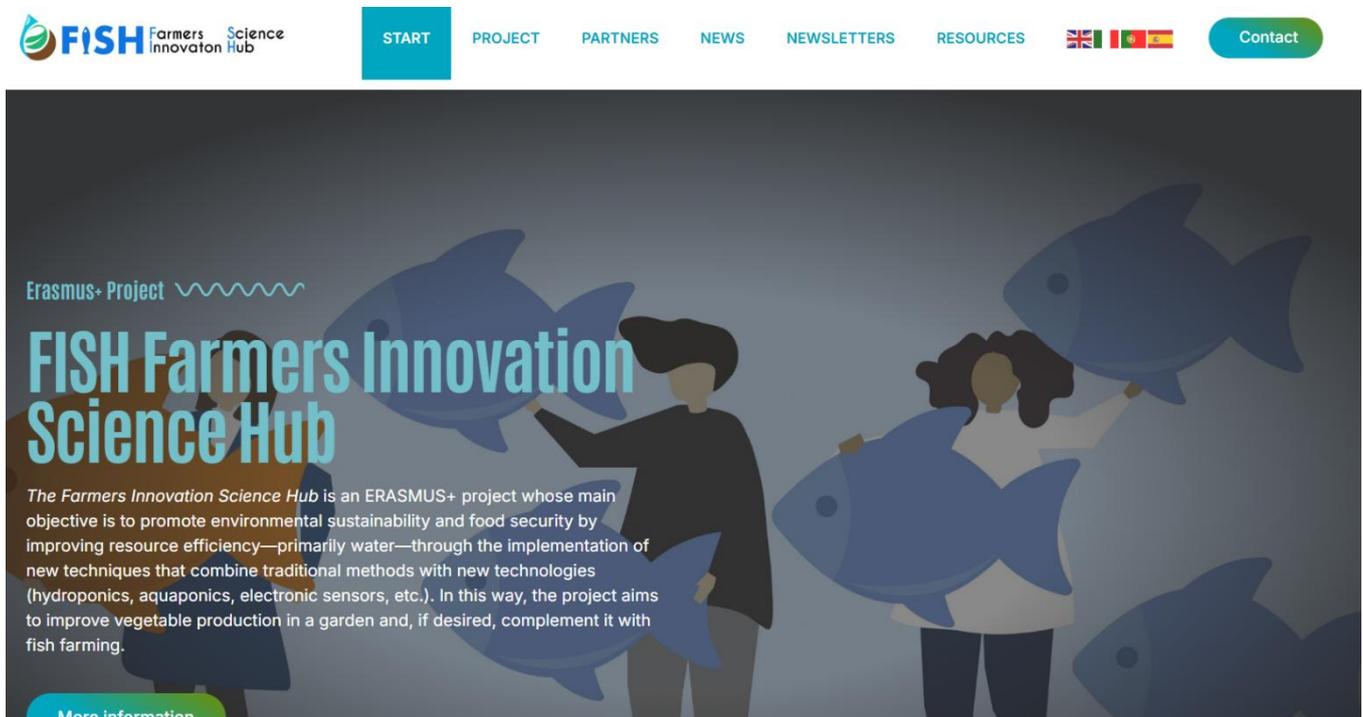
Two target groups are distinguished according to different adult profiles:

- **People with experience and knowledge** who are already developing production initiatives for educational, leisure and/or self-consumption purposes and who belong to a collective (such as an association of allotment growers or a socio-cultural association), an institution (such as schools or universities) or who carry out a professional activity (farmers and extensive livestock producers).
- **Individuals interested in a personal basis** and at a domestic scale. They are people with varying levels of knowledge and experience in self-consumption initiatives.

The priority group for the project is the first of the two above.

Using a participatory methodology, a series of training, research and knowledge-exchange activities have been carried out throughout 2025, of which this manual is the result.

As the project is planned to continue over time, readers are invited to visit its website ([www.hidroedulab.eu](http://www.hidroedulab.eu)) to keep up to date.



## 1.2. Partner Organisations in the FISH Project.

Below is a brief description of the organisations that have collaborated in the project.

### 1.2.1. Spain

#### IMAGINA, Educación y Ocio, S.L.

Founded in 2005, IMAGINA is an Andalusian consultancy specialising in educational and training programmes, campaigns to promote participation, and environmental projects. Its main line of work is designing and delivering educational and training activities for people of all ages—from Early Years and Primary Education to senior citizens, including young people in secondary schools and universities.

It addresses sustainability, STEAM approaches and environmental awareness in educational and community gardens in a hands-on way, through plant and fish cultivation, among other actions such as learning to compost organic waste.

IMAGINA specialises in social activation, engaging public entities with groups, companies and associations, and also works in urban areas undergoing social transformation. It stands out in the field of environmental education, promoting circular economy, water saving and sustainable production, among others.

#### Asociación Plantío Chinampa

Plantío Chinampa is an organisation dedicated to the study and promotion of aquaponics and other sustainable, environmentally respectful production systems. Its members include researchers and lecturers from the University of Seville.

Its name evokes the chinampas, an ancient Mesoamerican system of cultivation on floating islets used by pre-Hispanic civilisations to expand arable territory on lakes (such as Xochimilco, Mexico). The association adapts these principles to modern contexts—especially in Spain—focusing on research and dissemination of aquaponics and on the development of other sustainable production systems. Its goal is to produce in ways that reduce ecological impact.

To this end, they organise practical workshops aimed at individuals, farmers and educators, and collaborate on training programmes for schools and other centres, using aquaponics to teach biology, sustainability and circular economy.

They develop ornamental aquaponic projects, with decorative systems for homes or public spaces that integrate fish and plants—such as those installed at the School of Agricultural Engineering (ETSIA) of the University of Seville; educational projects using aquaponics as a didactic tool in schools and secondary schools—such as at IES Joaquín Romero Murube in Seville; and family systems with accessible designs for

self-consumption at home or in communities, promoting food sovereignty—such as the project “El Milagro de los Peces” carried out in the Polígono Sur of Seville.

### **Alamillo Park Office**

Alamillo Park is a natural space located within green areas spanning the municipalities of Seville and Santiponce, Andalusia. From its operational office—part of the Regional Ministry for Development, Territorial Articulation and Housing of the Government of Andalusia—the park’s natural resources are managed and numerous educational, cultural, sports, leisure and charitable activities are organised.

The park is an open meeting place for all kinds of people and groups.

### **Torreblanca Verde**

Torreblanca Verde is an ecological and social initiative born from the TAR Group of the School of Engineering at the University of Seville and the Juan Antonio González Caraballo Civic Centre in Torreblanca, in collaboration with neighbourhood associations and residents—one of Seville’s most deprived districts. It is a transformative movement in the conception of public spaces, seeking to improve their image and, in turn, how neighbours and visitors perceive the environment.

All actions promoted by this initiative—supported by the TAR Group, the Civic Centre and, crucially, the residents themselves—aim to contribute as far as possible to improving public spaces without depending on public administrations, but rather through community participation and the collaboration of entities from and in the Torreblanca district.

## **1.2.2. Italy**

### **APS We Do FabLab**

We Do FabLab is a shared fabrication laboratory and social-innovation hub based in Omega (Italy), created to promote sustainable, inclusive and participatory practices in education and technology. The association acts as a platform for collaboration between schools, citizens and the local area, with a strong commitment to environmental sustainability, social inclusion and the digital transition.

In sustainability, the association experiments with and promotes solutions linked to circular economy, self-production, and the mindful use of natural resources (as in hydroponics and biomaterials projects), integrating low-impact technologies and environmentally respectful learning pathways.

On inclusion, the association develops intergenerational and intercultural activities involving young people, older adults and people with fewer opportunities, using creativity and craft as tools for active participation and access to digital culture.

Finally, We Do FabLab is strongly committed to the digital transition, offering training in digital fabrication, programming, AI applied to education, and prototyping with tools such as Arduino, Micro:bit and 3D printing. Technology thus becomes a lever for active citizenship and educational innovation.

### **Pro Senectute ODV**

For 45 years, the Pro Senectute association has worked in volunteering for active ageing and for “communication” between generations. Its mission is to promote active ageing through volunteering and awareness-raising cultural initiatives. Thanks to an agreement with the Municipality of Omegna, the association manages the “Oasi della Vita” space. This includes a park, a café-restaurant, and around fifty allotments cultivated by older adults, users of social services and schools. It also has infrastructure for cultural, educational and leisure activities.

### **VCO Formazione**

VCO Formazione was founded in 2003 from the union of several training organisations in Italy’s Piedmont region, offering services in training, guidance and active employment policies in the area. It promotes and organises two- and three-year courses for young people of compulsory school age to prepare them for different professions. It also offers school and career guidance to support the development of the competencies needed for people to define a training, academic and professional pathway.

In doing so, the school promotes labour inclusion and the discovery of one’s talents and potential, guiding people towards opportunities for personal, educational and professional development.

## **1.2.3. Portugal**

### **Associação Terra Maronesa**

“*Terra Maronesa*” is a Portuguese community of practice that, from a holistic and systemic perspective, seeks to valorise the habitat territory of the indigenous Maronesa cattle breed and a rich food heritage in its economic, cultural, social, environmental and tourism dimensions.

It was founded in 2018 in response to the crisis caused by the abandonment of the traditional agro-silvo-pastoral system, the decline of grazing and of technical fire use, which led to the invasion of scrubland, increased wildfire risk, erosion, and loss of soil

fertility and carbon. In the face of this deterioration, Terra Maronesa proposes an integrated and modern model of territorial management that combines traditional and scientific knowledge: “*pyric herbivory*”, a synergistic management of grazing and controlled burning.

The association works primarily along two lines of action: firstly, local and regional development through the promotion of well-being and the creation of social, economic, cultural and environmental value in the territory; and secondly, the development of civic, professional, human and social capacities among the population.

Its activity covers the following topics: extensive production methods; landscape management, carbon sequestration and environmental sustainability; balance between people, animals and nature; complementary product and service offerings; integrated management of activities/business; collaboration and collective action; and the digital economy.

It is formed by a group of farmers and, above all, livestock keepers experienced in sustainable, environmentally respectful production. Its aims include the conservation of its heritage and the development of the civic, professional, human and social capacities of its members and of the rural populations where it operates.

Terra Maronesa leads or participates in flagship projects such as LIFE Maronesa, Rebanhos+ and a protocol with REN introducing the idea of “animal forest brigades” for preventative fuel management. It has also created the Shepherds’ School and the House of Livestock, training centres that professionalise the livestock sector.

### **1.3. Structure of This Manual.**

This Aquaponics Manual and Other Sustainable Production Methods is organised into two clearly differentiated parts.

The first part, more theoretical in nature, introduces principles for sustainable production of plants and fish through sustainable agriculture, hydroponics and aquaponics, while also providing examples of good practice currently being developed in Europe.

Secondly, and with a distinctly practical focus, it describes different initiatives that can be developed. These range from a more domestic, urban scale—such as creating a seed germinator, a wicking bed or an aquaponic system—to a more professional and extensive scale, such as a mixed farm.

The intention is to encourage use either as a whole or in separate parts, adapting to each person’s needs and context.

Lastly, it is complemented by a series of tutorial videos that allow readers to delve more deeply into its contents.

#### 1.4. Who Can Use This Manual.

This practical manual is intended for people who are considering improving their plant and animal production systems—mainly fish through aquaponics—or starting out with such initiatives, whether for self-consumption, commercial or educational purposes, in urban or rural settings and at any chosen scale. As examples, it may suit a system covering the patio or garden of a city home or an extensive mixed farm. The initiatives can also be applied in an educational centre to produce both “food and science”. Likewise, this manual may be used in developing regions or countries to improve food security. Thanks to aquaponics and hydroponics, fresh and safe food can be provided in areas where access to arable land is limited (as may occur on islands or in cities).

**Aquaponics stands out for its scalability.** Using water tanks with a volume of 1,000 litres and a growing surface area of around 3 m<sup>2</sup>, highly effective initiatives for domestic self-consumption can be achieved, enabling the simultaneous production of various plant species, herbs and fish such as tilapia. This approach—ever more widespread among enthusiasts—is ideal for those wishing to grow their own food in small spaces and urban contexts, or in an educational centre or community garden.

Commercial aquaponic systems require a high initial investment and more complex technical management. Successful projects have been developed on islands or in hard-to-reach areas where the availability of certain foods is not always guaranteed, or by producing monocultures of species such as basil and other varieties highly sought after by the hospitality sector (as is the case, for example, in Asian cuisine).

Because keeping larger numbers of fish can entail greater risks of disease and the need for treatments that use antibiotics—which may be lethal for the biological bacterial filter—in such cases **the aquaponic system can be decoupled** so that “contaminated” water does not continue along the traditional route towards the filter and the hydroponic growing system.

## 2. Sustainable Plant and Fish Production in Europe.

The agricultural–livestock system can benefit substantially from the integration of aquaponics, sustainable agriculture, and sound livestock-management practices. A clear example is the valorization of organic livestock residues (such as manure), which can be repurposed as biofertilizers for crops and aquaponic systems. Likewise, nutrient-rich water originating from aquaponics can be applied to fertilize pastures or agricultural fields, thereby closing nutrient cycles and reducing the need for external inputs.

Productive diversification—combining crop production with livestock and managed grazing—not only increases the system’s resilience to climate or market changes but also improves food security and the economic sustainability of farms. Sustainable grazing management (for example, through rotational grazing techniques) can regenerate soils and stimulate biodiversity, aligning with the principles of regenerative and sustainable agriculture.

The integration of these systems creates synergies that enhance the reduction of the ecological footprint and increase resilience to environmental challenges, forming a more efficient and stable model than traditional agriculture and/or livestock farming.

### 2.1. Sustainable Development and its Link to the Sustainable Plants and Fish Production.

Food production worldwide is facing unprecedented pressures. Some of the problems and challenges confronting the agricultural and livestock systems that supply food chains include: the scarcity of natural resources; the need to feed a growing population; political and socioeconomic tensions at local, national, and international levels; and the stress placed on natural ecosystems as a result of the environmental impact of human activities and the effects of climate change.

On environmental matters, since the second half of the 20th century, growing environmental concern has led to key international agreements. The **1972 UN Conference in Stockholm** marked the beginning of global environmental action, recognizing environmental degradation as an international issue. Reports such as ***The Limits to Growth by the Club of Rome*** (also from 1972) warned about the risks of unlimited economic and demographic growth, emphasizing the need to rethink sustainable development.

In 1987, the **Brundtland Report** introduced the concept of **sustainable development**, balancing present and future needs across environmental, social, and economic dimensions. This was later followed by **the 1992 Rio Earth Summit (Agenda 21)** and, more recently, the **UN’s 2030 Agenda with its Sustainable Development Goals (SDGs)**.

Along this path toward more sustainable production, good practices have been developed in the agricultural and livestock sectors—**such as organic farming**—and other production methods have been expanded and refined, including hydroponics, aquaculture, and aquaponics, which have been used since ancient times.

**Hydroponics** is the method of growing plants in nutrient-enriched water, without soil. **Aquaculture** is the breeding and raising of fish, and finally, **aquaponics** emerges as a system that integrates both.

In this context, aquaponics emerges as a response to the global sustainability challenges in food production. It combines traditional aquaculture (fish farming) with hydroponics (growing plants in water) in a closed-loop system where the waste from one becomes nutrients for the other. Before delving into practice and explaining how to carry it out, it is important to understand its sustainable context and biological foundations.

Within this framework, aquaponics and sustainable agriculture emerge as innovative, practical solutions for transforming agri-food systems toward greater efficiency, resilience, and respect for natural ecosystems. These initiatives make it possible to “live and produce within the limits of the planet”—as proposed by the previously mentioned Club of Rome—by reconciling food production with environmental protection and social justice. For example, aquaponics directly contributes to several of the UN 2030 Agenda’s SDGs:

- **SDG 2:** Zero Hunger. It enables continuous production of fresh food (even in urban areas or regions with poor fertile soil) and provides sources of animal protein.
- **SDG 6:** Clean Water and Sanitation. Its recirculating systems minimize water consumption and waste.
- **SDG 12:** Responsible Consumption and Production. It is an efficient circular model that reduces waste and optimizes resource use.
- **SDG 13:** Climate Action. It lowers greenhouse gas emissions compared to traditional agriculture.
- **SDG 15:** Life on Land. It protects soils and biodiversity by avoiding excessive use of pesticides and chemical fertilizers.

Moreover, integrating aquaponics with other agricultural practices (such as reusing nutrient-rich aquaponic water for pasture irrigation) creates synergies that reduce the ecological footprint and increase the resilience of the production system. Diversification—combining crop production, fish farming, and managed grazing—improves food security and economic sustainability while regenerating soils and biodiversity according to the principles of regenerative agriculture.

And last but not least, the adaptability and scalability of production systems are immense, ranging from small home projects to large commercial operations. An aquaponic system can be sized to fit a balcony or backyard in an urban setting, or a garden in a community center or educational facility, often used to produce vegetables and fish for personal consumption. In these cases, besides providing fresh and healthy food, it serves as a tool for sustainability education. On a commercial scale, aquaponic facilities have even achieved organic certifications and supply restaurants or local markets

## 2.2. The Principles of Sustainable Agriculture, Hydroponics, and Aquaponics

### 2.2.1. Agriculture and Livestock: Crops and Livestock in Balance

Sustainable agriculture and livestock farming is a way of producing food by combining crops and animals so that the soil improves over time, water is used rationally, and animal welfare is genuinely ensured. It integrates practices that close cycles: crops feed the livestock; properly managed manure returns to the fields as fertilizer; and plant residues are composted. In this way, the cultivation area functions as a living ecosystem “that yields today without compromising tomorrow.”

It can be developed in small gardens complemented by animals such as chickens, in community garden and composting programs in urban settings that include avi-compost systems—the one located in Parque de Los Sentidos in Noáin (Navarra, Spain) being a notable example—and on farms and agricultural holdings of various sizes, including those spanning several hectares.

It is recommended to produce according to organic standards, following recognized regulations that prohibit synthetic fertilizers and pesticides (primarily using organic fertilizers) and require animal welfare, organic feed, and preventive health care. It is important to note that if the products are to be sold with an organic label, certification is required.

Other environmentally friendly options include **integrated production and extensive production**. In integrated production, the farm is conceived as a coordinated whole: crops + livestock + trees/garden, creating a connection between activities: straw → bedding → compost → soil (green mulches, etc.); chickens → insect control; legumes → natural nitrogen. In this system, targeted and rational support measures can be used (traps, pheromones, etc.), with prevention and efficiency being prioritized.

