AQUAPONIC
PROJECT
PROPOSAL

L’ORTO DE LU SUD[1]

Terra mara e nicchiarica
vistuta de spine e de cramigna,
e a ‘gne vvanna
cime curve e ssiccate.

Fernando Rausa

Atuhor: Gianlorenzo De Santis
Photos and graphic design: Gianlorenzo De Santis
Icons: freepik.com

---

[1] From: Fernando Rausa, Terra mara e nicchiarica. Manni Editori, 2016.

PROJECT DESCRIPTION

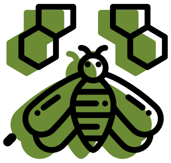
The project proposed is an integrated, agricultural system that is composed by a hydroponic and aquaculture (aquaponics) recirculating cycle, and a separate insect rearing unit.

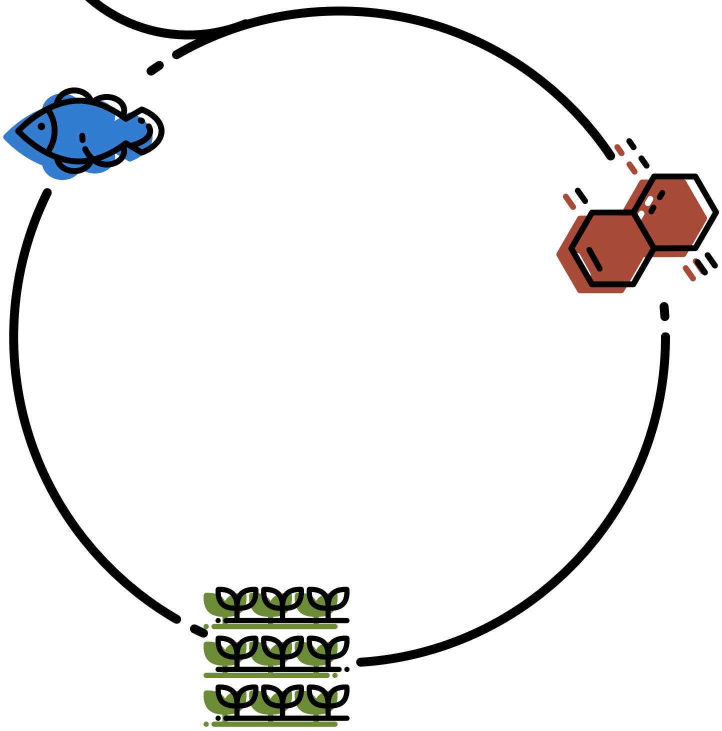
AQUAPONIC UNIT

Aquaponics is the integration of hydroponic plant production with aquaculture, two of the most productive methods in their respective fields (Somerville & FAO, 2015), combining them into a sustainable agricultural integrated and virtually closed system.

Such system uses the recirculating water from the fish rearing tanks, full of metabolic wastes, which are a source of nutrient, to aid the production of the selected crops in the hydroponic section, process that subsequently remove toxic substances for the fish. This creates a natural biological cycle that: 1) supplies nitrogen to the crops; 2)minimizes the use of non-renewable resources; 3) maximizes the value of by-products, thus providing economic benefits that can increase over time. (Masser, Rakocy, & Losordo, 1999; 2003, 2006; Tyson, Treadwell, & Simonne, 2011)

This integration has numerous advantages, that tackle key issues in the current, both global and local, agricultural landscape, and it is deemed by multiple prestigious sources (FAO *in primis*) as a viable, sustainable and efficient production system (Mullins, Nerrie, & Sink, 2015; Somerville & FAO, 2015).





WATER USE

The first evident benefit of using recirculating aquaculture systems (RAS) is the efficient use of its main resource, the water.

Water use is maximized, which means that its consumption is significantly reduced, in comparison to traditional agricultural and aquaculture systems. Different estimates account for water savings ranging from 80 to 90% (Somerville & FAO, 2015).

