Guidelines on the design, realization, and management of hydroponic and community gardening systems

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SECTION 1 - GUIDELINES FOR COMMUNITY GARDEN

1. General indications for planners

Community vegetable gardens are an alternative solution to provide social and economic benefits to local farmers. Farmers can share investment costs, facilitating technology adoption, and increasing the market value of their produce. The introduction of water-saving technologies, such as drip irrigation and mulching, further supports the sustainability of these gardens, fostering the sustainability of agricultural systems against climate change. Furthermore, community gardens are a tool for mitigating social exclusion and empowering women. The technical implementation of a community garden should follow different steps, starting from finding the beneficiaries, understanding their objectives which are essential for the technical design of the garden, and finishing with the on-site construction management. The different steps are here resumed and represent a general guideline for municipalities and planners to implement community gardens in different sites.

1.1. Implementation steps

1. **Find beneficiaries involved**. The beneficiaries must be identified before the implementation of the garden, as the technical design will be affected by the number of potential farmers involved, as well as their age. Younger farmers, more typically in rural areas, can tolerate a lower (or even any) degree of mechanization and larger plots to access the market, while elder farmers, more typically in urban environments, could benefit from simple machines (for instance for tilling the soil) or might require smaller plots just for self-consumption.

2. **Find the site**. The site where to implement the garden should be as flat as possible, with little or no slope (<3%), and should be accessible and easy to reach from the beneficiaries. Agreements with local rural farmers available to host the community garden can be reached, although municipal and abandoned lands can also be adopted. In the latter case, pollution risk must be assessed. Heavy metals can potentially contaminate soils close to urban or industrial sites and can reflect the safety of vegetables, while rural soils are, in general, safer than urban soils. This consideration reflects both on the soil analysis and on agronomical

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choices. In the site, the water availability is essential: the presence of a well (or the possibility of digging one), or in urban or periurban areas, the use of tap water or the recollection of rainwater are alternatives that must be assessed. Once the site has been identified, the geographical coordinates must be recorded.

3. **Soil and water analysis**. Soil analysis is needed to understand the main characteristics of soil needed to support agronomical techniques. Soil must be sampled at a depth of 30 cm, which is the layer of soil where most vegetable roots grow. In a surface of 1 hectare (1 ha=10,000 m^2), 10 sampling points are considered sufficient. If the soil is abandoned, or not cultivated for a lot of time, the first layer (5-10 cm) of soil must be removed before the sampling, as it could falsify the result of the analysis (e.g., the organic matter content); if the soil is cultivated (e.g., in rural area), it is frequently mixed by the tillage, so removing the first layer of soil is not necessary. When sampling the soil, it is necessary to avoid those portions that are not representative (e.g., maintaining a distance of 5 meters from borders, drain lines, or trees is sufficient). Standard soil analysis must include: pH, electrical conductivity, organic matter, soil texture (clay, silt, sand content), carbonate content, total N, assimilable phosphorus, exchangeable potassium, microelements content (magnesium, copper, iron…), cation exchange capacity, C/N ratio. If pollution risk exists, then also heavy metal content is recommended. Water analysis should be carried out as well, checking the salinity (electrical conductivity), sodium and chloride, sulfate, (bi)carbonate, iron, magnesium, calcium, pH, suspended solids, nitrates and ammonium, and heavy metals.

4. **Identify the business model.** The business model of the garden must be identified as it can reflect on the technical design. This may imply a confrontation with potential farmers, assessing whether community gardens would mainly be used to access local markets or for self-consumption (reflecting, in turn, on the plot size). Here, eventual marketing strategies could be considered: association constitution, community garden logo, product transformation (e.g., local spices), and packaging.

5. **Technical design**. The technical design should define the plot size, the garden layout, the irrigation system layout, and its constructive characteristics, but also additional elements that could be useful for the livelihood of the garden (e.g., warehouse installation or a social area). The

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technical design must take into consideration not only the beneficiaries' number but also their objective. Farmers more oriented to the market would need a larger plot, while farmers more oriented to self-consumption could need a smaller plot. In general, 30-40 m^2 $plot^{-1}$ is sufficient for one person and for self-consumption, while the dimension could be extended up to 200-400 m^{-2} $plot^{-1}$ for farmers oriented to the market. In the latter case, working this area manually might require efforts that could no be sustainable in the long period, and simple and common machineries (handheld rototiller) could be purchased. The technical design should start from the coordinates to quantify the extension of the area, and Google Earth is a suitable and open-access tool for this task. Then, the cultivable area – including plots – and corridors must be identified, as well as the warehouse, the well, a site where to stock organic matter (e.g., compost), a nursery site where to produce seedlings to be transplanted (including a table, nursery trays, shading materials, and tank for storing the nutrient solution), and even a social area could be included if the budget allows for it. If the site is not equipped with electricity, then solar panels are needed to be installed to feed the irrigation.