Extensive production is more often associated with livestock, with herds grazing on natural pastures and crop residues under moderate stocking rates and rotational grazing (moving the animals and allowing the grass to rest is what enables higher yields and

long-term sustainability). When properly managed, this type of production regenerates meadows, reduces the risk of fires, improves the landscape and animal welfare, and helps prevent rural depopulation.

In addition, it is also very interesting to incorporate **the principles of permaculture as a design method**, which seeks efficient, diverse, and easy-to-maintain systems “designed to last.” Although its practices go beyond the scope of this project, it is a useful tool that proposes actions such as water capture and storage; creating small level ditches or raised beds to slow runoff; rainwater harvesting systems; ponds for irrigation and beneficial fauna (amphibians help control potential pests); and the reuse of treated greywater for irrigating hedges, among others.

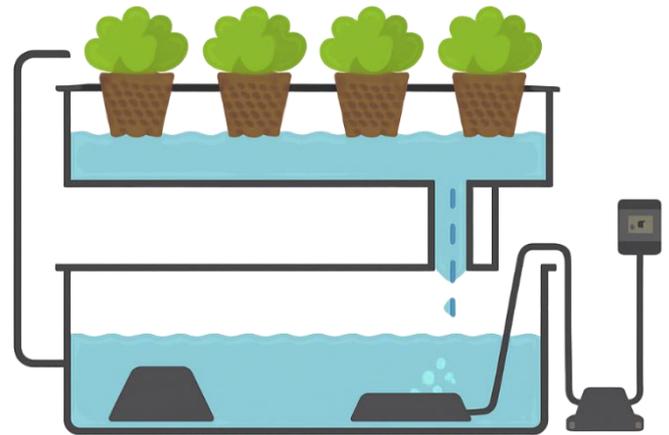
The advantages of sustainable agriculture and livestock farming include:

- ✓ **More fertile and porous soils.** The use of compost, crop rotations, and cover crops increases organic matter, improves soil structure, and reduces erosion. Roots penetrate deeper, and plants grow healthier
- ✓ **Animal welfare and preventive health.** Shade, clean water, space to move, and planned grazing reduce stress and the need for medications. It is based on the principle of calm animals and stable production.
- ✓ **Water savings and reduced pollution.** Adjusted irrigation (drip systems, mulching) and proper management of manure and slurry prevent losses and runoff that could contaminate rivers or wells.
- ✓ **Circular economy on the farm.** Straw is used as bedding and later as fertilizer, crop residues provide additional feed for a few hours, and waste is transformed into compost. This results in fewer external purchases and greater self-sufficiency.
- ✓ **Climate resilience.** Soils rich in life retain moisture better during droughts and drain more efficiently during heavy rains. Additionally, they store carbon, helping to mitigate climate change.
- ✓ **Useful biodiversity and fewer pests.** Flowering hedges, crop associations, and rotations provide shelter for pollinators and beneficial fauna, reducing pest pressure without relying on chemicals.
- ✓ **Food quality and trust.** Clean and traceable practices produce food with better flavor and fewer residues, valued in direct sales and short supply chains.

As explained later when discussing hydroponics and aquaponics, these technologies can be integrated with a sustainable approach to recycle nutrients, save water, and complement production, while always maintaining the primary goal: living soil, healthy animals, and high-quality food.

### 2.2.2. Hydroponics: Soil-Free Cultivation.

Hydroponics is the method of growing plants in nutrient-enriched water, without soil. Since aquaponics integrates hydroponics, it is useful to understand its foundations. In hydroponics, plant roots grow in inert media or substrates that provide support (such as gravel, sand, perlite, and/or expanded clay) but do not supply nutrition. All nutrients are delivered through the water in the form of a nutrient solution prepared with the essential elements the plant needs.



The **advantages of hydroponics** include:

- ✓ **Water savings:** Water is continuously recirculated within the system, with very little lost through drainage or evaporation. Hydroponics is estimated to use only a fraction of the water required for soil-based irrigation, making it ideal for arid regions.
- ✓ **Fewer pests and diseases:** By not using soil, many soil-borne pests and associated pathogens are avoided. Inert substrates are free of weed seeds and harmful bacteria, reducing the need for pesticides. Additionally, substrates can be reused after disinfection, lowering costs.
- ✓ **Cultivation in non-agricultural spaces:** Hydroponics allows gardens to be set up on rooftops, indoors, in containers, or on infertile soils where conventional farming is not possible. This opens the door to urban farms, vertical gardens, and local production in unexpected locations.
- ✓ **Full control over nutrition:** The hydroponic grower can precisely control the nutrient composition and pH of the water supplied to the plants, adjusting them in real time according to the needs of each growth stage. This precise control often results in faster growth and higher yields compared to soil, where plants depend on natural soil conditions.
- ✓ **No weeds:** Without soil, there are no weed seeds, eliminating weeding labor and competition for nutrients with the desired plants.

As explained later in the aquaponics section, hydroponics becomes natural organic hydroponics when the nutrients come from fish instead of dissolved commercial fertilizers. This makes it even more sustainable, as no synthetic chemicals are added and biological waste is recycled.

### 2.2.3. Sustainable Aquaculture.

**Aquaculture** is the controlled breeding of aquatic organisms (fish, crustaceans, mollusks, aquatic plants—such as watercress or duckweed for feed—algae, like wakame or nori, or cyanobacteria such as spirulina) in confined environments. It is a major global source of animal protein (approximately half of the fish consumed worldwide comes from aquaculture), alleviating pressure on wild fisheries. However, traditional intensive aquaculture faces two major challenges to become sustainable:

- **Wastewater management:** Fish tanks produce nutrient-rich water (effluent) that, if discharged untreated, can cause eutrophication (excessive algae growth) and **hypoxia** (oxygen deficiency) in rivers and coastal areas. This environmental impact necessitates methods to treat or reuse the water.
- **Dependence on commercial feed:** Fish feed is often made from fish meal and oil or other ingredients whose production has environmental impacts (e.g., overfishing for fish meal or deforestation for soy cultivation). Without alternative feed sources, aquaculture can solve one problem while creating another.

Aquaponics creatively addresses the first challenge: instead of treating nutrient-rich water as waste to be discarded, **it is reused as fertilizer for plants**. In this way, aquatic pollution is avoided, and two types of production are achieved with the same water. In other words, aquaponics turns an environmental liability (aquaculture effluent) into a resource for another activity (hydroponics). This closes the nutrient cycle: nothing is wasted, everything is transformed.

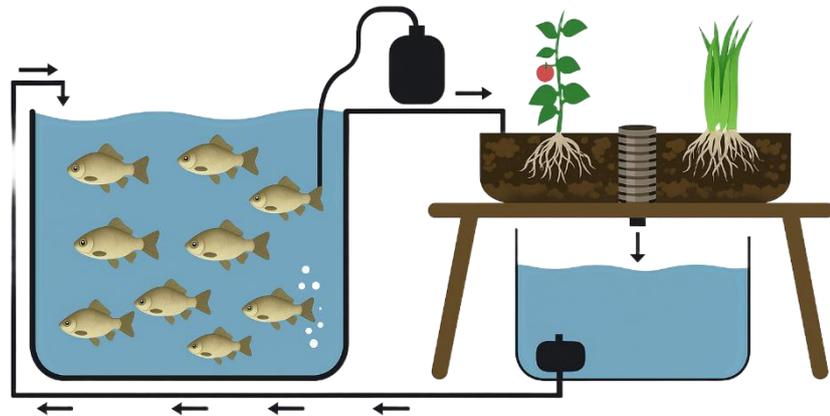
Regarding the second challenge, aquaponics does not directly solve it (aquaponic fish still need feed), but its holistic approach encourages research into more sustainable feeds and the integration of systems such as **insect or worm farming** that recycle organic waste into fish food. Additionally, because aquaponics is generally smaller in scale than industrial fish farms, it is more feasible to experiment with homemade or local feeds (such as vegetables, crop residues, etc., depending on the fish species).

Overall, aquaponics represents a more **ecological and integrated** vision of aquaculture, aligned with the principles of the Circular Economy. By controlling water recirculation and utilizing all by-products, aquaponics minimizes the water and chemical footprint of fish production. **Economically**, after the initial investment in equipment, operating costs are low, and two harvests (fish and plants) are obtained in parallel. **Socially**, it enables the local production of high-quality protein and vegetables, even in isolated rural communities or marginalized urban areas, improving food security and providing educational and green employment opportunities. In developing countries, small family aquaponic systems can empower women and vulnerable populations by providing food and additional income, reducing dependence on arable land.

## 2.2.4. Aquaponics

Aquaponics is an innovative and natural technique that integrates fish farming (primarily) with plant cultivation in a single biological system. Essentially, it leverages the natural nitrogen cycle: waste produced by the fish (mainly ammonia) is transformed by bacteria into nutrients that plants can assimilate; in turn, the plants absorb these nutrients, purifying the water, which is then returned to the fish tank. This creates a symbiotic relationship in which each component benefits the others:

- **Fish** provide organic waste rich in nitrogen compounds.
- **Nitrifying bacteria** convert the fish's toxic waste (ammonia) into non-toxic forms (nitrates) that feed the plants.
- **Plants** absorb these nutrients from the water for growth, filtering and improving water quality.



In an aquaponic system, three main components coexist: fish, plants, and bacteria, forming an interdependent ecosystem. In practice, a basic aquaponic system consists of:

1. **Fish tank** (aquaculture): a container where fish are raised and fed regularly.
2. **Biofilter** (bacterial colony): usually located near the root area or in a specific filter with porous materials (such as expanded clay), where nitrifying bacteria settle to purify the water.
3. **Hydroponic plant system**: can be a grow bed with inert substrate, nutrient film technique (NFT) channels, floating rafts, etc., where plants grow without soil.
4. **Recirculation pump**: moves water from the fish tank to the plants and back, maintaining a constant flow.

This system is circular and sustainable, with water acting as a nutrient carrier and being constantly reused, drastically reducing consumption compared to traditional agriculture (with losses only from evaporation, plant transpiration, and the portion of water incorporated into plant biomass during growth). By eliminating soil, many terrestrial pests are avoided, and food can be grown in small spaces (e.g., patios, terraces, or urban environments) previously considered unsuitable for agriculture. Additionally, by recycling fish waste as fertilizer for the plants, the use of external chemical fertilizers and waste generation is minimized, making aquaponics a clean and eco-friendly method.

## 2.3. Example of Good Practices in Europe

### 2.3.1. COST Action FA1305.

COST is the abbreviation for the project “*EU Aquaponics Hub: Achieving Sustainable Integration of Fish and Vegetables*,” which was carried out between 2014 and 2018. Its main objective was to promote the development of aquaponics in Europe. This project established a network of scientific and technical collaboration to advance aquaponics as a sustainable production

In the COST FA1305 project, researchers investigated how aquaponics can enhance sustainable food production by optimizing resource use and reducing waste, highlighting the role of microorganisms in the optimization of these systems.

The main objective of COST FA1305 was to promote the development of aquaponics in Europe, exploring the feasibility of these systems as a sustainable alternative to conventional agriculture.

Its specific objectives included:

- ✓ Consolidate existing knowledge on aquaponics, expanding the network of experts in the field.
- ✓ Facilitate the exchange of knowledge among researchers, industry, and policymakers.
- ✓ Analyze the role of microorganisms in the interaction between fish and plants.
- ✓ Optimize production by using beneficial microorganisms that promote plant growth and fish health.

To achieve this, a platform called the EU **Aquaponics Hub** was established, bringing together researchers, companies, and policymakers. Thanks to this platform, the EU became a global leader in aquaponics.

As part of its outreach efforts, 24 peer-reviewed scientific articles were published. Seventeen technical fact sheets on aquaponics were produced. Additionally, numerous outreach events and seven international conferences were held.

Regarding training, 7 training schools were established, hosting students from 21 different countries. Numerous educational videos were made available online, and various materials and resources were developed in collaboration with universities.

To promote technological innovation in aquaponics, different techniques were explored to improve efficiency, solutions were studied to optimize plant nutrition using fish waste, and the designs of the most efficient aquaponic systems were analyzed.

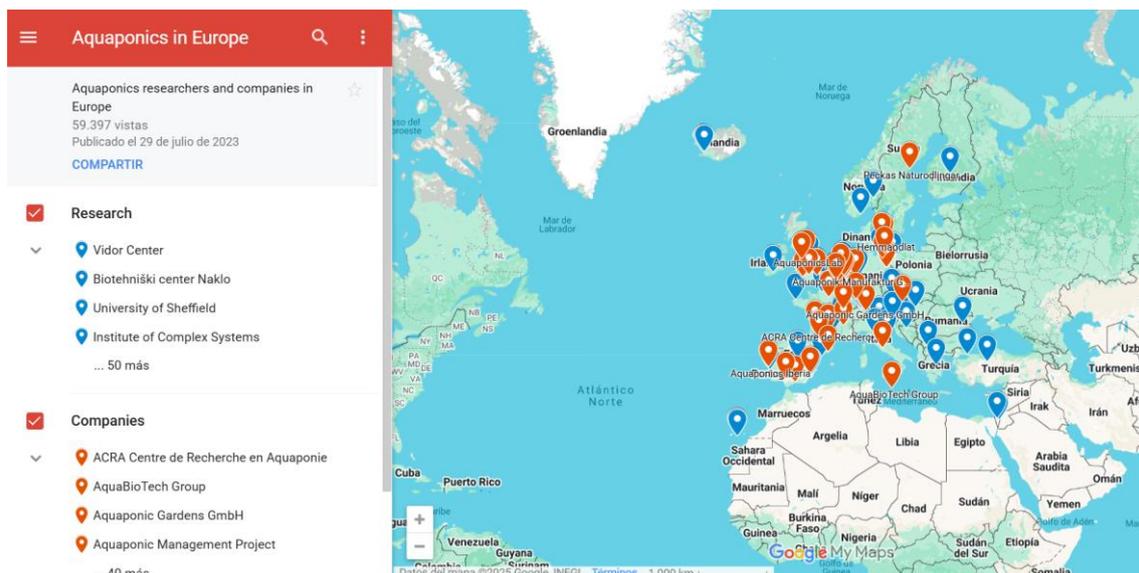
All of this had a positive impact on EU society and industry, evident in:

- ✓ **Economic development and new business opportunities:** Different business models for urban aquaponics and large-scale production were explored, leading to the creation of new aquaponic companies across Europe. Beyond Europe, aquaponics was promoted in developing countries, with studies conducted in Asia and Africa.
- ✓ **Advances in policy regulations:** Recommendations were developed for EU regulations to govern these new aquaponics practices. Additionally, the creation of a European Aquaponics Association was proposed to promote common standards. Finally, initiatives were presented to support aquaponics within the Common Agricultural Policy.
- ✓ **Sustainability and environment:** Thanks to the aquaponics projects carried out, water and fertilizer consumption has been reduced through various strategies to minimize the environmental impact of agricultural production. This production model has also been applied in areas with scarce water resources and in urban agriculture.

As a result of these outcomes, COST Action FA1305 can be considered a complete success, achieving unprecedented expansion in research, training, and global collaboration in aquaponics, consolidating it as an emerging sector in Europe. This project has laid the foundations for the EU to continue developing aquaponics as a sustainable alternative for food production in the future, contributing to various Sustainable Development Goals (SDGs).

However, there are still actions to be taken. Primarily, international collaboration with different regions of the world in the use of aquaponics should be promoted. It is essential to continue research with a focus on sustainability and efficiency. The EU also needs to establish clear regulations for aquaponics. Efforts should be made to reduce initial costs and develop financial incentives to facilitate the adoption of aquaponics in the industry.

This maps shows all the current aquaponics projects being carried out in Europe.



### 2.3.2. Project “Oasis for Healthy Aging”

Funded by the Piedmont Region in Italy, it naturally intertwines with the objectives and practices of the FISH project, as both share the common link of We Do FabLab, which promotes them within a broader process of social innovation and environmental sustainability. While FISH explores accessible technologies for hydroponic and aquaponic cultivation and educational models related to sustainability, “Oasis for Healthy Aging” adapts and applies these principles in the context of active aging, promoting care for the territory through the participation of older adults. In both projects, conscious use of natural resources, co-design of spaces, and an intergenerational approach serve as key tools for creating new forms of well-being and civic engagement.

The project focuses on civic engagement and the active participation of older adults, manifested through collective activities and the development of intergenerational relationships. It is supported by Pro Senectute, which manages 70 social gardens that have been active for decades in the Oasi della Vita of Omegna Bagnella, overseen by its volunteers. In these gardens, the project aims to promote sustainable agricultural practices through information and training in advanced cultivation techniques such as hydroponics, aquaponics, and wicking beds.

The main objective is to improve the quality of life of the gardeners, facilitating active community participation through learning and the sharing of skills. Young students in the agricultural program of the training institution VCO Formazione are given the opportunity to engage in a “learning by doing” approach during training activities and to learn from the richer experiences of their elders.

Through these actions, the project aims to:

- ✓ Inform and train, offering training sessions and interactive workshops on sustainable cultivation techniques for older adults, focusing on hydroponics, aquaponics, and wicking beds, and involve students from local agricultural programs as assistants during the workshops.
- ✓ Promote active aging, evidencing how active participation in cultivation can improve the physical and mental well-being of older adults.
- ✓ Encourage hands-on experimentation and knowledge exchange, through the organization of workshops for setting up hydroponic and wicking bed kits, where older adults are accompanied by students to share skills and experiences, creating a collaborative learning environment.
- ✓ Foster intergenerational knowledge exchange, cheering older adults to share their traditional agricultural practices while students bring new perspectives and skills.

- ✓ Conduct studies to monitor and evaluate the impact of new techniques on agricultural production, product quality, and environmental sustainability.

On the land designated for the social gardens, Pro Senectute had two unused greenhouses that WeDo FabLab, together with students from VCO Formazione's agricultural program, refurbished by installing three different types of hydroponic towers.

In addition to the towers, the students have begun implementing Smart Gardens: small domestic greenhouses designed for soilless, automated plant cultivation. The plant roots are continuously submerged in a nutrient-enriched water solution, while a small pump recirculates the water and an integrated LED system simulates sunlight.

### 2.3.3. The Greenhouses of the Margherita Gardens

In the Italian city of Bologna, within the urban park Giardini Margherita, lies *“Le Serre dei Giardini”*, or the greenhouses of the gardens—a public space refurbished and transformed into a hybrid cultural center that integrates art, social entrepreneurship, and urban agriculture. It occupies a total of 650 m<sup>2</sup> of the former municipal greenhouses, restored thanks to the investment of the social cooperative Kilowatt, with support from the Emilia-Romagna region.