Furthermore, being a closed system, the input requirement is very low and it needs only to account, during standard operations, for the natural evaporation and for the plant uptake (Mullins et al., 2015; Pattillo, 2017; Rakocy et al., 2003; Somerville & FAO, 2015).

Water quality is, therefore, a vital aspect to monitor in such system and its parameters should be closely checked and adjusted.

SOILLES GROWING

The use of soilless agricultural solution has been on the surge in the last few years. Many hydroponic solutions are appearing day after day on the market. For example, this has been one of the main focus of the 2017 Seeds and Chips Global Innovation Summit held in Milan and that witnessed the presence of the 44th President of the United States, Barak Obama.

Avoiding using soil for crop production has direct positive impact on the soil itself.

An immediate consequence of this, is that the set-up of a RAS facility, in a relatively small area, does not require any preparation to the soil itself and it can be performed in zones where the composition or the fertility of the soil (non-arable, urban areas, degraded, with high salinity or even deserts) does not allow for traditional means of production (Georgia Pollard, James Ward, & Barbara Koth, 2017; Leoni, 2003; Somerville & FAO, 2015).

Nutrients are not dispersed in the soil, which means a better control and a better delivery rate of such nutrients to the plant. It drastically reduces the risk of harmful contamination of the soil, groundwater and the general environment. Furthermore, using this technique to produce crops, even in the case of intensive monoculture, does not degrade the soil, depleting its substance composition: a process called soil erosion, which it has been in the last decades one of the main environmental concern, especially in areas with high agriculture intensity (Atasu, 2016; European Commission & Directorate-General for Agriculture and Rural Development, 2006; Leoni, 2003; Somerville & FAO, 2015).

IMPROVED PRODUCTION AND YIELD

Production of crops and fishes is maximized, and the cost is contained.

Fish yield is improved, thanks to the higher fish density allowed by the recirculating water system, and due to the controlled rearing production environment, that can be maintained all year round, with minimized health risk (Bernstein, 2011; Pantanella, 2012; Timmons & Ebeling, 2007).

Crop yield as well is increased up to 100%, with respect to conventional horticulture (Resh, 2012) due to various factors(Bailey & Ferrarezi, 2017; Leoni, 2003):

- Higher plant density, which is possible in soilless cultivation, thanks to lack of nutrient competition between crops.
- Better environmental and climate control of the growing conditions, which also leads to a better quality, more marketable, products.
- Shorter production cycles and higher number of harvest per year.
- Less (near zero in optimal condition) impact of external pathogens.

These benefits lead to an overall better production efficiency: for example, in the case of tomatoes 95% of produce reaching harvesting maturity, with respect to the 75% of traditional techniques.

OPERATING COST AND LABOUR

Even if an aquaponic system requires a constant monitoring, with relative adjustment to the requirement of its various components (mainly water quality and filter efficacy checks, fish feeding), it is deemed to have very light labour requirements.

Furthermore, many of the main daily operations required could be easily, alongside a slightly higher initial investment, automated and digitalized. Especially regarding the monitoring operation, resulting in significant labour intensity and time savings (Mason, 2011; Somerville & FAO, 2015).

ORGANIC BY DEFAULT

By its own intrinsic characteristics an aquaponic system is inherently organic by default and it easily maintained so. Particularly regarding the water PH, through organinc allowed substances (European Commission & Directorate-General for Agriculture and Rural Development, 2017).

Makign it easy to obtain the organic certification, which will improve the final prodcut overall value and its market potential.

GREENHOUSE ROUTE

There are various viable way to implement such system, but one of the most diffused (Love et al., 2014, 2015) is the enclosure of the entire plant into a greenhouse. This poses varius benefits. It allows for example for a higher degree of environmental control allowing year-round growth at optimum rates (Masser et al., 1999) increasing at the same time the level of Biosecurity and lower risk from outer contaminants (Somerville & FAO, 2015).

REDUCING THE INPUT

Water, energy, and fish feed are the three largest physical inputs for aquaponic systems (Love et al., 2014).