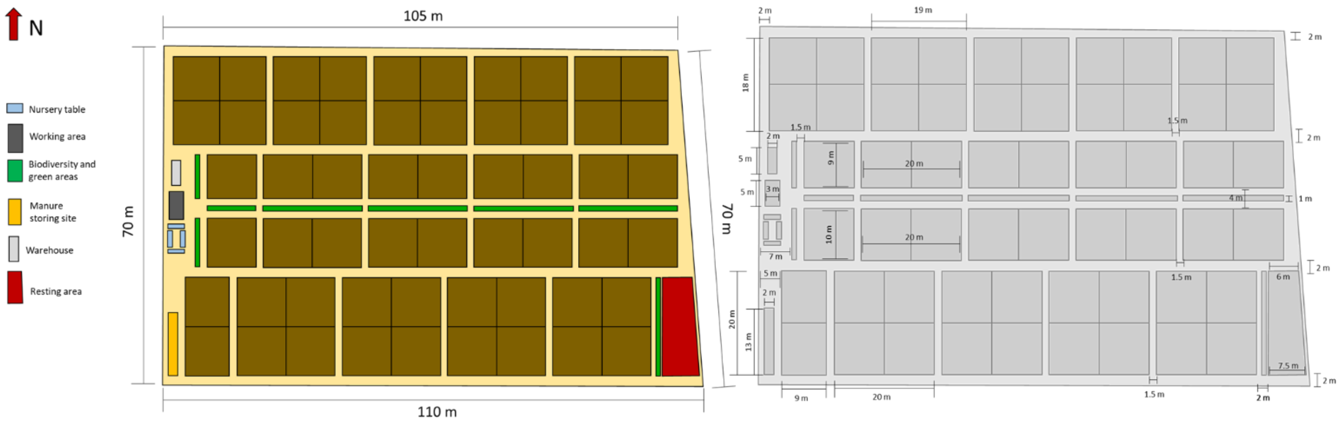

Figure 1 Example of a technical design of a community garden

6. **Material availability and quotation**. Once the technical design has been defined, material availability must be assessed, and a quotation must be obtained

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from local suppliers. Local suppliers could also provide technical support in technical planning, for instance, in defining the irrigation materials.