In this vibrant environment that blends creativity and nature, Serra Madre stands out: a greenhouse and café where coworking stations are literally immersed in an aquaponics system called Serra Orto. In other words, entrepreneurs and visitors work or relax surrounded by hydroponic grow beds with fish and plants, exemplifying a harmonious coexistence of technology, collaborative work, and ecology.



The project consists of three main elements:

- The pond: Holds 10 m<sup>3</sup> of water and houses over 200 fish, including koi carp, guppies, medaka, and others.
- The “aquaponic table”: This is the feature that defines the entire system and makes it unique in Italy. It consists of 12 mini-ponds of different sizes, connected by the principle of communicating vessels.
- The “vertical towers”: 21 towers, each 3 m high, with 11 slots per tower, allowing a total of 231 plants to be grown vertically while occupying less than 4 m<sup>2</sup> of ground space.



The motivations of the project are:

- Reduce human impact on the environment and preserve resources for future generations.
- Initiate awareness-raising about new soilless cultivation systems.
- Experiment with “zero-meter” production to supply the VETRO bistro at Le Serre.
- Sensibilizar e involucrar a quienes frecuentan Le Serre, haciendo que las personas entren en contacto con el sistema, comprendan su funcionamiento y participen en su cuidado.

Raise awareness and engage visitors to Le Serre, allowing them to interact with the system, understand how it works, and participate in its maintenance.

#### 2.3.4. Nemo Garden

This is an innovative initiative located on the coast of Noli, in the Liguria region of Italy, involving the cultivation of terrestrial plants in underwater environments, creating a true aquatic garden. The system uses air-filled spheres anchored to the seabed to grow vegetables under regulated conditions beneath the ocean. It was launched by Sergio Gamberini, an experienced diver and botany enthusiast, who conceived the idea while on vacation, initially experimenting with basil—a key local crop and essential for pesto preparation. By enclosing the plant in a submerged protective barrier, it benefited from evaporation for irrigation, resulting in specimens with high levels of antioxidants, important not only nutritionally but also from a pharmaceutical perspective.

Following the success of the initial trial, the garden now hosts around 40 varieties of terrestrial plants, such as thyme, strawberries, oregano, and cherry tomatoes, all aromatic and horticultural types, grown using hydroponic techniques.

The purpose of this project goes beyond expanding the limits of food cultivation; it aims to do so sustainably, harmoniously integrating with the marine environment. The biospheres, called domes or spheres, are transparent air-filled structures placed in shallow areas, functioning as underwater greenhouses that take advantage of the constant temperature and high humidity of the water to promote plant growth.

These installations create an artificial ecosystem that benefits local marine life, functioning as artificial reefs that provide shelter and foraging areas for mollusks, crustaceans, and small fish, thereby contributing to the preservation of ecological balance and promoting biodiversity in the area. In fact, their deployment has been shown to have positive effects on marine diversity.

Each of these spheres can hold up to 120 plants per production cycle. The cultivation approach focuses on hydroponics, providing a controlled environment where traditional soil is replaced by an inert medium irrigated with a solution rich in essential nutrients. The plants grow under a pressure of 1.8 bars, which apparently accelerates their development. Additionally, the domes protect them from harmful external factors. The system is powered by solar energy for monitoring and desalination processes, creating a self-sufficient microclimate optimal for growth without the need for additional energy resources.

Compared to conventional agriculture, the “Nemo Garden” stands out for its superior protection against diseases and pests, thanks to its isolation in a controlled space, free from terrestrial risks. Furthermore, plants grown there have been found to exhibit higher concentrations of antioxidants and essential oils, indicating a nutritional quality superior to that of soil-grown crops.



Watch on Youtube: <https://www.youtube.com/watch?v=OaQpXSYsgr4>

### 2.3.5. Project “The Miracle of the Fish”

“The Miracle of the Fish” is an aquaponics project in Polígono Sur, one of the most impoverished areas of Seville, aimed at training local families to install small-scale food production systems in their homes that combine fish farming and plant cultivation. The initiative has been made possible through the collaboration of the associations Plantío Chinampa and Verdes del Sur, as well as the University of Seville and the Joaquín Romero Murube Secondary School (IES) located in the neighborhood. The project seeks to promote food self-sufficiency, social integration, and community training, using a prototype that integrates a fish tank with an upper plant tray, providing food with minimal water consumption.

The project began in 2012 with a pilot experience in one of the neighborhood homes. The aquaponic installation placed there contributed to feeding an entire family, producing 20 kilograms of fish and 60 kilograms of assorted vegetables in just 4 m<sup>2</sup> using only 2,800 liters of water. In 2014, the project reached its peak participation, involving a total of 180 families, all composed of individuals with fewer opportunities and living in an urban context, in a neighborhood considered the poorest in Europe.



Watch on Youtube: <https://www.youtube.com/watch?v=2QICEobU2ac>

Alongside that installation, another was set up at the IES Joaquín Romero Murube to teach students and their families about this sustainable food production system, so they could replicate it in their own homes.

The project has 4 objectives:

- ✓ **Food self-sufficiency:** Enable neighborhood residents to grow their own food, including both fish and vegetables.
- ✓ **Social integration:** Revitalize the neighborhood through community collaboration and the creation of a network of local producers.
- ✓ **Generate self-employment:** Demonstrate the viability of these food production systems, which are more economical and sustainable, while saving water and energy, providing a potential source of income in an area severely affected by unemployment.
- ✓ **Educational tool:** Use the method as an educational resource in the area, highlighting both its practical application in homes and its environmental and sustainable aspects.

Currently, Plantío Chinampa remains an active association within this project, continuing to develop aquaponics as an educational tool at the IES Joaquín Romero Murube, while also advising various organizations and individuals on aquaponics. Much of the content in this manual is based on their expertise.

### 2.3.6. Aquaponic System at the Escuela Técnica Superior de Ingeniería Agronómica (ETSIA), University of Seville

Led by Professor Víctor Fernández Cabanás, ETSIA at the University of Seville has maintained an aquaponic system at its facilities for several years. Located in the school's greenhouses, there are three different types of innovative systems: a vertical ornamental aquaponic garden, a wicking bed, and a vegetable garden, all using NFT methods and based on FAO models.



Watch on Youtube: <https://www.youtube.com/watch?v=1CW9VmlW6IY>

### 2.3.7. Aquaponic System at the Sollo Restaurant, Fuengirola, Málaga (Spain)

In 2016, the Sollo Restaurant, led by chef Diego Gallegos, a Michelin Star winner, became a pioneer by being the first to self-supply not only organic vegetables but also the fish served in its dishes, thanks to an aquaponic system installed on-site.

To carry out this project, the restaurant collaborated with the La Caixa Foundation and Aula del Mar, which handled the installation and maintenance of the tanks. The aquaponic system consists of three freshwater tanks, each with a capacity of 5,000 liters, producing approximately 150 kilograms of fish per year per tank, following organic aquaculture standards for animal density (20 kilograms per cubic meter).

During the summer season, the tanks are stocked with species such as tilapia, catfish, various types of carp, shrimp, and prawns. In the winter season, as water temperatures drop, sturgeon, trout, and tench are also introduced.



Watch on Youtube: <https://www.youtube.com/watch?v=DxenQPL7WE0>

This project is not the only initiative promoting the commercial side of aquaponics in the province of Málaga. The La Caixa Foundation, together with Aula del Mar and the Kilometre Cero Gastronomic Club, runs courses on “Aquaponics and Sustainable Fish Cooking,” introducing over 150 students and culinary professionals in the province, as well as unemployed and socially at-risk youth, to the benefits of aquaponics and the preparation of vegetables and fish produced through this system.

### 3. Creating an Aquaponic System

Aquaponics is the combined cultivation of fish, or more broadly aquatic organisms (**AQUA**culture), and soil-less plants (hydro**PONICS**) in a recirculating water system.

**AQUACULTURE**



+

**HYDROPONICS**



To properly set up and manage an aquaponic system, it is first important to understand how an aquaponic system works.

After feeding, fish release their waste and organic matter into the water (urine, feces, and ammonia from the gills in freshwater fish), which are transformed into mineral salts by millions of bacteria and other beneficial microorganisms. These mineral salts serve as nutrients— “food” for the plants—which absorb them through their roots, thereby cleaning the water, which then returns purified to the fish to restart the cycle. Aquaponics replicates **the nitrogen cycle** found in nature, or more broadly, the mineralization of organic matter, which naturally purifies and maintains the balance of rivers, streams, seas, and, in general, all water bodies on the planet. In a controlled aquaponic system, this natural cycle is recreated while simultaneously producing food in the form of fish and plants.

#### **DID YOU KNOW...**

Bacteria carry out many chemical reactions to break down the waste from fish and their leftover food, but one of the most important is nitrification. This process is crucial because the ammonia ( $\text{NH}_3/\text{NH}_4^+$ ) released by fish in their urine or through their gills is highly toxic to the fish themselves and must be removed as quickly as possible. Certain bacteria convert it rapidly into nitrite ( $\text{NO}_2^-$ ). However, nitrite is also very toxic, so another type of bacteria transforms it into nitrate ( $\text{NO}_3^-$ ), which is no longer toxic at the concentrations normally found in water.

Aquaponics is not a new invention; Asians were already practicing it in their rice paddies thousands of years ago, and the Aztecs perfected it in their “chinampas” in the central valley of Mexico centuries ago. About 30–40 years ago, this “invention” was modernized to make it more productive, without altering the basic natural mechanism that nature uses to purify water.

- **Aquaponics has benefits** compared to aquaculture and soil-based or soilless agriculture (hydroponics), such as:
- Water savings (only for the initial filling of the installation and to replace losses due to evaporation). Less water required to produce 1 kg of fish and plants.
- No chemical fertilizers are used (the dissolved nutrients in the water come from the mineralization carried out by bacteria on the fish waste).
- High-quality and healthy plants and fish for human consumption, without potentially dangerous chemical residues (since neither chemical fertilizers, nor pesticides, nor antibiotics or disinfectants are used).
- Low or zero environmental impact (the wastewater from the aquaponic installation has low levels of nitrates and phosphates; and no contaminating residues).
- Obtaining two sources of income, plants and fish, that share infrastructure and costs.
- Productivity levels similar to or higher than those in agriculture, hydroponics, and aquaculture separately.
- Fewer fish and plant root diseases (due to beneficial bacteria that compete against bacteria and fungi that cause diseases).

On the other hand, **aquaponics has weaknesses** and aspects that require special attention, such as:

- Prior study to minimize energy costs for the recirculation pump, air compressors, and possible climate control.
- Accidental power outages can put the entire aquaponic system at risk by stopping the water recirculation that transports nutrients and oxygen.
- Availability of fish species adapted to the climate of each country.
- Availability of commercial feed for the fish.



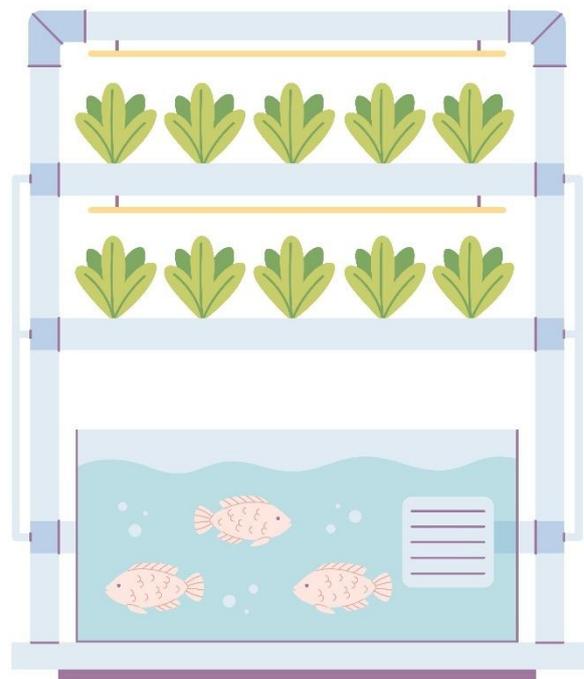
Finally, **aquaponics requires prior training and education** in the following aspects:

- Simultaneous management of the 3 groups of living beings (fish, plants, and bacteria) that coexist in the aquaponic installation, until achieving a balance that allows the well-being of all three and, at the same time, optimal production of fish and plants for consumption.
- Control and regulation of certain water parameters such as oxygen, pH, nitrates, or temperature.
- Biological and ecological control of plant pests and fish diseases.
- Control of solids or sludge in the aquaponic installation.

Aquaponics allows for the production of very healthy and high-quality vegetables and fish, which in many countries are certified as sustainable and organic production. Given the pollution in many areas of our Planet and the ongoing difficulty in most cases to know the origin of the food we buy and eat, aquaponic systems, as well as organic farming and other sustainable systems for family-level food self-sufficiency, are becoming a means to contribute to food sovereignty.

### 3.1. What Does a Basic Aquaponic System Look Like?

In the drawing on the right, a basic design of an aquaponic installation can be observed, called the floating root system. This is an example of an aquaponic installation where the plants grow under hydroponic conditions (without soil). Later in this guide, two other hydroponic systems are explained: the substrate or seedbed system and the NFT.



In an aquaponic installation, the fish are kept in a tank where they are fed. The water from this tank, loaded with their waste and organic matter, is carried by a pump and a tube to trays where plants are growing with their roots directly immersed in different substrates (expanded clay, gravel, broken bricks, volcanic gravel, etc.), through which

the water is filtered. In these substrates, millions of beneficial bacteria nest that transform the organic matter and waste carried by the water into mineral salts (NUTRIENTS), which the plants directly absorb to grow. The plant roots absorb the mineral salts, and the clean water returns through a drain to the tank where the fish are, starting the recirculation again.

To design the system correctly, two key points must be taken into account:

- The first is to find within the installation a place for the fish, a place for the plants, and a place for the bacteria, and to place a water pump recirculating the water between the 3 places connecting them.
- The second key is to find the optimal proportions (called "ratio") between the number of fish, plants, and bacteria, so that they are in a healthy and productive balance for all three. We will discuss the ratio in section 3.2.4 of this manual.

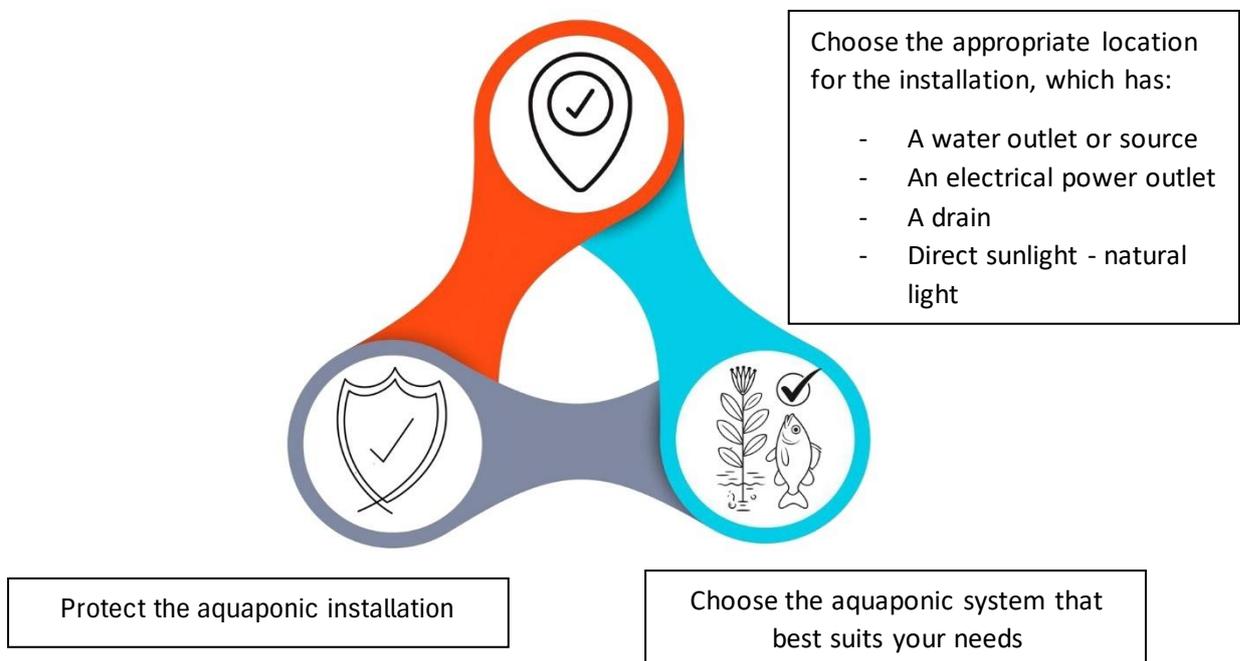
### 3.2. Before the installation of an Aquaponics system.

Setting up an aquaponic system at the family level is straightforward, although it is always recommended to start with a small installation with few fish, to learn the basic management. Subsequently, the installation can be expanded and start producing more fish and more plants.

#### 3.2.1. Prior Conditions.

Before designing, assembling, and starting up an aquaponic installation, one must consider some prior conditions. It is essential to meet all these conditions; otherwise, it will not be possible for the aquaponic system to function.

Therefore, it is important to take into account the following conditions:



## The Appropriate Location

**Water outlet or source.** The water for your aquaponic installation must have a minimum quality, and sometimes it is necessary to perform a water analysis. It can range from rainwater or well water to osmotized or distilled water, or even a mixture of all these. Tap water from the mains can also be used, although this may be prohibited or restricted at the municipal level. In any case, it is not an environmentally sustainable solution for use in aquaponics.

Small corrections can be made to improve water quality, for example, adjusting its pH with acids or bases, mixing it with other waters to lower the salt levels, or -if using tap water from the mains- eliminating chlorine residues (either by stirring it for a few hours or letting it rest until the chlorine dissipates).



On the left, you can see a family-scale aquaponic installation made with IBC or GRG-type tanks, with the fish below and the plants above. Inside the substrates where the plants insert their roots, the bacteria are found protected from light.

**Drains.** Periodically, washes or water changes must be performed in aquaponic installations, and therefore, it is necessary to have a drain available. However, it is recommended to collect the water in containers and use it for irrigation, as it is a natural fertilizer for your garden.