As already mentioned, the water input, in optimal conditions, is minimal (one of the key benefit of such systems).

As for the energy input, it is key for the survival of the entire system. it is required continuously for the correct function of the water and air pumps that keep the recirculating system flowing. This input requirements can increase if the system also uses additional mean to control the growing environment: for example, growing lights and temperature and airflow system in greenhouses. However energy input cost can be reduced, at the expense of a slightly higher initial investment, by employing alternative, sustainable, energy sources (solar, wind, biofuel, etc…). A more desirable choice because it helps to further reduce the carbon footprint and contributes to the overall added value of the final product (Bernstein, 2011; Pantanella, 2012; Pattillo, 2017; Somerville & FAO, 2015; Tyson et al., 2011).

The last input required, therefore a component of the operating cost, is the fish feed. Feed is essential because is the source of all the nutrients (principally nitrogen) used by the system, substituting more expensive commercial hydropponic nutrient solutions. It needs to be carefully quantified to fit the system requirements and it represents one of the most expensive input. Here is where the insect rearing component of the project becomes relevant:

> “Insects are a healthy nutrient source because they are rich in protein and polyunsaturated fatty acids and full of essential minerals.”
> (Somerville & FAO, 2015)

And they can be used to substitute or complement the fish feed, drastically reducing this portion of the operating cost. (Engle, 2015; Graber & Junge, 2009; Charlotte L.R. Payne, Scarborough, Rayner, & Nonaka, 2016; Somerville & FAO, 2015)

INITIAL INVESTMENT

After listing the benefit of aquaponics, it is appropriate also to mention that, plausibly, the major barriers to the implementation of these systems: the first is the higher initial set up cost, in confront to traditional agricultural techniques; the other is the moderate energy input required, which is alreadu been adressed in the previous section (Engle, 2015; Love et al., 2015; Pattillo, 2017; Rakocy et al., 2003).

The initial investment is typically paid back in 3 to 4 years (Nelson & Pade, 2010a, 2010b). There are various means aimed to reduces and contain the cost of such investment: for example, renting existing greenhouse (which is usually the most expensive component of an aquaponics installation) could reduce the payback time up to just 1 year (portfarms, 2016); another possible way is to design the system with a modular approach (using the NFT[1] method) in mind, to be able to more easily upscale at a later time (Georgia Pollard et al., 2017; Pattillo, 2017).

1. Nutrient film technique. It consists of narrow plastic channels for plant support with a film of nutrient solution flowing through them.(Rakocy, Masser, & Losordo, 2003)

REFERENCES

Atasu, A. (Ed.). (2016). Environmentally Responsible Supply Chains (Vol. 3). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-30094-8

Bailey, D. S., & Ferrarezi, R. S. (2017). Valuation of vegetable crops produced in the UVI Commercial Aquaponic System. Aquaculture Reports, 7, 77–82. https://doi.org/10.1016/j.aqrep.2017.06.002

Bernstein, S. (2011). Aquaponic gardening: a step-by-step guide to raising vegetables and fish together. Gabriola Island, BC: New Society Publ.

Engle, C. R. (2015). Economics of Aquaponics. SRAC Publication, 5006.

European Commission. (2017). Report on the implementation of the Circular Economy Action Plan. Retrieved from http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

European Commission, & Directorate-General for Agriculture and Rural Development. (2006). The Leader approach: a basic guide. Luxembourg: EUR-OP.

European Commission, & Directorate-General for Agriculture and Rural Development. (2017). "BASIC SUBSTANCES" THAT MAY BE USED IN ORGANIC AGRICULTURE IN ACCORDANCE TO ANNEX II OF COMMISSION REGULATION (EC) No 889/2008. Retrieved from https://ec.europa.eu/agriculture/organic/sites/orgfarming/files/basic_substances_approved_in_organic_agriculture.pdf

European Network for Rural Development. (2017). Green Economy opportunities for rural Europe - For, Europe - 2017.pdf. EU RURAL REVIEW, (23).