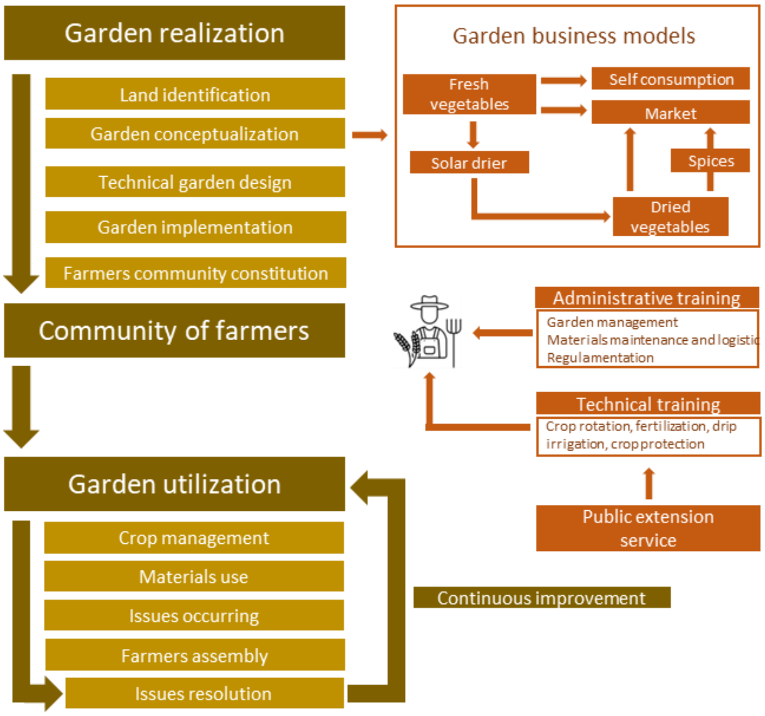

Figure 2 General workflow to plan, implement, and stimulate a community garden

7. **Work management**. First soil must be levelized (ensuring that soil moisture is optimal for any soil tillage, not too wet or dry). Then the areas where to install the different garden components have to be marked (warehouse, well, cultivable plots…). Finally, organic matter (e.g., compost and/or animal manure matured for at least 6 months) can be supplied to the soil at the rate of 2-3 kg m-2, and then the soil can be tilled at 30 cm before crop planting.

8. **Technical and organizational training.** Technical training is essential to make community gardens sustainable, especially if beneficiaries are not experts or familiar with agriculture. Crop rotation, drip irrigation, fertilization, manuring, mulching, and sustainable crop protection are essential training to be provided. Also, training related to organizational topics is warranted, especially if beneficiaries never collaborated in the association. Misunderstanding and issues associated with the community management of materials are warranted, and resolution of conflict strategies has to be considered as well. These might include

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the constitution of a farmer assembly that meets periodically and resolute conflicts fostering continuous improvement.

9. **Start the cultivation.** Farmers can start the cultivation utilizing training materials to support the agronomical choices and sustainably grow the garden. The farmers will participate in all the garden activities related to cultivation, management, and administrative activities. Respecting the rules, co-decided, is of utmost importance.

The present guidelines are a useful tool for planners and local agronomists to promote community gardens in cities and rural settlements, providing an overview of the workflow to adopt.

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SECTION 2 - GUIDELINES FOR HYDROPONIC GARDEN

2. Introduction

2.1. General background

The global population faces many challenges regarding food production, food security, food safety, and environmental health issues, mainly due to climate cycles and human adverse effects.

For centuries, rural areas were the main place where the population lived. However, people, especially young adults, moved to cities during the last century due to industrialization and urbanization trends. Accordingly, most of the global population lives in urban areas today. Furthermore, these migratory movements have transformed many people from producers to consumers.

World population growth, particularly in cities, climate change, global warming, and resource limitation, implies the need for innovative and more efficient food production to overcome the challenges in the food supply chain.

Urban farming is an innovative solution for producing food in cities largely based on semi-protected cultivation techniques adopting soilless systems. Advanced technologies for greenhouse production of vegetable crops or for automated circular hydroponic systems have been well developed and implemented in many parts of the world, particularly in developed countries. However, in many developing countries, farmers cannot adopt these systems due to their complex management and high initial investments. Therefore, simplified hydroponics must be introduced to local farmers with little experience or scarce investment capability.

On the other hand, urban farming can significantly contribute to the food supply and balanced nutrition of urban dwellers. In many parts of the world characterized by poor climatic or soil conditions, adopting simplified soilless systems can guarantee a constant production of fresh vegetables that can combat malnutrition. When resources like water or fertilizers are scarce or environmental conditions (e.g., temperature) can limit food production, simplified hydroponics may help maintain nutritious food production.

Fresh leafy vegetables are the main crops produced in such systems, although other crops like fruit, root, or stem vegetables can also be grown. Vegetables

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have a significant role in human diets, thanks to their capability to supply minerals and vitamins.

The local context of Fernena

Fernena is a small town in Jendouba province, north of Tunisia. The territory's morphology is mainly hilly, and arable crops are the most cultivated. Autumn-winter cereals (wheat, barley, and oat) often alternate with fava beans.

Figure 3 Typical rural landscape in Fernena (credit Cerasola V.)

The percentage of farms producing vegetables is very limited, which negatively affects the nutritional quality of local diets as vegetables are known to be rich in essential nutritional compounds. The lack of adequate technical means (agricultural machinery) and economic resources prevents the development of traditional on-soil horticulture in the intervention area. In addition, the morphology and topography of the area, characterized by large hills with steep slopes, are a strong technical obstacle to implementing traditional soil-based horticulture.

However, according to the first results of the survey conducted in WP3 (see D3.3), local farmers already have a high propensity to introduce new and more profitable crops with better nutritional profiles, and vegetable crops are capable of meeting this need.