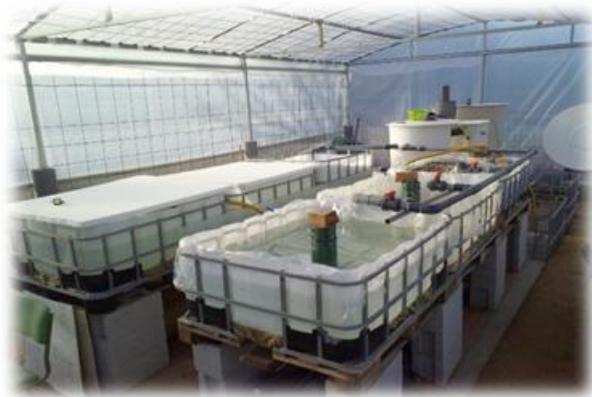
**Area with direct sunlight and shaded area.** Plants in aquaponics must receive sunlight, while fish and bacteria must remain in darkness or shade (shade netting, insulating or reflective materials, or any other material that prevents light passage can be used).

**Power Source.** It is necessary that the electrical devices in your installation (water pump and air compressors) are connected to an electrical panel with protection against potential short circuits or power surges.

### **Protecting the Aquaponic Installation.**

It is necessary to protect the installation from heavy rains and strong winds, as well as from sudden temperature changes. The electrical connections must also be protected.

Therefore, it is necessary to place the installation under a **roof** or inside a **shed, shelter, or small greenhouse.**



### **Choosing the type of aquaponic installation (installation design).**

#### **Choosing the three places for the fish, the bacteria, and the plants**

In any type of aquaponic installation, there must be three places or spaces for the three types of living beings that will coexist in it:

These places or spaces can be all three together, or each one separated independently, or two of them grouped and the other independently.

#### **REMEMBER...**

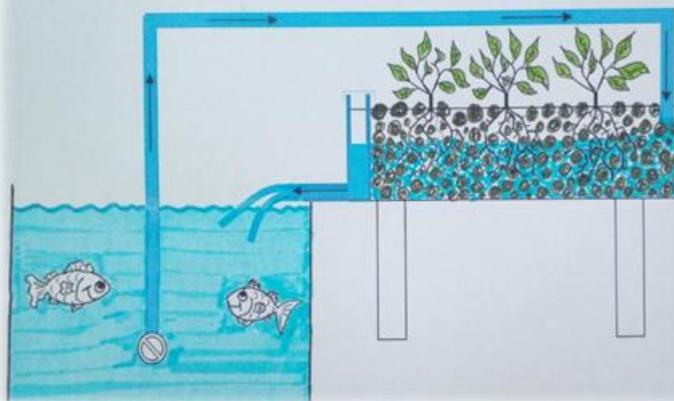
It is always better to start with a small, simple installation with few fish, to learn how to manage it and understand how it works correctly so that fish, plants, and bacteria can coexist satisfactorily. And once you have learned the basic management and how to correct the errors that arise, then, and only then, expand the installation by adding more fish and more plants, or by making a new and larger one.

### **3.2.2. The 3 types of hydroponic systems that can exist in an aquaponic installation.**

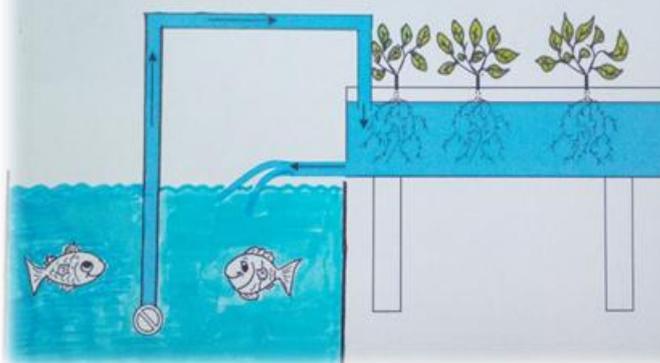
In an aquaponic installation, the plants grow with their roots directly immersed in the water from which they absorb the nutrients

There are 3 types of hydroponic systems, and depending on the one we use in the aquaponic installation, we will have different types of installations as shown below:

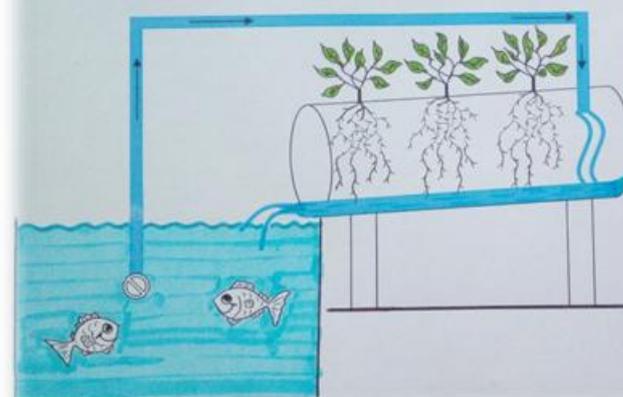
**Hydroponics in substrates** or seedbeds (*“grow bed”*). The plants grow in trays where there are very porous materials (substrates) such as expanded clay, volcanic stone, river pebbles, bio-balls, etc., where bacteria grow in trillions.



**Hydroponics in floating bed or floating root** (*“Raft system”* or *“Deep water culture”*). Here, the plants float on white corks and grow with their roots directly submerged in the water.



**Hydroponics in nutrient film** (*“NFT”*: *Nutrient Film Technique*). The plants are placed in holes made in PVC pipes and their roots stretch downward seeking the nutrients that pass mixed with the water in a thin film or layer.



### 3.2.3. Examples of simple aquaponic installations.

Below, some simple aquaponic installations for educational and family self-consumption purposes are listed, which are suitable for getting started.

- **Pools/ponds or irrigation tanks:** Reuse the pond as a tank, with nearby growing beds. Large volume and simple, unless you want to increase yield and use aeration to promote water circulation. The image shows an irrigation tank for avocados and mangos and a family farm in Algarrobo, Málaga.
- **Aquariums + mini tanks and tubes:** A household aquarium connected to small tanks/pipes. Ideal for a home or an educational classroom. In the image, the installation is located in the building of the Escuela Técnica Superior de Agronomía (ETSIA) at the University of Seville. It combines vegetables, medicinal plants (*Bacopa monnieri*), and ornamental fish.
- **Small tanks:** A barrel used as a fish tank and a grow bed. Low cost and easy to maintain. In the image, an aquaponic system at La Milagrosa School in Dos Hermanas, Seville. It combines vegetables and ornamental fish.
- **Vertical ornamental system:** A vertical garden placed above an aquarium. It requires lightweight plants. It has an aesthetic and educational purpose. In the image, the installation at the Joaquín Romero Murube High School in Seville, combining ornamental plants and goldfish (*Carassius auratus*).
- **IBC-tank systems:** A cut IBC container: fish tank at the bottom, grow bed on top. Robust, inexpensive, and modular. This system is one of the most popular and widely used worldwide due to its simplicity and practicality. In the image, the aquaponic system installed in the patio of a house in Seville.

### MORE INFORMATION

This IBC-based system was developed in Australia and has spread across much of the world thanks to the “**Backyard Aquaponics**” forum. You can find more information at <http://www.backyardaquaponics.com/forum/>

Also, in 2011 **Backyard Aquaponics** published the digital and interactive book “*The IBC of aquaponics*”.

- **IBC with vertical plants:** IBC used as a tank + vertical tower of pots. High density and space-efficient. In the following image, on the left, an aquaponic installation on a pyramid structure at the Higher Technical School of Agricultural Engineering (ETSIA) of the University of Seville; on the right, a vertical PVC-tube installation by the Huerto Lazo association in Cajiz, Málaga.
- **Aquaponics using barrels or cylindrical tanks (“Barrel ponics”):** Similar to the previous system but taking advantage of the cylindrical shape of these tanks. The example image is taken from the *Backyard Aquaponics* forum.
- **Combined IBCs (FAO designs):** Several IBCs connected with sedimentation, biofilter, and grow beds. A proven and scalable design. In the illustration, taken from the FAO publication “*Small-Scale aquaponics food production*”, It shows an

aquaponic installation with plants grown in a hydroponic (“*Grow bed*”). In this case, the fish occupy a separate tank, while the plants and bacteria share the same space in trays filled with expanded clay substrate.

Illustration of a small media bed unit



- **Family system with tanks and tubes:** Small tank with channels/rafts. Basic, continuous production for self-consumption. The image shows an aquaponic installation using NFT systems, with monocultures of tomatoes, lettuce, and strawberries, combined with tench (*Tinca tinca*). Located in the greenhouse of the Escuela de Agronomía (ETSIA) at the University of Seville.



- **Family aquaponics with tanks and ponds:** Aquaponics using root or floating bed systems (“Raft System” or “Deep Water Culture”). In the image, monocultures of basil combined with tench (*Tinca tinca*) in the greenhouse of the Escuela de Agronomía (ETSIA) at the University of Seville.



#### **TIP:**

It is very useful to make a drawing or a small plan of the aquaponic installation, along with a list of all the materials needed for assembly.

It is also important to spend time searching for and locating, via the internet, phone, or locally in the city or town where the installation will be set up, the companies and suppliers of the materials and equipment required.

#### **IMPORTANT**

For a small aquaponic installation that does not require construction work, no permits are needed. If a large expansion of the installation is planned, involving construction or a new electrical installation, it is necessary to consult the relevant public authorities to determine whether permits are required.

Similarly, for large installations, an environmental impact assessment by the municipality may be necessary, as well as approval from the public agricultural authority to ensure compliance with animal welfare requirements. Finally, if the plants and fish are intended for human consumption, the corresponding permits from the public health authority will also be required.

In any case, for small or family installations for self-consumption, public permits are usually not necessary.

### 3.2.4. The RATIO

The “RATIO” is an indicator that relates the **amount of daily feed** (in grams) given to the fish with the **surface area of plants** (in m<sup>2</sup>) that can be cultivated in the aquaponic installation.

For example, if the Ratio has a value of 20 g/m<sup>2</sup>, it means that with 20 grams of daily fish feed, 1 m<sup>2</sup> of plants can be grown in the aquaponic system.

The number of fish and their total weight (or biomass) determines the amount of daily feed they need. Part of this feed is later transformed into waste released into the water by the fish (feces, urine, and ammonia). Bacteria then convert this waste into minerals that the plant roots absorb. Therefore, the amount of fish feed determines the plant cultivation area that can be sustained in the installation.

There are various reference values for the RATIO, as it depends on the fish species in the system and the type of feed they consume. It also depends on the temperature and the type of plants being grown (whether for leafy greens or fruit production).

To start and have a good reference, the following general value from the FAO can be used:

#### TIP

Approximately 50 grams of fish feed can sustain 1 m<sup>2</sup> of plant cultivation.

The Ratio is a very important indicator for maintaining the aquaponic system at an optimal level of fish and plant production.

### 3.2.5. Choosing the Fish Species

The choice of fish species depends on the purpose of the aquaponic system whether it is intended for educational use, as a hobby, for self-consumption, or for commercial production.

For beginners in aquaponics, it is better to choose a species that is hardy, easy to maintain, can tolerate both low and high-water temperatures, and is readily available along with its feed. One fish that meets these criteria and is easily found in aquarium stores is the goldfish (*Carassius auratus*). This is an ornamental species not intended for human consumption, but it is an excellent choice for learning, practicing the management of an aquaponic system, and gaining experience.



Goldfish (*Carassius auratus*)

A hardy species that tolerates both high and low temperatures is the common carp (*Cyprinus carpio*), which also grows quickly at moderate temperatures of 25–27°C. The tench (*Tinca tinca*) is also very resilient, although its growth rate is slow.



Common carp (*Cyprinus carpio*)



Tench (*Tinca tinca*)

For people with more experience in aquaponics, warm-temperate fish species that grow very quickly can be used, such as tilapia (*Oreochromis spp.*). Their water temperature range is between 18–20°C and 30–32°C, with optimal averages around 25–27°C.

In cold climates, it is necessary to keep the water temperature above 13–15 °C in winter; otherwise, tilapia will die. For cold climates, trout (*Trutta fario*) can be used, with optimal water temperatures around 15 °C (temperatures above 20 °C for several days can make trout sick or cause death)



Tilapia (*Oreochromis niloticus*)



Trout (*Trutta fario*)

### 3.2.6. Choosing plant species

In an aquaponic installation, many types of plants can be grown, both those consumed as greens (lettuce, chard, etc.) and those consumed for their fruits (tomatoes, peppers, eggplants, pumpkins, cucumbers, etc.). Tubers such as potatoes or carrots can also be cultivated, as well as aromatic plants, ornamental plants, flowers, and even some trees.

As with the choice of fish species, the selection of plants will depend on the purpose of the aquaponic installation, whether it is for self-consumption or commercial use. It is also possible to grow a single type of plant (monoculture) or mixtures of them (polyculture).

### 3.2.7. Fish density and size of bacterial biofilters

**Fish density** is the total weight of the fish in the system (in grams or kilograms) per 1,000 liters of water ( $1 \text{ m}^3$ ) in the tank or container where they live. For example, if I have 20 fish each weighing 1,000 grams living in a tank containing 1,000 liters of water, the density will be  $1 \text{ kg/m}^3$ . Density is important because for every 1,000 grams (1 kg) of fish, approximately 250 grams of solid waste is produced (feces, uneaten food, remnants of bacteria and algae, etc.). Therefore, higher fish densities generate more waste, which can become dangerous if it accumulates, as it reduces oxygen in the water and increases toxicity. For this reason, at high densities (usually above  $1\text{--}5 \text{ kg of fish/m}^3$ ), sedimentation tanks are installed at the outlet of the fish tanks to capture part of the excess solids, which must then be removed from the system.

#### TIP

For beginners in aquaponics, it is advisable not to exceed a fish density of  $1\text{--}5 \text{ kg/m}^3$ . Once one has learned to manage fish at these low densities, the density can then be increased. Normally, family-scale aquaponic systems can operate at densities of  $20\text{--}25 \text{ kg of fish/m}^3$ , requiring the use of the aforementioned sedimentation tanks.

**The size of the biofilter** is the last important aspect when designing an aquaponic system. The biofilter is the part of the system where water-purifying bacteria accumulate at very high concentrations. There must also be a balance between the number of fish, plants, and the amount of bacteria that transform their waste (urine, feces, and ammonia) into mineral salts for the plants

Normally, the biofilter is another tank where a porous substrate is introduced, allowing bacteria to colonize and multiply in large quantities. The most popular and inexpensive substrate in aquaponics is expanded clay, also called "leca," which is also used in construction for insulating roofs and coverings.

The size of the biofilter is an indicator of the maximum number of bacteria the system can support.



#### **TIP**

There is a very simple method that uses 4 basic mathematical formulas to accurately calculate the size of a biofilter based on the weight of the fish and their feed. However, a practical and approximate rule can also be used, since the size of the biofilter (expressed in liters of substrate, in our case expanded clay) is usually at least 10% of the total water volume in the aquaponic system. For example, if the total water volume circulating through the system is 1,000 liters, 100 liters (10%) of expanded clay balls will be needed to fill the tank that will function as the biofilter.

### **3.3. Installation of the Aquaponics system.**

This chapter of the manual is presented in video format, showing step by step the assembly of 2 types of family-scale aquaponic systems for self-sufficient production of fish and plants:

#### **Installation with an IBC-type tank.**

This is the simplest family aquaponic system, built using a single IBC-type tank (as shown in the following image). These tanks are cubic, approximately 1 meter wide, 1.20 meters long, and 1 meter high. They can be obtained anywhere in the world, either new, semi-new, or used. Once cleaned, they are cut along with their metal frame, leaving a higher section (where the fish will be kept) and a lower section (minimum 23 cm, maximum 35 cm) that will serve as the grow bed for the plants. This grow bed is placed above the fish tank, and a hole is made in its base where a bulkhead fitting with a drain pipe is installed. Some drains use the well-known “auto-siphon” or bell siphon



### **MORE INFORMATION**

The use of IBC tanks to build aquaponic systems has spread rapidly around the world since the 2000s, and this global diffusion was supported by an international aquaponics forum called “*BackYards Aquaponics*,” based in Australia. Many aquaponic producers from various countries exchanged a large amount of information about aquaponics on this forum, and in 2011 “*BackYards Aquaponics*” published an interactive digital book. “*The IBC of aquaponics*” (BackYards aquaponics. 2011).

The video explains step by step how to assemble an aquaponic system using an IBC tank, including the modifications introduced by the Plantío Chinampa Association, mainly in the drainage (bell siphon) and in the connection for pumping water up to the area for plants and bacteria.



Watch on Youtube: <https://youtu.be/1D2voKFtJo>

### 3.3.1. FAO-type installation with 2 IBC tanks and the 3 hydroponic systems.

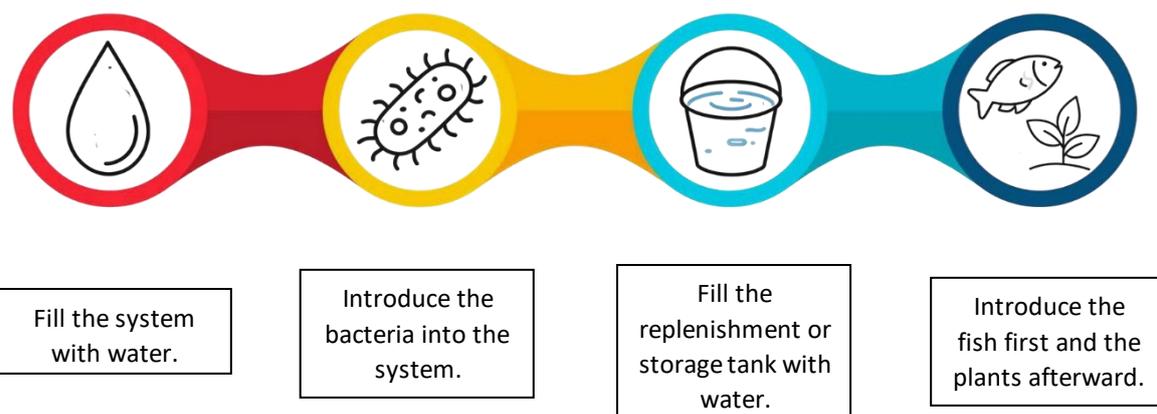
It is a small-scale installation described by the FAO in its manual. “Small scale aquaponics food production”. The Plantío Chinampa Association introduced modifications to this installation to make it more productive, adapt it to the climate in the city of Seville (Spain), and integrate the three hydroponic systems for plant production in the same installation: NFT (“Nutrient Film Technique”); DWC (“Deep Water Culture”) or raft/root bed system; and GW (“Grow Bed”) or arlita grow bed system.