Georgia Pollard, James Ward, & Barbara Koth. (2017). Aquaponics in Urban Agriculture: Social Acceptance and Urban Food Planning. Horticulturae, 3(2), 39. https://doi.org/10.3390/horticulturae3020039

Graber, A., & Junge, R. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. Desalination, 246(1–3), 147–156. https://doi.org/10.1016/j.desal.2008.03.048

Leoni, S. (2003). Colture senza suolo in ambiente mediterraneo. Bologna: Edagricole.

Love, D. C., Fry, J. P., Genello, L., Hill, E. S., Frederick, J. A., Li, X., & Semmens, K. (2014). An international survey of aquaponics practitioners. PloS One, 9(7), e102662.

Love, D. C., Fry, J. P., Li, X., Hill, E. S., Genello, L., Semmens, K., & Thompson, R. E. (2015). Commercial aquaponics production and profitability: Findings from an international survey. Aquaculture, 435, 67–74. https://doi.org/10.1016/j.aquaculture.2014.09.023

Mason, J. (2011). Commercial hydroponics. Gold Coast: ACS Distance Education. Retrieved from https://www.overdrive.com/search?q=BC5CB979-6D6E-42DE-8597-044B72B0433F

Masser, M. P., Rakocy, J., & Losordo, T. M. (1999). Recirculating aquaculture tank production syste ms. SRAC Publication, 452.

Matsumoto, M., Masui, K., Fukushige, S., & Kondoh, S. (Eds.). (2017). Sustainability Through Innovation in Product Life Cycle Design. Singapore: Springer Singapore. https://doi.org/10.1007/978-981-10-0471-1

Mullins, C., Nerrie, B., & Sink, T. D. (2015). Principles of Small-Scale Aquaponics. SRAC Publication, 5007, 1– 8.

Nelson & Pade. (2010a, 2017). Investment / ROI | Nelson & Pade, Inc. Retrieved November 6, 2017, from https://aquaponics.com/business-opportunities/investment-roi/

Nelson & Pade. (2010b, 2017). What is the ROI on a commercial aquaponics venture? | Nelson & Pade, Inc. Retrieved November 6, 2017, from https://aquaponics.com/ufaqs/what-is-the-roi-on-a-commercial-aquaponics-venture/

Pantanella, E. (2012). Nutrition and quality of aquaponic systems (Phd). Univesità degli Studi della Tuscia, Viterbo.

Pattillo, D. A. (2017). An Overview of Aquaponic Systems: Hydroponic Components.

Payne, C. L. R., Scarborough, P., Rayner, M., & Nonaka, K. (2016). A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. Trends in Food Science & Technology, 47, 69–77. https://doi.org/10.1016/j.tifs.2015.10.012

portfarms. (2016, December 10). Renting Greenhouses for 1 year Return on Investment. Retrieved November 6, 2017, from https://portablefarms.com/2016/1-year-roi-aquaponics/

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2003). Aquaponics—Integrating Fish and Plant Culture. SRAC Publication, 454(16), 1–16.

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006). Recirculating aquaculture tank production systems: aquaponics—integrating fish and plant culture. SRAC Publication, 454, 1–16.

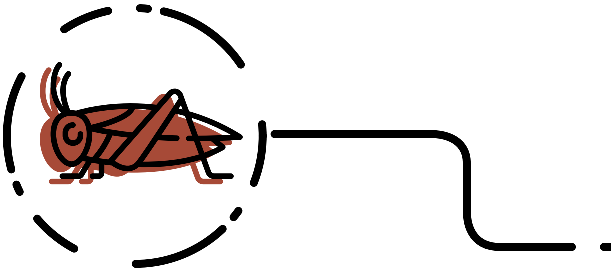
Resh, H. M. (2012). Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower. CRC Press.

Somerville, C., & FAO. (2015). Small-scale aquaponic food production: integrated fish and plant farming. Food and Agriculture Organization of the United Nations.

Timmons, M. B., & Ebeling, J. M. (2007). Recirculating aquaculture.