Nonetheless, Fernena farmers are experiencing the effects of climate change, and the lack of water is among the biggest challenges they face. The increase in fertilizer costs and the unbalanced diet, mainly based on cereals, are further challenges that are difficult to overcome. Although vegetables are essential to

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meet the nutritional needs of Fernena farmers, they are highly demanding of water and fertilizers. Also, the drought risk already experienced by farmers leads to the search for new water-saving strategies.

Simplified hydroponic systems represent an innovative technology for the local context, capable of addressing the various technical and economic obstacles that limit vegetable production in local agricultural systems. The specific activities regarding implementing simplified hydroponic systems in Fernena will foster the principles of circular economy: in particular, the adoption of recycled and local materials (plastic bottles, local organic matter, and compost) is promoted. The present manual represents guidelines to support farmers in realizing a simplified hydroponic system.

2.2. Why simplified hydroponics?

Soilless or hydroponic cultivation is a technology for producing plants out of the soil. In hydroponic systems, plants' roots directly float in a nutrient solution or are supported by an inert substrate that can regularly be fed with a nutrient solution. Compared to traditional soil cultivation, hydroponic cultivation enables for an easier control of plant growth in a protected greenhouse or sheltered place. This system is a major adaptive innovation for urban and rural areas, where limited arable fertile soil is available, or in arid regions, where the soil is not fertile and cultivable. Such systems allow the cultivation of vegetables even in the absence of arable land, occupying small areas. They have low investment costs, as they are also made from recycled materials, and they are simple to manage, and easily replicable even without advanced technical knowledge. They have excellent water and fertilizer use efficiency, meeting the needs of the farmers of Fernena. Also, decoupling production from the soil reduces the need for pesticides to control soil-borne diseases.

The characteristics of a simplified hydroponic system are as follows:

- It takes the basic concepts of hydroponics but avoids the complicated, advanced, or automated technologies,
- Low cost for construction and maintenance,
- It is a technique that is easy to learn limited competencies and skills,
- It highly depends on low-cost and local recycled materials such as plastic bottles, wood, and disposables,
- It requires low energy inputs,
- It is a sustainable production system, with high water and mineral nutrients use efficiencies
- It enables mainly vegetable production.

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2.3. Simplified nutrient film technique (NFT) system

Different typologies of simplified hydroponic systems exist, but the present guidelines aim to show the implementation plan for the simplified nutrient film technique (NFT) system. This system consists of horizontal pipes where an electric pump pumps a thin layer of nutrient solution. The nutrient solution flows inside the pipes, slightly tilted at a 2% slope, and it is recollected by a drainage system that delivers it to the tank, where it is stored before being reused.

Figure 4 Simplified NFT system in Colombia (foto Michelon Nicola)

The system is composed of a few elements:

1) Irrigation system, composed of a tank, electric pump, irrigation pipes and connectors
2) A structural frame is composed of cylindric PVC poles where plants are transplanted (including final caps) and supporting materials to allow the poles to be raised in a horizontal orientation (plastic, iron, or wooden).

The system can also work in open air, but a shading net is necessary when the air temperature is excessive during summertime. This can be installed as a supplemental net in a greenhouse (as done in experience in Fernena) or as a building frame where only the shading net is installed on the roof without any plastic cover.

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Figure 5 Greenhouse on a rooftop in Tunisia (Credit Jamai D.)

2.3.1. Implementation steps

The pilot system consists of a greenhouse (3x8 m) containing 4 modular hydroponic systems, each containing 5-6 cultivation poles. A single tank is included and buried in the soil below one module, where the pump is submerged to feed all the hydroponic modules. An electric actuator (in red in Figure 2) is installed to set the irrigation recipe (the timing of irrigation and the timing of the drying period).

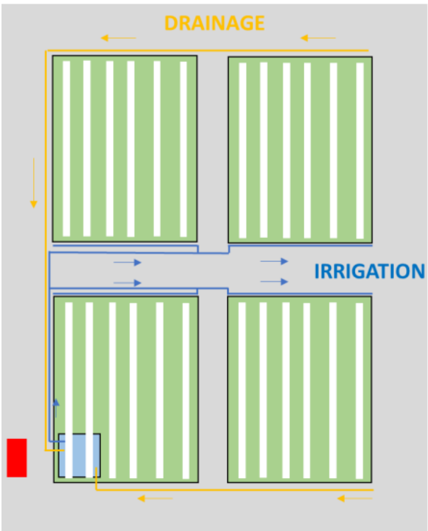

Figure 6 Design of a simplified hydroponic greenhouse

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The steps for the implementation of the simplified BFT system are resumed here:

1. **Design of the system and material purchase**: the system is designed according to the available space and dimensions required by the beneficiary, and the materials needed were quantified and purchased. The materials included: a greenhouse (3x8 m) covered with an insect-proof net (perimeter) and a shading net (on the roof); irrigation materials, iron for supporting frame, plastic white pipes for cultivation, pump, tank, electric actuator, electrical conductivity meter, pH meter, precision scale for nutrient solution realization, mineral fertilizers
2. **Soil levelling:** a flat area must be chosen (the flatter**,** the better), which must be levelized as much as possible. In this stage, a hole in the soil has to be realized where the future tank for the irrigation will be placed. Then, the soil should be covered with a plastic sheet to allow walkability inside the future greenhouse
3. **Greenhouse iron frame installation**: The iron frame that supports the greenhouse (e.g., the insect-proof net, the roof plastic cover, and the shading net) must be fixed to the soil.

Figure 7 Soil levelling and iron frame installation (Credit Jamai D.)

4. **Covering with the perimetral insect-proof and shading net.** The insect-proof net can be installed on the perimeter, while on the roof a plastic sheet is installed to further protect the electric actuator that will be subsequently installed. A removable shading net can be installed on the roof. Removing the shading net is essential; otherwise, it will affect plant growth during short daylight periods (winter).

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5. **Installation of the iron frame supporting the white poles for plant cultivation.** This iron frame must be installed to ensure a slight slope that does not exceed 2%. The slope can be checked with a bubble level. To reduce costs, plastic or recycled wooden pipes can also be used instead of iron.
6. **Placement of the channels for cultivation**. The white channels can be perforated with a drill to create the holes where the plants will be transplanted. In general, highly dense holes (with short sparring in between them) can be adopted, and empty holes can also ensure the planting density for lower-density crops (e.g., tomatoes). Once they are holed, they can be placed on the supporting iron frame.

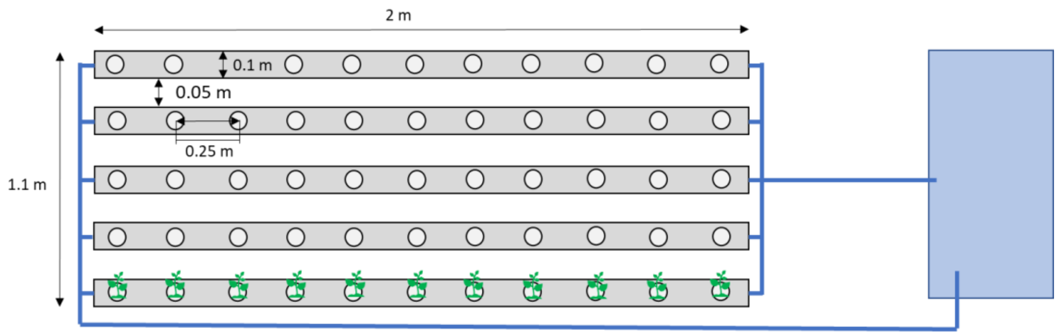

Figure 8 Top-view schematic representation of modular simplified NFT system

7. **Installation of the irrigation and drainage system**. The pump can be installed and connected to the irrigation system installed and connected to the different cultivation channels. Each channel will have only one outflow pipe that supplies the nutrient solution. The draining system will be installed on the other side of the channels to recover the nutrient solution and send it to the tank to restart the cycle.
8. **Installation of the electric actuator and connection to the pump**.
9. **Test of the system and transplant.**

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Figure 9 Farmer involved in transplanting lettuce during a training day (Credit Jamai D.)

Figure 10 The NFT system after 50 days of cultivation of romaine lettuce (Credit Cerasola V.)

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	Days												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Design of the system and material purchase	■	■	■	■	■	■	■	■	■	■			
Soil levelling								■	■	■			
Greenhouse iron frame installation											■		
Covering with the perimetral insect-proof and shading net											■		
Placement of the channels for cultivation												■	
Installation of the irrigation and drainage system												■	
Installation of the electric actuator and connection to the pump												■	
Test of the system and transplant													■

Figure 11 Gantt chart for the implementation of the simplified NFT hydroponic system

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