The image shows a family-scale aquaponic system with a clarifier, 5 PVC pipes, and 2 IBC tanks: one serving as the fish tank, and the other cut into two halves—one for a DWC system collector and the other for a grow bed with arlita (“GB”). The arrows indicate the direction of water flow from the submersible pump located inside the collector at the lowest point of the installation.

### 3.4. After the installation.

Once the assembly of our installation is complete, we need to carry out four operations or actions to start up the system.



**1. Fill the system with water.**

The first step is to fill the system and connect the pump, which will start recirculating water through all its components. This must be done first because it allows us to check for leaks or water losses. If any leaks are detected, they must be repaired before proceeding with the remaining steps.

**2. Introduce the bacteria into the system.**

Next, nitrifying bacteria must be added to the water in the system. These bacteria can be easily obtained from aquarium stores. Once added, the system should be run **for 4–6 weeks, WITHOUT ANY FISH OR PLANTS**, allowing the bacteria to multiply into the millions (mainly in the biofilter). Every 2–3 days, a small amount of finely ground fish food is added to the water, which, as it decomposes, serves as food for the bacteria.

**3. Fill the replenishment or storage tank with water.**

It is necessary to fill a separate tank that is not connected to the aquaponic system. This tank will serve to store water and replace losses due to evaporation and evapotranspiration, as well as to provide water for periodic cleaning and water changes in the system.

**IMPORTANT**

If the water in this tank comes from the public water supply, it should not be used in the aquaponic system until 24–48 hours have passed, allowing the chlorine to evaporate (otherwise it will kill the bacteria).

**4. the fish first and the plants afterward.**

After 4–6 weeks, introduce the fish into the corresponding tank of the system. The fish should not be placed directly into the tank; first, they need to be acclimated to the type of water in which they will live.

The acclimation process is simple: place the bag containing the fish into the tank or reservoir, but keep it closed so that the water inside the bag does not mix with the tank water. Let the bag float for 30–45 minutes until the temperature of the water inside the bag and the tank equalizes. Then, open the bag



and add a small amount of tank water into the bag, and wait 15 minutes. Repeat this step two more times. Finally, release the fish into the tank.

Feed the fish daily, and after 10 days to 2 weeks, measure the nitrate level in the water. When it reaches 30–40 ppm (parts per million or milligrams per liter), the first plants can be introduced.

#### **REMEMBER...**

The number of plants that can be added is proportional to the number of fish and the amount of food they consume daily, as explained in section 3.2.4 regarding the RATIO.

### **3.4.1. The 20 operations or routines for an aquaponic system**

Routines are the daily, weekly, biweekly, or monthly tasks that must be carried out in the aquaponic system to ensure it functions properly and produces well, while keeping the fish, plants, and bacteria healthy and thriving. In a familiar, well-understood home aquaponic system, these routines usually take no more than 5 to 10 minutes of work per day. Only tasks such as cleaning the substrates or siphoning the solids that accumulate in certain areas of the tanks will take a bit more time when they need to be done.

#### **DAILY ROUTINES**

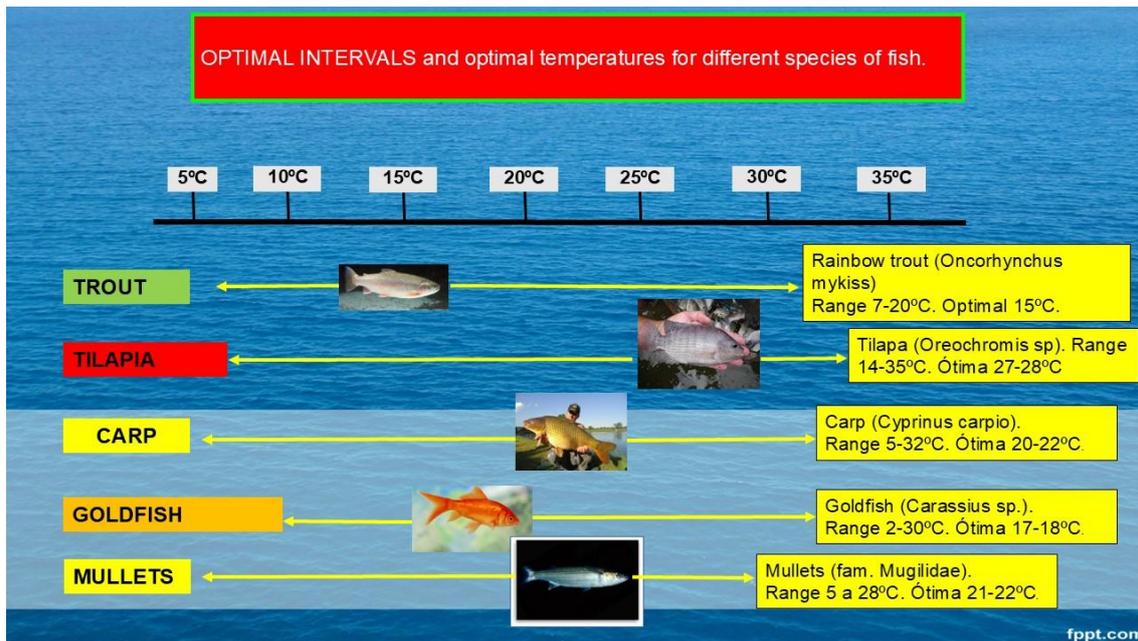
##### **Routine 1. Measure and record the water and air temperature.**

At higher temperatures, the fish will eat more, so the daily food ration should be slightly increased. At lower temperatures, they will eat less, so the ration must be reduced. If the water temperature rises or falls significantly, going outside the optimal range for the species in your system, the fish will eat much less, and the food ration must be drastically reduced.

#### **IMPORTANT**

It is essential to monitor the daily food rations because any leftover food decomposes quickly in the water, causing dissolved oxygen levels to drop rapidly, which is dangerous for fish, plants, and bacteria.

Therefore, it is necessary to measure the water and air temperature approximately every 24 hours, at the same time each morning, recording the maximum and minimum values (there are thermometers that can perform these measurements).



## **Routine 2. Measure and adjust the water pH.**

pH measures the acidity level of the water in the aquaponic system. It should be checked at least once a week using a pH meter. The water's pH is different when the system first starts running compared to weeks or months later. Depending on the stage (at the beginning or after the system has been operating for several months), different actions will be needed to control it and keep it within the optimal range for the fish, plants, and bacteria.



Let's see, then, how to act in each of the two situations:

- First weeks or 3–4 months: at the start of the system's operation.

The water pH will begin to drop (becoming more acidic) due to bacterial activity and fish respiration, until it stabilizes at an optimal value around 7. Depending on the pH of the water used to initially fill the system, the pH will need to be adjusted in two different ways or with different procedures.

- Case A) If the water used to initially fill the aquaponic system or to replace losses due to evaporation has a neutral pH (around 7) or less than 7.5 (rainwater, osmotized water, or well/agricultural

water with neutral pH), then no action is necessary—just let the pH gradually decrease to 7 or below.

- Case B) If the water used for filling or replacing evaporation losses is “hard” water with a high pH (greater than 7.5, often above 8), then the pH must be corrected, because many plants cannot absorb nutrients dissolved in water at pH levels above 7.5 through their roots.
  - Option B.1: Add “muriatic acid” (commercial hydrochloric acid at 15–20%) to the aquaponic system water before adding any fish or plants (as explained in the previous section), at a dose of 180 ml of acid per 900 liters of system water. This lowers the pH from approximately 8 to 7.5. Measure the pH 2–3 hours after adding the acid. If the pH has not decreased enough, add another 50 ml and re-measure after 3 hours until the pH reaches 7.5.
  - Option B.2: Add rainwater, osmotized water, or well water (if its pH is below 7.5), or a mixture of these.

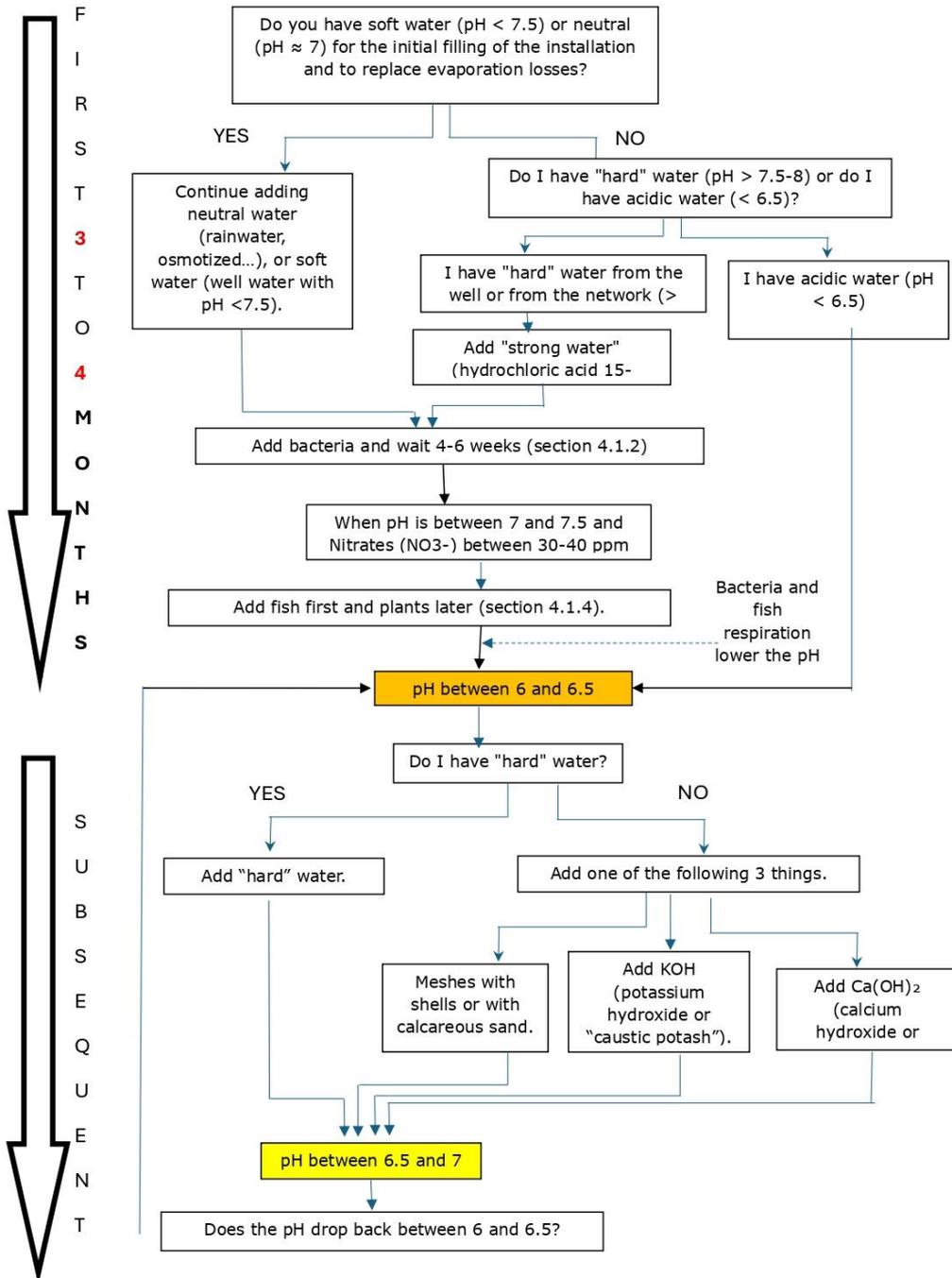
- After the first 3–4 months:

The water pH will drop to 6.5 or lower. At this point, it is necessary to raise the pH to 6.5–7 (if it falls below 6.5, the nitrifying bacteria slow down and low-dose toxins like ammonia and nitrites can accumulate dangerously in the water). This can be achieved in several ways:

- Option A) Add “hard” water directly to the aquaponic system without adding muriatic acid (acid is only used to lower pH, never to raise it).
- Option B) If “hard” water is not available, there are several alternatives:
  - Option B.1: Place mesh bags with calcareous sand or crushed shells in areas of water flow within the aquaponic circuit, so that the water slowly dissolves the carbonate from the shells or sand.
  - Option B.2: Add caustic potash (potassium hydroxide, KOH) or calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) at a dose of 3.7 grams per 800 liters of system water every 3 days. Monitor to ensure the pH stays around 6–6.5 or slightly higher.

As the fish grow and consume more food, the pH may drop below 6.5 every 2–4 days. For this reason, the pH should be measured at least weekly or every 3 days, and if it falls again below 6.5, repeat one of the operations described above.

**Figure 31.** Diagram of procedures for regulating pH in an aquaponic system



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## **IMPORTANT**

You must be VERY CAREFUL when handling chemicals with very low pH (highly acidic) like “muriatic acid,” or with very high pH (highly basic) like caustic potash or calcium hydroxide. ALWAYS follow proper safety measures (protective goggles, gloves, etc.) and always add these chemicals to the water, never the other way around (NEVER pour water onto the chemicals).

### **Routine 3. Observe the fish daily.**

You should check the fish every day, for example, during one of the feeding times (the daily ration is divided into 2–4 feedings). Observe if they are active, without injuries or spots, etc. If any fish are dead, it is important to remove it from the water immediately.

### **Routine 4. Observe the plants daily.**

Check whether the plants are green and vigorous, growing well; or, on the contrary, if they are weak, growing poorly, if the leaves are changing from their normal color for each species, if they are becoming too elongated, or if they are being attacked by any pests (aphids, whiteflies, spider mites, fungi, etc.). Remove any dead leaves or plants that have died.



### **Routine 5. Check water flow and look for leaks.**

The water must circulate properly throughout the system to deliver oxygen and nutrients to the fish, plants, and bacteria. Make sure there are no blockages or leaks and adjust the flow rates if you notice a decrease in water volume between tanks or at the inlet of any tank (especially the fish tank).

### **Routine 6. Feed the fish.**

The amount of food that the fish eat daily is called the RATION, which usually needs to be divided into several feedings per day to prevent leftover food from decomposing in the water. There are automatic feeders for aquariums and fish ponds that can be programmed to distribute the ration up to 4 times a day. Basically, there are two ways to feed the fish:

By direct observation:

Take a small amount of food in the morning, weigh it, and add it to the tank. If the fish eat it within 3–4 minutes, add the same small amount again. Continue adding small portions (with the same weight) until you observe that the fish no longer eat and no food remains. Sum all the small portions added to determine the maximum amount the fish can consume in one feeding. In the afternoon, repeat the same procedure until the fish stop eating and no food is left. The sum of the food given in the morning and afternoon will be the daily ration. As the fish grow, this ration should be gradually increased.



Using feeding tables:

Most fish maintain their body temperature equal to the water in which they live. For each fish species, there is an optimal temperature range in which they grow, feed, and reproduce under the best conditions. For example, tilapia have an optimal range of 27–28°C, while trout prefer around 13–15°C.

At higher temperatures, fish are more active and eat more—but only up to a limit, above which each fish stops eating. For instance, a tilapia will consume more daily food at 28°C than at 23°C. However, above 33°C or below 18°C, they begin to eat less or stop eating altogether.

For this reason, feeding tables exist for many fish species, each corresponding to a specific temperature. Depending on the temperature, each type of fish consumes a different daily amount of food (different RATIONS). Below is an example of a feeding table for tilapia at 27°C water temperature.

<b>Approximate weight of tilapia (in grams)</b>	<b>Daily feed ration for tilapia (this is the percentage of the total weight of all the tilapia in the system).</b>	<b>Number of times the daily feed ration is distributed.</b>
0,1 to 1 gram	10 %	
1 to 10 grams	6 %	6
10 to 30	5 %	6
30 to 50	4 %	6
50 to 70	3 %	4-5
70 to 100	2,7	4-5
100 to 150	2,5	4
150 to 200	2,2	4
200 to 300	2,0	3
300 to 400	1,9	3
400 to 500	1,7	3
500 to 600	1,5	2

For example, if there are 10 tilapias in the aquaponic system, each weighing 50 grams, the total weight (total biomass) will be 500 grams of tilapia. According to the feeding table, they should receive 3% of their body weight daily, which equals 15 grams of food per day, divided into 4–5 feedings.

These tables refer to dry pellet food, which is the usual commercial form for fish feed. Another option for small family aquaponic setups, when there are only a few fish, is to make part or all of the fish food at home, or to supplement the pellets with fresh food such as leafy vegetables, flours, etc., or live food, such as duckweed, worms, or black soldier fly larvae. Each fish species may or may not accept these foods, so testing is necessary.

Weighing the fish occasionally can help check their growth. It is not necessary to weigh all of them—just take a sample, weigh them, and then extrapolate to the total number of fish in the system using a simple proportion. With the total biomass, the daily feed amount can be adjusted according to the feeding table.

### **Routine 7. Feed your plants.**

In aquaponics, it is not necessary to add chemical fertilizers to the water, because the plants feed on the mineral salts contained in the aquaponic “nutrient soup,” which are produced by bacteria transforming the waste that fish release into the water after

eating. The greater the total biomass of all the fish in the system, the more waste they release into the water and the more mineral salts are available to feed your plants. Therefore, the cultivation area for your plants can be expanded as the fish grow.

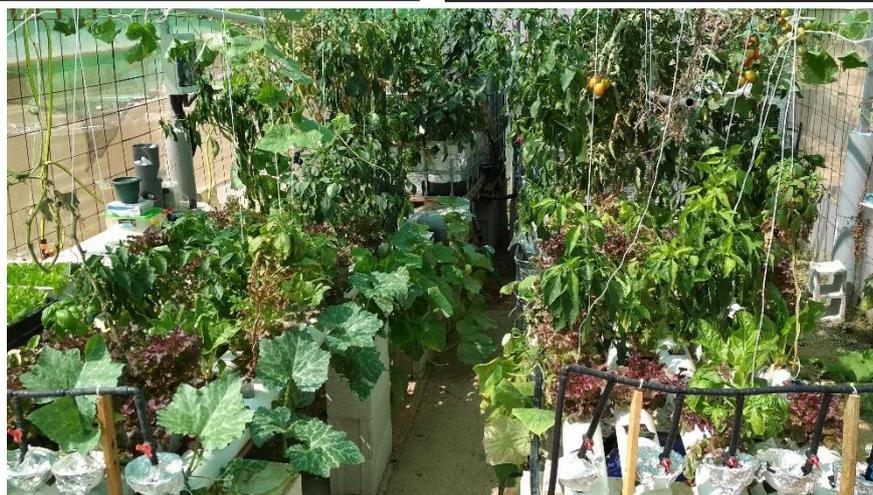
However, no aquaponic “soup” is perfect, and some nutrients may be more abundant than others. Of the 16 essential nutrients that plants need to live and grow well (nitrogen, phosphorus, potassium, iron, calcium, etc.), aquaponic systems usually contain all of them, but some may be in low amounts and insufficient for strong, healthy plant growth. In these cases, nutrient deficiencies appear in the plants, visible on the leaves (color changes, deformities, etc.), and the missing nutrients must be added, either directly to the water or sprayed onto the leaves.