Tyson, R. V., Treadwell, D. D., & Simonne, E. H. (2011). Opportunities and challenges to sustainability in aquaponic systems. HortTechnology, 21(1), 6–13.

van Huis, A. (2013). Edible insects: future prospects for food and feed security. Rome: Food and Agriculture Organization of the United Nations.



INSECT REARING UNIT

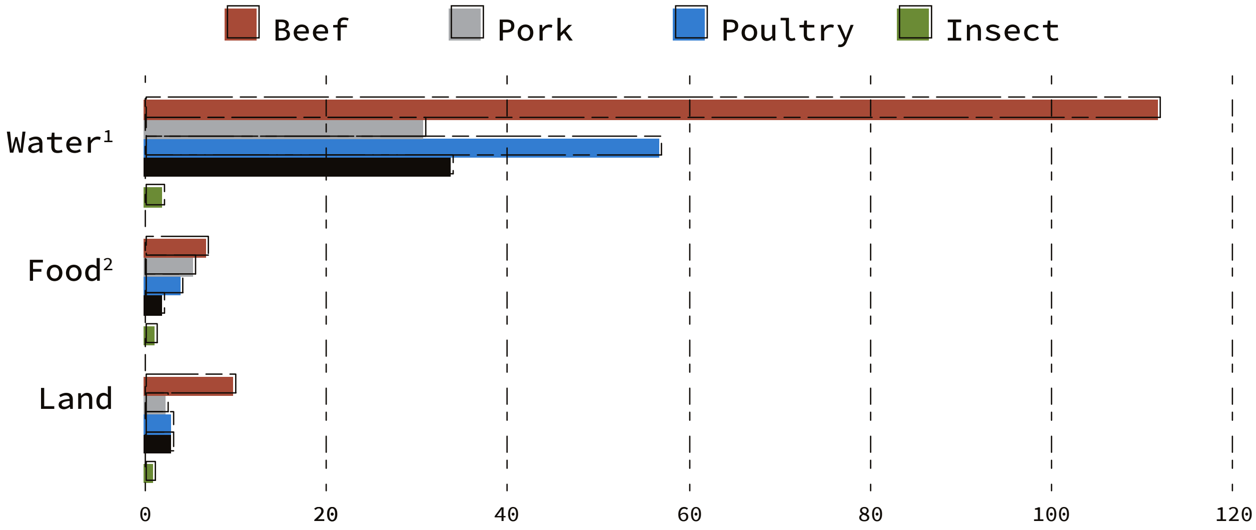
Insects have been identified as one of the few sustainable alternatives capable of feeding the planet in the future. And their adoption in the “West World” is growing slowly, but steadily, with a sudden surge of interest in the last few years, trend that is believed to endure (De Santis, 2016).

Aquaculture, as a source of fish supply for human consumption, in the last 3 decades, increased its share compared to wild capture, fulfilling up to about 50% of the global fish demand (FAO, 2016; van Huis, 2017).

To support this unprecedented growth there has been a corresponding rise in the demand, production, and price of fish meal. Fsih meal comes primarily from discarded fish stocks of wild caught marine fish, which, is one of the leading reason behind the incumbent issue of overfishing and marine biodiversity erosion (Dossey, Morales-Ramos, & Rojas, 2016, Chapter 1; FAO, 2016; van Huis, 2017, Chapter 1). Fish meal is used not only in aquaculture but also in many other traditional livestock farming (Poultry and swine mainly). A lot of effort is beign put to find an alternative, more sustainable(both economically and environmentally), feed source that needs to be rich in protein and lipids. And insects, in particular species like house flies, black soldier flies, and crickets (Dossey et al., 2016; van Huis, 2017) have been identified as one of the most promising, sustainable, substitute or complement to fish meal and their viability as animal feed has been evaluated in may studies. (Dossey et al., 2016; FAO, 2016; van Huis, 2017; van Huis, Dicke, & van Loon, 2015).