2 aquaponic systems when introducing the first plants



The same installations 2 months later



And those installations after 5 months

## WEEKLY ROUTINES

### Routine 8. Measure nitrates in the water.

The nitrate level in the water indicates the amount of nutrients available for the plants. Normally, when nitrates exceed 30–40 ppm or mg/liter, the total nutrients in the “aquaponic soup” are at sufficient levels for the plants.

As the fish grow, they eat more food, and the nitrate levels will also increase. When nitrates reach 80–90 ppm, or above 120–140 ppm, more plants can be added to the aquaponic system. Normally, the nitrate level in the water is not toxic for the fish, plants, or bacteria, unless it reaches very high concentrations (over 300–500 ppm).

There are two ways to reduce the nitrate level in the water without stopping feeding the fish:

- By performing water changes, usually when nitrate levels exceed 200 ppm. A water change consists of removing a known volume of water from the aquaponic system and replacing it with the same volume of fresh, clean water (see Routine 16).
- By increasing the plant growing area within the installation.

El The nitrate level can be easily measured using test kits available at aquarium stores.

### **Routine 9. Possible application of treatments to correct potassium and other nutrient deficiencies in plants.**

Potassium deficiencies are corrected by spraying a mixture of potassium sulfate in water onto the leaves. In summer or at high temperatures, the mixture should be 7.5 grams per liter of water, while in winter or at low temperatures, it should be 15 grams per liter. This mixture is sprayed on both the top and underside of the leaves, preferably early in the morning or in the evening.

The treatment is repeated every 3–4 days until the symptoms disappear. In the image on the right, the typical dry spots indicating potassium deficiency are shown, in this case on a zucchini leaf.



In the image on the right, chlorosis on strawberry leaves due to iron deficiency is shown (the leaf veins remain green while the areas between the veins turn yellowish or pale green). The correction of iron deficiencies is explained in Routine 14, which is carried out on a biweekly basis.



### **Routine 10. Possible application of treatments against pests of plants and fish.**

In aquaponics, pesticides cannot be used against plant pests, nor antibiotics to treat fish diseases, because both kill the bacteria that purify the water. And without bacteria, aquaponics does not work.

For plant pests, ecological products are used that do not harm the bacteria. It is very important to start applying them when we observe that the pest attack is beginning, not when it has already spread. Below we list some of the most common treatments used in aquaponics:

- Treatment against insects such as aphids, whitefly and thrips: prepare a mixture of 20 milliliters (ml) of potassium soap in 1 liter of water and spray on the upper and underside of the leaves. This mixture can be more effective if 3 ml of 70° alcohol and 1–2 ml of neem oil are added. Apply every 3–7 days.

In the image, aphids on a cucumber leaf from an aquaponic installation.



#### **IMPORTANT**

Neem oil can be toxic to fish. Although in this case it is very diluted in the liter of water of the mixture, to prevent part of the mixture from filtering into the water of the aquaponic system, plastic bags or pieces of absorbent paper can be placed under the plants before spraying.

Another treatment is nettle slurry (commercial or homemade). Prepare a mixture of 50 to 150 ml of nettle slurry in 1 liter of water and spray it onto the leaves. Repeat every 3–7 days.

- Treatment against red spider mites: prepare a mixture of 3 grams of micronized sulfur powder in 1 liter of water and spray it onto the leaves. Repeat every 7 days until the red spider mites are controlled. Also use plastic bags and/or absorbent paper to prevent part of the mixture from filtering into the water of the installation.

- Treatment against fungi (powdery mildew, “sooty mold”, etc.): use the same previous mixture with micronized sulfur powder in water. Apply every 7 days.
- Treatment against slugs and snails: use iron sulfate in pellet form spread around the base of the plant.

Fish do not usually get sick in aquaponics, as long as good water conditions are maintained (adequate pH, temperature and oxygen level), the solids (sediments at the bottom of the tanks) are removed frequently, and they are fed properly. In case any disease appears, the fish must be removed to small tanks with good aeration in which the chemical treatment to cure the disease has been dissolved. This way of treating fish diseases is called “baths”, and they can contain common salt and other substances such as hydrogen peroxide, antibiotics, etc. In these “baths” the fish remain for a few minutes and are then returned to the corresponding tank of the aquaponic installation.

### **Routine 11. Harvest plants, introduce new seedlings and install stakes.**

When the plants (their leaves or fruits) are ready for consumption, they must be harvested and then another seedling of the species we want must be planted in the space they left.

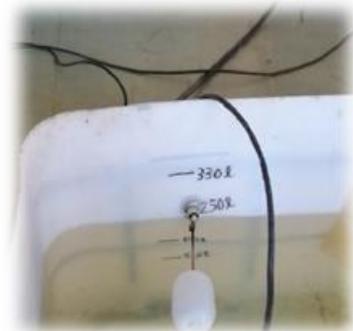
In aquaponics, plants grow at a higher density, closer to each other, therefore we must think about which part of the installation to plant them in so that the taller or larger ones do not cast excessive shade on the smaller ones. Due to this higher density, it is also necessary to stake some large plants (eggplants, tomatoes, peppers, cucumbers, melons, watermelons, pumpkins, etc.), and to prune the lower leaves to shape the plant so that it grows upwards. Staking, in addition to supporting the plant, also serves to guide it where it suits us best so as not to shade other plants.

Some lettuce varieties, such as “Romana”, require their leaves to be tied (when they have a minimum of 20) in the upper third of the plant, so that the central heart grows compact and acquires a lighter color.

## **FORTNIGHTLY ROUTINES**

### **Routine 12. Replenish water losses due to evaporation and plant evapotranspiration.**

As air temperature rises, water in the aquaponic system evaporates, so the evaporated water must be replenished. It is useful to mark the water level in the sump or any other tank and use it as a reference to know how much water has evaporated and how much needs to be added. The water level also decreases due to plant evapotranspiration.



To restore the normal water level in the installation, water from the replacement or storage tank is used. Additionally, a level gauge or float ball can be installed, connected by a hose to the storage tank, so that it automatically introduces the water.

### **Routine 13. Measuring oxygen in the water (optional).**

Measuring the oxygen level in the water is not necessary if the fish are observed every day, as they are the living beings in the installation that suffer the earliest from a sudden decrease in oxygen in the water. If they stop eating and appear at the surface of the tank opening their mouths, this indicates that there is a lack of oxygen in the water.

It is also important to know that oxygen levels begin to decrease if the fish density or their size increases significantly, if there is an accumulation of solids in the water, and if the water temperature rises. It is necessary to be attentive to these changes. Oxygen is not only important for the fish or the roots of the plants, but also for the bacteria to properly decompose the fish waste.

However, dissolved oxygen can be easily measured with tests available in aquarium stores. It should be measured in the fish tank, with the pump turned off for a few minutes and without capturing bubbles in the water sample. If the oxygen is below 4 ppm, more aeration will need to be added to the fish tank, with a small air compressor, or with other devices (waterfalls, Venturi system, etc.).

### **Routine 14. Possible application of treatments for iron deficiencies and other nutrients in plants.**

If the plants show iron deficiency, the treatment to correct it is very simple, by adding iron chelate (Fe-EDDHA) directly to the aquaponic installation water every 15 days. Dissolve 9 grams of iron chelate powder in 1 liter of installation water collected in a bottle or container. Mix it and add 100-150 ml of this mixture. The water will turn a reddish color similar to red wine. This substance is also used in organic farming and does not harm the bacteria, fish, or plants.

### **Routine 15. Water changes.**

A water change consists of removing a volume of water from the installation and adding the same volume of new and clean water. Water changes are done in 2 cases:

- Case 1. If the nitrate concentration in the water exceeds 200-250 ppm (mg/liter). This case is not frequent, because this concentration is rarely exceeded. If it is exceeded, a small amount of water can be removed, for example, 50 liters of water from the installation, and then 50 liters of clean water added. Measure the nitrates again after 1 hour to see how

much the nitrate levels have decreased. Depending on the nitrate reduction, the volume of water in the change is increased or decreased.

- Case 2. If it is observed that many solids are accumulating at the bottom of the deposits (the fish tank, the settlers, or the collector if the installation has one).

Case 2 is the most frequent. The solids or sludge consist of:

- Remnants of fish waste (mainly feces).
- Remnants of uneaten food.
- Dead remnants of algae, bacteria, and plant roots.

These settle and deposit at the bottom of the installation's deposits. When they accumulate excessively, they must be removed as soon as possible, as they can produce toxic gases dissolved in the water and a rapid decrease in dissolved oxygen.



The larger the fish (higher fish density), the more they will eat and, therefore, the greater the amount of solids that will accumulate at the bottom of your deposits. It is estimated that for every 1 kg of food (in dry pellets), 250 g of solids or sludge are produced, so the higher the fish density, the more often solids will need to be removed.

The solids are removed by suction using a submersible pump attached to a hose; or directly by gravity using a hose filled with water or by sucking with the mouth (the first method is recommended). When sucking the solids, water from the installation is also sucked, so it is necessary to monitor the volume of water with solids that is removed from the installation, in order to replace the same volume with clean water. Thus, in this operation, two things are being



accomplished: performing a water change and removing solids.

### **IMPORTANT**

If arlite beds or growth beds (the “grow bed” system) are used as biofilters for the bacteria, it may be necessary to clean the arlite once a year (again, depending on the fish density). In the case of the NFT system, you will have to clean the inside of the PVC tubes, while in the floating root system, the cleaning will affect the bottoms of the trays where the corks float.



In summary, water changes can be used for several purposes:

- To improve the WATER QUALITY.
- To remove solids or sludge from the collector (Routine 21), the fish tank, or the settlers (Routine 17).
- To lower the pH (if the new water added to the installation is rainwater or osmotized).
- In EMERGENCY situations to reduce the concentration of toxins in the water, such as ammonia or nitrites.

#### **Routine 16. Filling the replacement or storage tank with water.**

The storage tank should always be full of water, as it will be used to replace losses due to evaporation, to perform water changes, or even for cleaning (the pump, filters, or filter sponges, etc.). During times of the year with high temperatures, evaporation will be greater, and it is necessary to always have water available in this tank.

### **MONTHLY ROUTINES**

#### **Routine 17. Suctioning solids or sludge from the settler.**

Remove the solids from the bottom of the settler by suction, as described in Routine 15, and replace with clean water from the storage tank, as described in Routine 16.

### **Routine 18. Cleaning the recirculation pump.**

Solids also adhere to the shaft and other parts of the pump, reducing its capacity to push water, oxygen, and nutrients. For this reason, the pump must be stopped, its parts disassembled, and cleaned. With higher fish density, it will be advisable to clean the pump more frequently. The image on the right shows the cleaning of the submersible pump.



### **Routine 19. Changing the filtration sponges.**

If there are filtration sponges in any area of the installation, they must be cleaned to avoid the accumulation of solids. In the image on the left, a filter material sponge full of solids.

### **Routine 20. Suctioning solids from the collector and the fish tank.**

Remove the solids from the bottom of the collector and the fish tank by suction as described in Routine 15; and replace with clean water from the storage tank.

## **3.5. Final recommendations.**

To conclude, a summary of the most important recommendations already mentioned in this beginner's aquaponics manual:

- It is better to start with a small and simple installation.
- Have a low fish density, between 1 to 5 kilos of fish per cubic meter of water.
- Choose a hardy fish species that can withstand low and high water temperatures and that can be easily purchased (both the fish and their food). One of the fish in Spain that meets these characteristics and is easily obtained is the goldfish, also called "red comet".
- Do not forget the electrical protection and safety elements in the installation; and the basic safety measures in case of use or handling of chemical substances.
- Do not overfeed the fish, observe if they eat well and do not leave food remnants. If there are remnants, reduce the portion.
- Monitor the water levels, pH, nitrates, temperature, and oxygen.
- Ensure that solids or sludge do not accumulate in the installation.

## 4. Agroecological Agriculture and Extensive Grazing.

Agroecological agriculture is a food production model that combines ecology, scientific knowledge, and traditional practices to create sustainable agricultural systems that are socially just and environmentally friendly. Its objective is to promote sustainability and resilience through the reduction of external inputs, efficient use of water, minimization of polluting emissions, valorization of waste (converted into by-products), and preservation of natural resources (fertile and healthy soil, water, biodiversity, etc.)

Unlike conventional agriculture, it avoids the excessive use of synthetic agrochemicals and is based on techniques such as the recycling of organic matter, crop rotation, and species association.

For its part, extensive grazing is a circular livestock system that uses large expanses of land for animals to feed, making the most of the available natural resources. This method, which requires low investments and is compatible with native breeds, offers significant environmental benefits, such as reducing the risk of fires, improving soil biodiversity, and conserving the landscape, while also promoting rural development and animal welfare.

It is based on:

- Permanent pastures and agricultural by-products
- Low dependence on external factors.
- Promotion of ecosystem services.
- Fight against desertification.
- Generation of income and retention of rural populations.



#### 4.1. Main challenges.

The main challenges currently facing the use of agroecological agriculture and extensive grazing are:

- **Lack of technical knowledge.**

There is limited access to both appropriate technology and the tools that make this type of system possible. This is compounded by the scarce research in this field, since R+D is usually focused on industrial agriculture rather than these agroecological or extensive models. This leads to great difficulty in adopting sustainable practices and integrating them with other agricultural activities.

- **Commercialization deficit.**

Agroecological and extensive systems usually need more time to achieve stable productivity, leading to low short-term profitability. This can cause demotivation among farmers considering this type of model. Additionally, there are no adequate incentives or support, as agricultural policies still favor intensive farms in many cases, and there is no investment in a specific certification system. This is compounded by the absence of specialized sales channels, resulting in low visibility in local markets and direct competition with cheaper and more accessible industrial products. All of this leads to low recognition of the value of extensive grazing and agroecological livestock farming.

- **Need for investment.**

Switching from the conventional model to an agroecological one involves investments and a learning period that can affect the producer's income. Infrastructures such as biodigesters, efficient water systems, renewable energies, and monitoring technologies represent a high initial cost that takes time to become profitable, so without adequate support or a high initial investment, these environmental systems are very difficult to adopt.

- **Insufficient regulation.**

Public policies with an integral strategy or specific standards for agroecological agriculture do not yet exist. Additionally, small farms face many bureaucratic and administrative difficulties in accessing the few aids or ecological certifications that currently exist.

- **Lack of generational replacement.**

The aging of the rural population and the scarce incorporation of young people into the countryside limit the continuity of sustainable practices. Techniques such as agroecology and extensive grazing are often perceived as outdated or less productive activities, causing rejection among young people.

## 4.2. Implementation strategies.

The challenges described above demonstrate that it is essential to address an integral approach that encompasses education, investment in R+D, regulation, and financing, in order to implement sustainable agriculture and livestock systems. Additionally, collaboration between sectors is also essential to overcome obstacles and ensure a sustainable future.

Based on these ideas, a series of measures or strategies is proposed to implement agroecological agriculture and extensive grazing systems.

- **Producer Training.**
  - Conducting courses, workshops, and technical assistance to teach techniques such as integrated resource management, ecological animal health, the use of by-products, composting and biodigestion, and pasture planning.
  - Create exchange networks and digital platforms to connect livestock farmers, technicians, and research centers for the exchange of knowledge.
  - Promote personalized technical advice to support the transition from conventional models.



Participants in the LIFE+ Maronesa Project.

- **Consumer Awareness.**
  - Conduct campaigns that highlight the environmental and social benefits of agroecological products.
  - Creation of a certified brand that recognizes local good practices to ensure trust.
  - Strengthen short marketing channels (direct sales, local markets, e-commerce) by expanding those that currently exist.

- Promote alliances between producers, consumers, and local administrations.
- Integrate extensive livestock farming into educational and environmental interpretation programs.
- **Research and Innovation.**
  - Valorization of by-products (wool, horns, cheese factory and slaughterhouse waste) for biofuels, cosmetics, construction materials, etc.
  - Substitution of plastics with biodegradable alternatives.
  - Implement adaptive management plans for droughts and climate variability.
  - Promote efficient water use (ponds, rainwater harvesting, drip irrigation in associated agricultural areas).
  - Design rotational or directed grazing plans that favour pasture regeneration and soil fertility.
  - Promote the use of native breeds adapted to the environment, more resistant to local conditions and with lower environmental impact.
  - Promote livestock-forestry integration (silvopasture) to make the most of natural resources, prevent fires, and conserve biodiversity.
  - Recover and maintain traditional infrastructures (watering troughs, sheep pens, live fences, drover's roads, and livestock trails).
  - Reduce dependence on external inputs (feeds, fertilizers, herbicides) through food autonomy and manure composting.
- **Financing and Support.**
  - Establish accessible lines of credit for small producers.
  - Promote incentives for sustainable infrastructures (renewable energies, community biodigesters, etc.).
- **Regulation and Public Policies.**
  - Develop a clear legal framework for circular agriculture.
  - Strengthen alliances between government, the private sector, and civil society.
  - Include extensive livestock farming as a key tool in the management of natural spaces and fire prevention, facilitating its inclusion in agricultural policy aids and rural development programs with conservation and sustainability objectives.

- Favor territorial contracts for sustainable exploitation.
- Simplify bureaucratic and administrative procedures for access to aids and ecological certifications.

### 4.3. Extensive livestock farming as part of the climate solution.

Contrary to the widespread perception that livestock farming is one of the main causes of climate change, extensive and agroecological livestock systems, when managed appropriately, can play a key role in mitigating and adapting to climate change.

Unlike industrial or intensive models, which rely on imported feeds, synthetic fertilizers, and high energy consumption, extensive livestock farming is based on the sustainable use of local natural resources, maintaining the balance between production, ecosystem, and climate.

To be part of the solution, livestock farming must be based on:

- and rotational pasture management.
- Use of native breeds and local resources.
- Integration of trees and natural vegetation.
- Reduction in the use of external inputs and fossil fuels.

According to FAO estimates (Food and Agriculture Organization of the United Nations), sustainably managed grasslands could offset up to 8% of global greenhouse gas emissions from the agricultural sector. This figure demonstrates the enormous potential of these ecosystems as natural carbon sinks and their strategic role in the fight against climate change.



#### 4.3.1. Carbon sequestration through well-managed grazing.

Rotational or rational grazing consists of dividing the pastures into plots and allowing sufficient rest time between grazing.

This favours the plants:

- Increase photosynthesis as they regenerate, capturing more CO<sub>2</sub> from the atmosphere.
- Develop deeper roots, which store carbon in the soil long-term.
- Improve the soil structure and fertility, increasing its capacity to retain water and resist erosion.

Various studies show that well-planned grazing can sequester between 0.5 and 3 tons of CO<sub>2</sub> per hectare per year, depending on the type of vegetation and climate. Thus, a FAO<sup>1</sup> analysis on managed grasslands indicates that, if soil organic carbon (SOC) is increased in the 0-30 cm horizon in grasslands through good management practices, it could sequester about 0.3 tons of carbon/ha per year. This would be equivalent to approximately 1.1 t CO<sub>2</sub>/ha per year (using the factor 3.67 to convert from C to CO<sub>2</sub>).

It is not the only study in this regard, as an Australian report on managed grazing (“managed grazing”)<sup>2</sup> describes average carbon gains of approximately 0.77 t C/ha per year (about 2.8 t CO<sub>2</sub>/ha per year) under certain optimal conditions, while a University of Cambridge study indicates that in European grasslands, SOC increases equivalent to about 5 ± 30 g C/m<sup>2</sup> per year were observed, which equates to 0.05 ± 0.30 t C/ha per year for the average of the collected data.

#### 4.3.2. Agrosilvopastoral systems: integration of trees, crops, and livestock.

Agrosilvopastoral systems combine woody vegetation (trees, shrubs), pastures, and animals in the same space.

These systems offer multiple climatic benefits:

- Capture carbon both in aboveground biomass (trees) and in the soil.
- Reduce erosion and increase water infiltration, making ecosystems more resilient to droughts.
- Modulate local temperatures and create microclimates that protect biodiversity and animal welfare.
- Allow the reduction of external inputs, as trees provide shade, natural forage, and organic matter.

Typical examples of these systems are Mediterranean dehesas, which store large amounts of carbon and support low-environmental-impact livestock farming, in addition to providing valuable habitats for wildlife.

<sup>1</sup> <https://www.fao.org/newsroom/detail/fao-publishes-its-first-global-assessment-of-soil-carbon-in-grasslands/en>

<sup>2</sup> <https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2025/general/new-study-managed-grazing-shows-promise-for-boosting-soil-carbon-in-temperate-pasture-systems>



#### 4.3.3. Reduction of net emissions and improvement of ecological efficiency.

An extensive and agroecological livestock system reduces its net emissions through several avenues:

- Decreases the use of synthetic nitrogen fertilizers, the main emitters of nitrogen oxides (N<sub>2</sub>O).
- Favors food autonomy, avoiding emissions associated with the transportation and production of feeds.
- Improves the methane balance: ruminants in grazing produce biogenic methane that forms part of a short natural cycle, unlike the fossil CO<sub>2</sub> released by industrial agriculture.
- Generates ecosystem services that offset emissions: water regulation, biodiversity, fire prevention, and maintenance of open landscapes.

Thus, in net terms, a well-managed extensive livestock system can achieve emissions close to zero or even be climate positive, by capturing more carbon than it emits.

#### 4.3.4. Additional benefits for climate adaptation.

In addition to mitigating climate change, this type of management helps adapt to its effects, as it has the following benefits:

- Improves soil resilience against drought and torrential rains.
- Diversifies production (meat, milk, wool, firewood, fruits, tourism services).
- Maintains mosaic landscapes, less vulnerable to fires and loss of biodiversity.

- Promotes local food sovereignty, reducing dependence on global markets vulnerable to climate crises.

#### 4.4. Notable cases studies.

##### 4.4.1. LIFE Maronesa Project.

The project is framed under the European Union's LIFE Programme, in the category of “Governance, Information and Climate Action” (Climate Change Adaptation), with the full title “*Market Awareness Raising for Opportunities in Needed Extensification and Soil-friendly Agriculture*”. The native Maronesa beef cattle breed, in northern Portugal, is the center of this project. This traditional breed—and the mountain pastures that sustain it—has been affected by abandonment, reduction in numbers, and degradation of the associated livestock and agrarian landscape. This degradation has led to an increase in scrubland, a reduction in quality pastures, less carbon capture in the soil, and a higher risk of forest fires.

Therefore, the main objective of the project is the conservation of the native Maronesa breed and its mountain ecosystems by promoting a sustainable model of extensive livestock production. In addition to disseminating, training, and valorising the Maronesa breed's production chain, making it economically viable and environmentally relevant. Thus, it seeks to improve soil fertility and increase organic carbon through rotational grazing, which also helps prevent fires and maintain biodiversity. The use of breeds adapted to the territory also results in less dependence on external inputs.

The project started in 2020, with a planned completion date in 2025. During this time, an improvement in soil fertility has been observed, along with an increase in the production of pastures and hay through the application of magnesium limestone and changes in flora. Additionally, mountain management has been improved, and the risk of fires has been reduced through directed grazing, scrubland interventions, and restoration of plant mosaics. Soil carbon monitoring is also being carried out, with improvements noted over the time it has been in practice.

Expanding these best practices to more livestock farmers is key so that the impact does not remain only in these demonstration areas. However, the change in mentality and livestock culture towards directed grazing, rotation, scrubland management, etc., requires training, incentives, and technical support.



Watch on Youtube: <https://www.youtube.com/watch?v=-mCM3LmdwuU>

#### 4.4.2. Casal da Bouça.



This is a livestock farm used as a model in the LIFE Maronesa project. Located in the village of Souto, in the municipality of Vila Pouca de Aguiar, in northern Portugal, it has around 120-130 Maronesa cows in an extensive regime, in addition to other species of sheep and goats.

This farm is characterized by applying extensive grazing, in which the Maronesa cows spend most of their time outdoors, among mountains and meadows. The cattle are surrounded by native trees that, in addition to providing shade, supply them with food. Holistic management is carried out, adjusting the livestock load to the soil's capacity. Thus, data such as the biomass consumed per cow per day and pasture productivity are being quantified, observing how the flora varies under different grazing regimes.

Within the biodiversity improvement activities, magnesium limestone and phosphorus have been applied to enhance the fertility of the “lameiros” (wet meadows) and increase pasture and hay production. Additionally, ponds have been created or improved to retain water during rainy periods and thereby improve the land's water retention capacity. Circular economy measures are also implemented, using the manure produced by the cattle to fertilize adjacent vegetable gardens.

To disseminate these practices and raise awareness about their advantages, guided visits to the farm are carried out and technical exchanges with other projects are conducted.

Among the results obtained, greater carbon sequestration has been verified by increasing soil organic matter and improving vegetation. The livestock's capacity to adapt to droughts or water variability has also been increased, and the risk of fires has been reduced thanks to grazing and better soil management. On the other hand, the ecological certification of the meat adds value to the product, facilitating its sale.



Watch on Youtube: <https://www.youtube.com/watch?v=pxnB0ir92Nc>

#### 4.4.3. Sustainable Chestnut Production in the Mountain Lands of Bragança.

In the mountainous areas of northern Portugal, soutos (chestnut groves) are traditional agroforestry systems with social, economic, and environmental importance. However, these ecosystems are in danger due to the loss of organic matter and increased erosion in hillside soils, water contamination, loss of fertility from tillage, pressure from diseases (such as *Phytophthora cinnamomi*), pastoral abandonment, and climate changes that alternate droughts with intense rains.

It has been verified that agroecological soil management helps mitigate these problems. The objective is to restore and maintain soil fertility and its water retention capacity, and to increase soil biodiversity and resilience to pests, diseases, and climate extremes. This improves chestnut productivity and quality in a sustainable way and favors ecosystem services, such as carbon capture, erosion control, or water regulation.

to chestnut groves, this agroecological management implies:

- **Maintain natural plant covers**, such as native grasses and herbaceous plants. Early mechanical cuts (in March-April) also allow for reducing water competition. With this, the soil is protected without increasing the risk of *Phytophthora* infection, and water infiltration on slopes is improved. It has been verified that chestnut groves with natural cover reduced erosion by 30% compared to plowed soil.
- **Controlled grazing with sheep**. It is recommended in spring, before chestnut flowering, with an animal load of 8–10 sheep per hectare, in rotation. This allows natural control of weeds and organic fertilization through manure. It also helps reduce the risk of fires.
- **Mulching with pruning residues**. By spreading a 5-10 cm layer around the tree with chestnut leaves and pruning remains (avoiding piling it against the trunk to prevent moisture and infections), we protect against erosion, in addition to allowing thermal regulation and gradual nutrient supply.
- **Minimize disturbance**. Avoid soil tillage, which spreads the disease and degrades the soil. If tillage is done, it should be superficial (5–10 cm) and only when strictly necessary.
- **Water management**. Capture and storage of rainwater in small ponds or infiltration ditches on terraces to recharge the soil profile. Mulching and natural plant covers also help reduce evaporation. Irrigation should only be for young plants or in critical years, using local sources or recovered water.
- **Natural pest control**, avoiding industrial herbicides, which leave the soil unprotected in winter. Thus, preventive health is carried out by maintaining healthy soil thanks to organic matter and a good structure that reduces the incidence of weakened roots and diseases such as *Phytophthora* in poorly drained soils.



These measures have been proven effective in sustainable chestnut production in the Mountain Lands of Bragança (Portugal). There, herbicides have been replaced by scheduled brush clearing, and sheep grazing has been introduced in collaboration with local shepherds. Training in agroecological soil management has reduced herbicide use by 90% and increased productivity by 15%. Thus, it has been demonstrated that

chestnuts can be produced without herbicides by combining natural covers, grazing, and local mulching. Additionally, this system offers further benefits, as the costs of machinery and chemical products have been reduced, and the product has been revalued through ecological certifications.

#### **MORE INFORMATION**

If you want more information, you can consult the [Chestnut Good Practices Manual](#).

#### **4.5. Lessons learned.**

The experience of these projects allows for the elaboration of a series of conclusions regarding future agroecological initiatives:

- **Local adaptation is key.** Breeds like the Maronesa or cases of systems like Casal da Bouça or sustainable chestnut groves show that territory-specific solutions are more effective than generic models.
- **Climate-biodiversity synergies.** All these farms demonstrate that climate mitigation and species conservation (for example, the Iberian wolf in grazing areas) can coexist.
- **Profitability.** Selling products with ecological certification or "carbon neutral" improves economic viability, which is why it is necessary to create quality seals supported by public administrations.
- **Training and knowledge exchange.** Training is key for farmers and livestock farmers to understand the advantages of this type of systems and know how to adapt them to their crops. Likewise, participating in knowledge networks, such as the Operational Groups of the CAP, will expand the tools and knowledge they can apply.
- **Political support.** It is fundamental that public administrations get involved and finance pilot projects based on these models.



## 5. Creating innovative farming systems and environmental monitoring with open-source technologies...

This part of the Manual aims to propose simple and effective solutions that allow both individuals and communities to implement low-cost, easy-to-build sustainable cultivation systems. For this reason, step-by-step operational instructions are illustrated below for the construction of some cultivation and monitoring systems that help address current problems such as drought and climate change, while also fostering collaboration and knowledge exchange. Specifically, three "do-it-yourself" (DIY) prototypes are presented: a seed germinator, an elevated *wicking bed* garden, and an electronic environmental monitoring system (homemade weather station with sensors).

### 5.1. Construction of a Wicking Bed.

In a world where water is an increasingly precious resource and many people live in urban environments without direct access to a garden, the wicking bed presents itself as a simple, economical, and sustainable cultivation solution for vegetables, aromatic herbs, and even flowers. It is an elevated garden bed system with self-watering by capillarity, which drastically reduces water consumption, facilitates urban agriculture (even for those with reduced mobility or little experience), and creates opportunities for learning and inclusion in schools, communities, and associations.

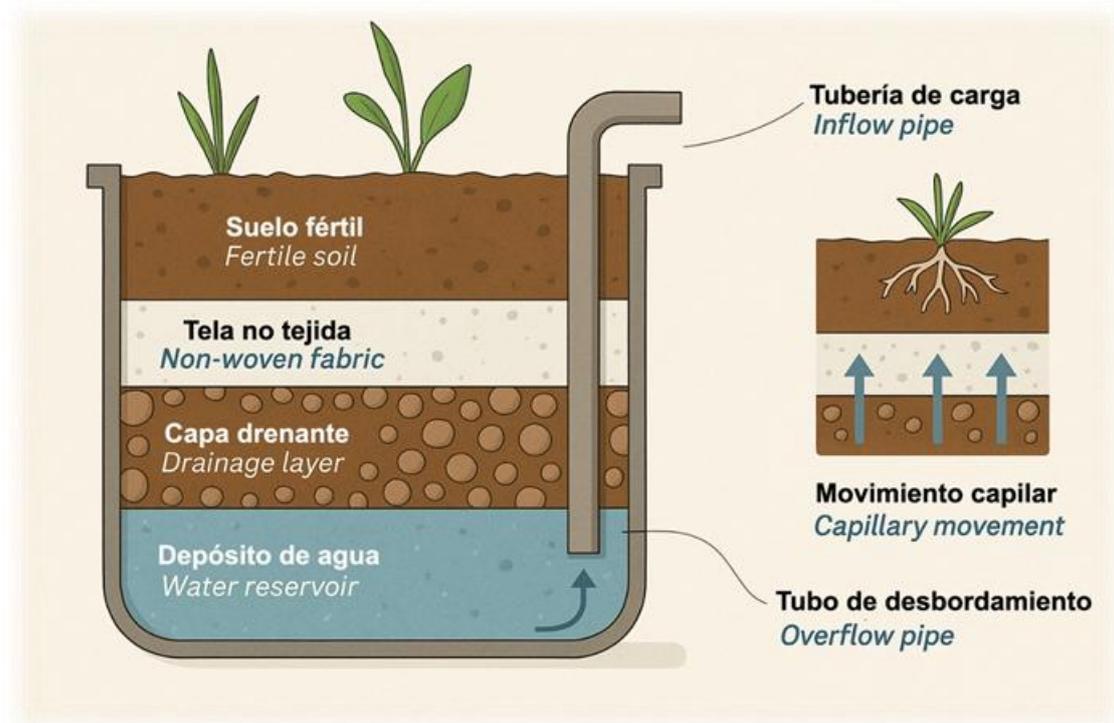
A wicking bed is an elevated growing box that incorporates a water reservoir at the base, which keeps the substrate moist through capillary action. The plant roots "drink" the water they need directly from below, eliminating the need for frequent watering. In practice, it consists of a wooden box waterproofed on the inside, whose bottom contains a layer of porous material (for example, expanded clay or gravel) that acts as a water reservoir. On top of this drainage layer, a geotextile fabric (also called non-woven fabric) is placed, and on top of it, the substrate or growing soil. Thanks to this design, the soil remains constantly moist through the capillary rise of water from the reservoir at the bottom, making the most of the water resource without losses due to percolation. Another benefit is that the stored water level can be controlled through a pipe system: one for filling from above and a lateral overflow pipe that prevents waterlogging, allowing excess to drain.

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#### Quick Notes

- This explanation details the structure and benefits of a wicking bed, ideal for environments with water scarcity.

- The system promotes water savings through natural capillarity.
- It is accessible for beginners and users with physical limitations.



Among the advantages of this system are:

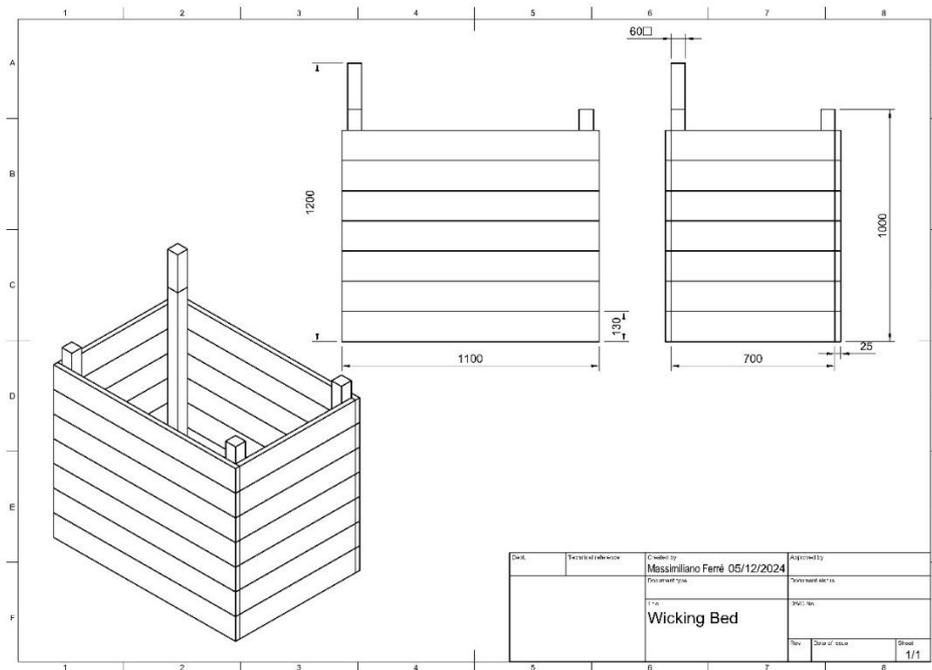
- ✓ Water savings: up to 80% less consumption than a traditional garden.
- ✓ Infrequent watering: ideal for hot climates or situations where daily watering is not possible. The reservoir provides several days (even weeks) of autonomy.
- ✓ Greater autonomy for plants: they always have the necessary moisture without water stress.
- ✓ Accessibility: being elevated, it is easy to handle for children, elderly people, or those with disabilities (no need to bend down and height can be adjusted).
- ✓ Material recycling: it can be built with reused or inexpensive materials.
- ✓ Adaptability: construction techniques can be adjusted according to needs (available space, desired size, type of crops, etc.).

### 5.1.1. Materials and Tools Needed

In the following table, the materials needed for a box of about 155 x 100 cm are listed, as well as their function within our installation.