Their feasibility is especially a direct consequence of their high protein and lipid content which is essential to the fish development and meat quality(Dossey et al., 2016; Surendra, Olivier, Tomberlin, Jha, & Khanal, 2016; van Huis, 2013a, 2013b, 2017).

Next are explained some of the more significant benefits of using insects as a protein source: the first three, tightly connected to each other, have a more specifically environmental dimension, while the last three also are associated with compelling economic advantages.



Source: Dossey et al. 2016

1. Liters per Gram of Protein

2. Grams of Food Input per 1 g Body Mass

LAND USE

As mentioned before, a better management of the land and soil's resources, is a key factor in building a more sustainable future.

> "Food production takes up almost half of the planet's land surface and threatens to consume the fertile land that still remains"
> (Dossey et al., 2016)

Insects can easily be reared in controlled, indoor, environments that make extremely efficient use of the vertical dimension, increasing the productivity per m^2 and avoiding the erosion and exhaustion of fertile soil.

To yield, for example, an analogue quantity of protein produced in 1 ha of land by mealworm rearing, milk protein would require 2.5 ha, chicken and pork around 2–3.5 ha, and beef requires up to 10 ha (van Huis, 2013a).

GAS EMISSION REDUCTION

In comparison to others conventional livestock farming, insect rearing produces far less ammonia and greenhouse gases (Dossey et al., 2016; Payne, Scarborough, Rayner, & Nonaka, 2016; van Huis, 2013a, 2017; Yen, 2015).

Estimates differ from species to species, but insects perform overall better regarding emissions. Ammonia levels, due to insect farming, are lower than for pigs and beef cattle. For example, crickets (Acheta domesticus), which are associated with the highest ammonia emission, still produce just around the 10% of the ammonia produced by pigs (calculated as mg of ammonia per kg of mass gain) and an irrisory amount compared to beef, which produce 2 to 3 times more than pigs. Crickets, moreover, along with migratory locusts (Locusta migratoria) and yellow mealworms (Tenebiro molitor) (which are currently three of the most reared species intended for food and feed), do not produce methane (van Huis, 2017).

WATER SAVING

The water use, also, in comparison to other livestock, is drastically reduced as insects obtain their water directly from food and have a lower feed requirements (Dossey et al., 2016; Sogari, 2015; van Huis, 2013a). When we consider the water needs per gram of protein, this is smaller even compared to plants (Costa-Neto, 2014; Shelomi, 2015; Soares & Forkes, 2014) Lower water usage also reduces the energy needed to pump or recycle more clean water for crops and vertebrate livestock (Dossey et al., 2016).

SHORT CYCLES

From a more economic point of view, the main benefits of insect rearing are that their short life cycles and their extreme efficiency in transforming feed into protein and nutrients (which is also, as said, one of the reason for their water use efficiency (van Huis, 2017)), which is particularly important, as “an increased demand for meat will cause a more than proportional demand for grain and high-protein feeds” (van Huis, 2013b).

This short life cycle, which it can also be further optimized in a controlled environment, means an improved productivity, which, along with their general inexpensiveness and relative easiness to rear, makes insect very cost effective to farm.

Estimates show that crickets are twice as efficient as chickens, 4 times more efficient than pigs and 12 times more than cattle. Therefore insects can operate as very efficient recyclers of organic waste into biomass of high nutritional value (Surendra et al., 2016). This means that many insects species can be reared with almost no additional feed crop production (Dossey et al., 2016).

FEED CONVERSION EFFICIENCY

> “The environmental benefits of rearing insects for food and feed are founded on the high feed conversion efficiency of insects.”
> (van Huis, 2013a)

Using as a parameter the Feed Conversion Efficiency, which simply is expressed as kg of mass gain per kg of feed input, the evidence says that crickets require only 1.3–1.8 kg of feed for every 1 kilogram of bodyweight gain., while 12.7, 5.9, and 1.7–2.3 kg of dry feed is needed fo beef cattle, pigs, and chickens, respectively, which means that they have an higher efficiency than any of the common livestock: more than twice higer than in chicks, 3 times higher than in pigs, 5 times higher than in sheep, and nearly 6 times higher than in cattle. (Lundy and Parrella, 2015).