<b>Materials</b>	<b>Practical Instructions</b>
Larch wood boards <sup>3</sup> (thickness 25 mm)	Maximum height of the box 90 cm
Wood screws Ø6×55 mm	To assemble the box structure
Waterproof PVC sheet (approx. 3 × 4 m)	To line the inside and make the water reservoir watertight
Gravel or expanded clay (about 300 L)	Material for the drainage layer (25–30 cm)
Geotextile fabric (or non-woven fabric)	To separate the gravel from the substrate and prevent the soil from clogging the drainage
Quality fertile substrate (approx. 1000 L)	Soil to fill the box. It is recommended to mix with compost to improve nutrients
Water loading tube (approx. diameter of 20 mm)	Vertical tube to fill the reservoir from the surface. It can be made of PVC or other rigid material.
Plumbing elbow 3/4" (elbow piece)	It will function as an overflow outlet for excess water (it will go on the side of the box, at a certain height).
3/4" brass tee	3-way "T" connector, used to join the vertical loading tube with the overflow elbow and the internal drain
Nipples (threaded tubes) 3/4" × 25 mm, 2 units	Threaded sections to connect the loading tube, the tee, and the elbow to each other, passing through the wall of the box.
Bulkhead fitting 3/4" (valve or pond fitting)	Drain piece that allows hermetic sealing of the overflow water outlet through the wood.
3/4" rubber gasket	Washer or rubber seal to ensure the watertightness of the hydraulic system in the joints (it is placed on the bulkhead/elbow so that water does not leak through the wall).

<sup>3</sup> Any weather-resistant wood will work; we recommend larch because it is durable and naturally water-resistant.



#### Necessary tools:

- Cordless drill (preferably with hole saw/crown bit for making wide holes in wood).
- Electric saw (circular or miter saw) or hand saw for cutting the boards.
- Sturdy scissors or utility knife for trimming the waterproof liner and geotextile fabric.
- Bubble level (spirit level) to check the horizontality of the box.
- Tape measure for measuring dimensions.
- Teflon tape (thread sealant) for plumbing connections.
- Heavy-duty stapler to secure the liner (optional).
- Work gloves and safety glasses (for safety when cutting and drilling).

#### 5.1.2. Step-by-Step Procedure

1. **Preparation of the box:** Cut the wooden boards to the desired dimensions (for example, forming a frame of 155 × 100 cm and approximately 90 cm high). Assemble the box by joining the boards with screws, using reinforcements in the corners (they can be square interior strips) to give it solidity. Place the already assembled box on a level and firm surface.



2. **Tube Installation:** Make a hole in one of the short sides of the box (approx. 20 cm from the bottom) to install the overflow tube. Insert the 3/4" elbow connected to the tee into that hole, so that the end of the elbow is flush with the interior (that will be the maximum water level). Cover the entire inside of the box with the waterproof liner, adjusting it well to the corners (you can secure it with staples or strips so it doesn't move). Then, place the loading tube vertically inside the box, which will pass through the base to the T (it will be the conduit to fill the water). Also place a perforated irrigation tube horizontally along the bottom (this tube, with multiple holes, will distribute the water from the reservoir evenly under the gravel; it can be, for example, a 20 mm PVC tube with perforations, connected laterally to the T). Finally, adjust and thread all connections (use Teflon on the threads to prevent leaks). At the end of this step, you should have a vertical tube upward (filling), a tee that connects to the perforated tube at the bottom, and an elbow that passes through the wall as the overflow.





3. **First watertightness test:** Partially fill the reservoir with water through the vertical loading tube and verify that there are no leaks in the connections (especially around the overflow hole and threaded joints). If it leaks, adjust the parts or add sealant until everything is watertight.

- Drainage layer:** Place the expanded clay or gravel filling the bottom of the box up to about 25–30 cm in height. This layer will surround the perforated irrigation tube. Check that the height of the overflow tube is slightly lower than the height of this drainage layer (the overflow should drain the water when the level exceeds the gravel, so that the substrate above does not get submerged). If necessary, adjust the position of the elbow.



- Placement of the geotextile fabric:** Spread the non-woven fabric over the gravel layer, covering it completely. This fabric will prevent the substrate from mixing with the gravel and clogging the drainage pores, but it will allow water to pass through by capillarity
- Substrate filling:** Fill the rest of the box with the prepared substrate (fertile soil, preferably mixed with compost). Fill to the edge, but without compacting excessively, simply settle the soil lightly with your hand to remove large air pockets.



- System startup:** Pour water through the loading tube until the lower reservoir is full. You'll know it's full when water starts coming out of the side overflow tube (the excess). Let it sit for a few hours and check the level again. The soil will absorb some water at the beginning, so the level may drop. In that case, refill if necessary until it stabilizes.

8. . **Planting:** The wicking bed is ready for planting! Sow or transplant your crops (vegetables, aromatic plants, flowers, etc.) according to the season. Place the plants on the surface of the substrate, leaving sufficient space between them, and water them lightly from above only the first time to settle the soil around the roots.



### 5.1.3. Maintenance and Management

- Check the water level periodically through the loading tube (a rod can be used or simply see if water is visible at the bottom of the tube).
- Refill the reservoir approximately every 1–2 weeks (the frequency will depend on the climate and type of plants). In very hot climates or dry seasons, check at least weekly.
- Avoid prolonged waterlogging: if heavy rains are expected, check that the overflow works and drains the excess; if the system remains saturated with water for too long, oxygen may be lacking in the roots.
- In winter (or in cold climates): drain or lower the reservoir level if there is a risk of prolonged frosts, to avoid damage from water freezing (ice can expand and break the liner or connections).
- Partially renew the substrate every 1–2 years, adding compost or new soil to replenish nutrients, as over time plants deplete part of the fertility.

### 5.2. Miniature Wicking Bed Prototype (Plan Germinator)

After presenting the full-scale wicking bed, we also propose a reduced-scale model—basically a mini-wicking bed—designed for those approaching this type of cultivation for the first time or with limited space. It is a very simple, portable, and low-cost structure that allows familiarization with the system without a major commitment to materials. Additionally, this mini garden can be used as a germinator to start seedlings from seed, which can then be transplanted to the large wicking bed or other pots.

Materials for the germinator:

- ✓ Plastic box of approximately 55 L capacity, preferably food-grade (without toxic substances) and with wheels or handles for easy movement. For example, a polypropylene storage container.
- ✓ Expanded clay (20 L) for the drainage layer. Alternatively, volcanic gravel or other light inert substrate.
- ✓ Plumbing kit and connectors in smaller size: basically a reduced version of the previous system. PVC tubes of Ø16 mm can be used instead of 20 mm, with their corresponding elbows, tees, and bulkheads with 1/2"



thread. A small section of perforated flexible hose will serve as the bottom irrigation tube.

- ✓ Geotextile fabric to separate the clay from the soil (a piece large enough to cover the surface of the box).
- ✓ Universal substrate (about 40–50 L) for filling the box (it can be mixed with peat or perlite to lighten it if the box is movable).

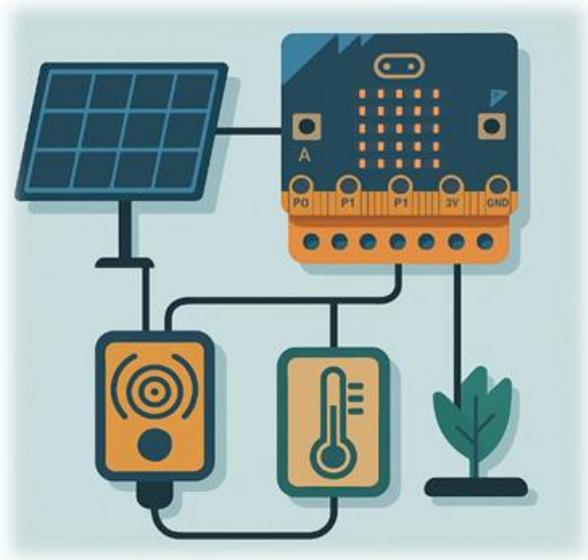
The assembly of this germinator is carried out in a similar way to the large wicking bed, adapting the dimensions: the wall of the plastic box is drilled to install a small lateral overflow tube (approx. 10 cm from the bottom, depending on the height of the box) and a small vertical tube is placed for water filling. At the bottom, the expanded clay is poured (about 10–15 cm forming the reservoir), then it is covered with the geotextile fabric and the substrate is added on top until filled. A perforated small tube distributed at the bottom (connected to the filling one) will ensure even irrigation. The water reservoir is filled through the vertical tube until it comes out of the overflow, and it's ready to use.

This small germinator is ideal for placing on a terrace or even indoors, near a window. It allows starting seedbeds by taking advantage of the wicking bed's self-regulating moisture: the seeds germinate in a substrate that is always moist but not waterlogged. Once the seedlings have grown sufficiently, they can be transplanted (with the root ball) to the larger garden or individual pots. Thus, the mini-wicking bed serves as a portable "nursery" and also as an educational demonstration: students or beginners can build it quickly and observe the germination cycle in a few weeks, while understanding the principle of capillary watering.



### 5.3. Environment Monitoring System with Micro:bit (DIY Weather Station).

To complement the previous cultivation systems, we propose setting up a small environmental monitoring station for gardens, using open-source and low-cost technology. The heart of this system is the BBC Micro:bit board, a compact microcontroller designed for learning programming, electronics, and computational thinking in an educational context. The Micro:bit includes integrated sensors (light, temperature, accelerometer, magnetometer), buttons, a LED matrix, and wireless connectivity, which allows for interactive projects with a very simple and accessible interface, even for absolute beginners.



In our case, Micro:bit was chosen for the monitoring station because it allows us to introduce basic concepts of programming and sensing in a practical and intuitive way, even with students without electronics experience. It also stimulates curiosity through direct experimentation, as participants can assemble and see their own environmental sensors work in real time. For this reason, Micro:bit has proven useful with children and young people at risk of social exclusion, as their projects are tangible and fun. Additionally, thanks to its flexibility, Micro:bit can be programmed both with visual languages like Scratch (the MakeCode environment) and in Python, adapting to different levels of competence and allowing progression to more advanced code when appropriate.

The weather station we propose will be powered by solar energy (photovoltaic panels + battery) and will be able to transmit the collected data in real time through a WiFi connection to a public website accessible at all times. In this way, local environmental data can be shared with the educational community or in citizen science projects.

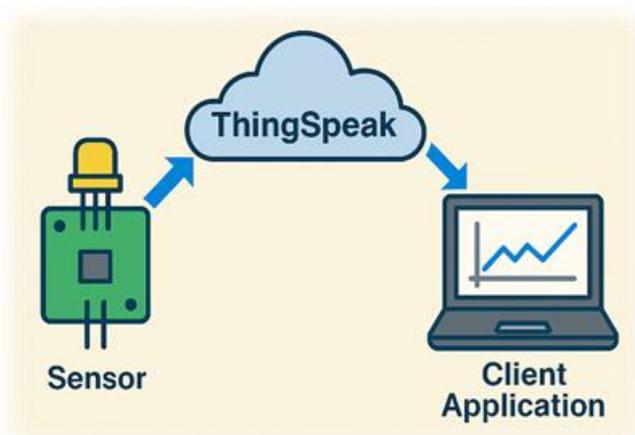
#### 5.3.1. IoT Kit (Internet of Things) for Micro:bit

To build a functional prototype for educational purposes, we opted for using an IoT kit designed for Micro:bit (in our case, the *ElecFreaks IoT:bit kit*). This kit includes a series of sensors, actuators, and communication modules that connect easily to the Micro:bit board, creating a device capable of collecting environmental data, processing it, and communicating it over the network.

The typical components of an IoT kit for Micro:bit are:

- ✓ Environmental sensors: for temperature, relative humidity, light, sound (noise), air quality (gas/CO<sub>2</sub>), soil moisture, atmospheric pressure, among others.
- ✓ Actuators: for example, a small buzzer for sound alerts, LED lights, or a mini relay to control external devices.
- ✓ WiFi module: generally based on an ESP8266 chip or similar, to connect the Micro:bit to the Internet via WiFi.
- ✓ Expansion board (shield) with battery support: the Micro:bit is inserted into this board, which provides additional ports and autonomous power. The IoT:bit expansion, for example, exposes all the Micro:bit pins to 3V on plug-type connectors and adds a real-time clock (RTC), an integrated WiFi module, and a battery slot, allowing for a long-lasting independent system.
- ✓ OLED display (in some kits): a small screen, typically 0.96" or 1.3", to display local data (temperature, etc.).
- ✓ Cables and quick-connection accessories (jumper connector cables, screws, etc.).

This kit will allow us to monitor environmental parameters in a garden or classroom (air temperature, humidity, solar light, noise level, soil moisture, presence of gases, etc.) and send data to cloud platforms (such as ThingSpeak, Blynk, IFTTT) to store them, visualize them graphically in real time, or activate alerts.



Additionally, it can receive remote

commands, for example, allowing a user from the Internet to turn on an actuator (such as an irrigation pump) if the humidity drops too low, or for the station to notify via IFTTT to the mobile when something happens (detected rain, etc.). Thus, we can create portable mini weather stations, automated irrigation systems, smart alarms (e.g., a buzzer that sounds if it's too hot in the greenhouse), etc.

### 5.3.2. Micro:bit Assembly



Each sensor or actuator connected to the Micro:bit behaves as a small circuit that always needs at least two connections: a positive power supply (VCC, generally 3V in the case of Micro:bit) and a ground (GND, earth). Additionally, in digital sensors, a third signal cable is required, which is responsible for transporting the data from (or to) the Micro:bit.

Some complex modules (for example, serial communication sensors I<sup>2</sup>C or SPI) may even require a fourth cable to synchronize clock signals or allow bidirectional communications, but in general terms, three cables are sufficient for most basic sensors. The IoT:bit expansion board mentioned previously facilitates these connections by providing triple ports (VCC-GND-Signal) ready to plug in sensors without the need to solder. Additionally, since Micro:bit operates at 3.3 V, all the chosen sensors work at that voltage, being within the maximum current that the microcontroller can supply without problems.

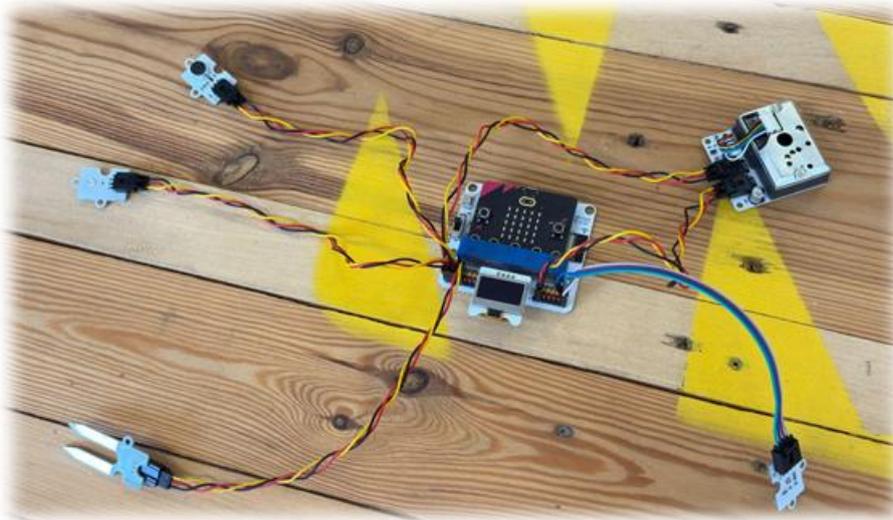
To program the Micro:bit, we use the official Microsoft MakeCode environment, available in a web version (<https://makecode.microbit.org>) and which can also be used offline. MakeCode allows programming with puzzle-like graphic blocks (very intuitive for beginners) or switching to text mode JavaScript/Python for greater control. Alternatively, it can be programmed in Python using editors like Mu or MakeCode itself in Python mode, which opens up more advanced possibilities if desired.

Our program for the station was developed in MakeCode using blocks. When the Micro:bit board starts up, the code performs the necessary initialization processes for the proper functioning of the entire system:

- Initializes the OLED screen (clearing any previous data and preparing the interface to display the readings).
- Establishes the WiFi connection using the integrated ESP8266 module, connecting to the local wireless network with the configured credentials (SSID and password).
- Configures the Micro:bit pins to communicate with each sensor (for example, establishing I<sup>2</sup>C communication with the temperature/pressure sensor, defining analog inputs for sensors if applicable, etc.).

After initialization, the main program enters an infinite loop that handles:

- Reading each sensor periodically (for example, every minute or the desired interval).
- Updating the OLED screen with the measured values (for example: 25°C, 60% HR, 1012 hPa, light 300 lx, noise 40 dB).
- Send the data to a web platform for logging. In our case, ThingSpeak was used, a free IoT service where data channels can be created. Through the ThingSpeak API, the Micro:bit sends an HTTP request after each reading with the new data, so they are stored in the cloud. Then, that data can be viewed in real-time graphs by accessing the public ThingSpeak channel or even embedded in a project website. (This process requires the Micro:bit to be connected to the Internet via WiFi. The IoT:bit board handles that, and MakeCode has extensions that simplify sending data to web services.)



#### **MORE INFORMATION**

If you want more information on how to assemble and program a Micro:bit system, you can check in the [Annex: Assembly and Programming of the Micro:bit System](#).

#### **5.3.3. Pedagogical Utility of Micro:bit**

This type of system is useful in education by introducing concepts of sensors, networks, and automation in a concrete way, which are usually abstract, turning them into something tangible that students can touch and understand. Additionally, its ease of programming through MakeCode (Microsoft's graphical editor for Micro:bit) or in Python allows starting with visual blocks and then progressing to writing code, adapting to the educational level (primary, secondary, vocational training, etc.).

Installing and connecting environmental sensors—such as dust particle sensors, luminosity, air temperature and humidity, soil humidity, atmospheric pressure, or noise—in a didactic context offers a real opportunity to make the normally invisible tangible. Students can collect local data from their school or community environment, learning on the go about air quality, microclimates, the water cycle, etc.

From a pedagogical point of view, students learn to read real-time data, reflect on phenomena such as air pollution or local climate changes, and link those observations to concrete actions for caring for and sustainable management of an orchard. While from a more technical or research perspective, the system enables comparing measurements at different points, observing seasonal or microclimatic variations, and verifying with data the effectiveness of interventions such as wicking beds compared to traditional methods.

In short, multi-sensor environmental monitoring, associated with a concrete and visible project like the orchard, contributes to "making the invisible visible": it shows how the interaction between environment and technology can generate new awareness and tools to address the current environmental challenges.



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