Similarly, protein conversion efficiency in house crickets is 23–35% , compared to the 5, 13, and 25% in beef cattle, pigs, and chickens, respectively (Dossey et al., 2016; Lundy & Parrella, 2015; van Huis, 2013b). This drastically reduce the amount of the feed input and, therefore, the production cost of high quantity and quality of this source of proteins.

ORGANIC SIDE STREAMS

One of the most important feature of insect rearing is the possibility to use organic side-streams, which can help reduce environmental contamination and tackle the issue of food waste. Globally, one-third of all food produced is wasted, amounting to 1.3 billion tons per year. (van Huis, 2013a, 2013b).

Organic side streams are teh result of bio-waste produced by agriculture, forestry, and households. Their use can aid in the reduction of the already low costs and environmental impact, of large-scale insects rearing and can create an alternate potential income for agri-businesses. (Nadeau, Nadeau, Franklin, & Dunkel, 2015)

Black soldier fly (Hermetica illucens), the common housefly (Musca domestica) and the yellow mealworm (Tenebrio molitor) are very efficient species at bio converting organic waste, but other insect species, such as crickets, can benefit as well from the substitution of feed with high quality organic side streams, like household and local market vegetable leftovers, which can help to make their farming more profitable (van Huis, 2013a).

FUTURE DEMAND

In 2018 shall enter into force the EU regulation on Novel Foods (EU, 2015), thanks to which insects food products, along with other food innovation (i.e. algae based products), will be freely produced, sold and bought in all the EU states, with all the food safety guaranties that the EU and the EFSA provide.

In the last few years there has been an unrelenting growing interest in this field accompanied by increasing investments: in America, millions of dollars have been already raised by insect food and farming companies (Klint Finley, 2016) and January (2017) the Netherlands-based insect farming enterprise Protix, a has raised €45 million, which is the largest investment on edible insects to date (Burwood-Taylor, 2017). Furthermore, such products are already present in the market (Repubblica.it, 2017).

CIRCULAR ECONOMY

One of the additional aim of the proposed integrated system is to adhere and take advantage from the growing global interest and current shift toward the Circular Economy. A circular economy promotes sustainable development by stimulating reduction of waste and enhancement of resource efficiency (Matsumoto, Masui, Fukushige, & Kondoh, 2017). Circular economy aims to ‘design out’ waste: Waste does not exist and products are designed and optimised for a cycle of disassembly and reuse.(MacArthur, 2013)

The agricultural sector is under pressure to obtain higher yields with less input, implementing alternative designs aimed toward a viable and sustainable agriculture. Furthermore, insects can be used as bio converter and they can grow on organic waste, following the Circular principles. (van Huis, 2013a)

The EU is significantly involved into promoting this shift: under the “Jobs, growth and investment” Priority, one of the three main policy areas is the move “Towards a circular economy”, defined as: “helping European businesses and consumers make the transition to a stronger and more circular economy where resources are used in a more sustainable way”. (European Network for Rural Development, 2017)

In particular, “Key actions have been undertaken in areas such as food waste, ecodesign, organic fertilisers, guarantees for consumer goods, and innovation and investments. Circular economy principles have also been gradually integrated in industrial best practices, green public procurement, the use of cohesion policy funds, and through new initiatives in the construction and water sectors.”

“Food waste is a key area in the circular economy and should be addressed at many levels along the value chain. The Commission has delivered on a number of actions supporting the fight against food waste and the achievement of the related Sustainable Development Goal in this area. It launched a stakeholder’s platform on food waste prevention, made progress in developing an EU methodology to measure food waste, and prepared EU guidelines to facilitate food donations and the use former foodstuff as feed”
(European Commission, 2017)

REFERENCES

Burwood-Taylor, L. (2017, June 14). Protix Raises $50m in Largest Insect Farming Investment on Record. Retrieved November 10, 2017, from https://agfundernews.com/protix-raises-50m-in-largest-insect-farming-investment-on-record.html

Costa-Neto, E. M. (2014). Insects as human food: an overview. Amazônica-Revista de Antropologia, 5(3), 562–582.

De Santis, G. (2016). Qualitative Research on the Attitudes toward Consumption of Insect Based Flours and Powders (Master Thesis). University College Cork, Cork, Ireland.

Dossey, A. T., Morales-Ramos, J. A., & Rojas, M. G. (Eds.). (2016). Insects as sustainable food ingredients: production, processing and food applications. London, United Kingdom ; San Diego, CA, United States: Elsevier/AP, Academic Press is an imprint of Elsevier.

EU. (2015). Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001. Official Journal of the European Union, 58(L 327), 28.

European Commission. (2017). Report on the implementation of the Circular Economy Action Plan. Retrieved from http://ec.europa.eu/environment/circular-economy/implementation_report.pdf

European Network for Rural Development. (2017). Green Economy opportunities for rural Europe - For, Europe - 2017.pdf. EU RURAL REVIEW, (23).

FAO (Ed.). (2016). The state of world fisheries and aquaculture: Contributing to food security and nutrition for all. Rome.

Klint Finley. (2016, July 3). You'll Eat Bugs. These Investors Are Betting Millions on It. Retrieved November 10, 2017, from https://www.wired.com/2016/03/investors-bet-millions-wont-balk-eating-bugs/

Lundy, M. E., & Parrella, M. P. (2015). Crickets Are Not a Free Lunch: Protein Capture from Scalable Organic Side-Streams via High-Density Populations of Acheta domesticus. PLOS ONE, 10(4), e0118785. https://doi.org/10.1371/journal.pone.0118785

MacArthur, E. (2013). Towards the circular economy.

Matsumoto, M., Masui, K., Fukushige, S., & Kondoh, S. (Eds.). (2017). Sustainability Through Innovation in Product Life Cycle Design. Singapore: Springer Singapore. https://doi.org/10.1007/978-981-10-0471-1

Nadeau, L., Nadeau, I., Franklin, F., & Dunkel, F. (2015). The Potential for Entomophagy to Address Undernutrition. Ecology of Food and Nutrition, 54(3), 200–208. https://doi.org/10.1080/03670244.2014.930032

Payne, C. L. R., Scarborough, P., Rayner, M., & Nonaka, K. (2016). Are edible insects more or less 'healthy' than commonly consumed meats? A comparison using two nutrient profiling models developed to combat over- and undernutrition. European Journal of Clinical Nutrition, 70(3), 285–291. https://doi.org/10.1038/ejcn.2015.149

Repubblica.it. (2017, August 14). Svizzera, insetti da mangiare in arrivo nei supermercati Coop. Retrieved November 10, 2017, from http://www.repubblica.it/sapori/2017/08/14/news/svizzera_insetti_da_mangiare_in_arrivo_nei_supermercati_coop-173049651/

Shelomi, M. (2015). Why we still don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework. Trends in Food Science & Technology, 45(2), 311–318. https://doi.org/10.1016/j.tifs.2015.06.008

Soares, S., & Forkes, A. (2014). Insects Au Gratin - An Investigation into the Experiences of Developing a 3D Printer that uses Insect Protein Based Flour as a Building Medium for the Production of Sustainable Food. In E. Bohemia, A. Eger, W. Eggink, A. Kovacevic, B. Parkinson, & W. Wits (Eds.), Design education & human technology relations: proceedings of the 16th International Conference on Engineering and Product Design Education, University of Twente, Enschede, The Netherlands, 4th-5th September 2014. Glasgow, United Kingdom: The Design Society.

Sogari, G. (2015). Entomophagy and Italian consumers: an exploratory analysis. Progress in Nutrition, 17(4), 311–316.

Surendra, K. C., Olivier, R., Tomberlin, J. K., Jha, R., & Khanal, S. K. (2016). Bioconversion of organic wastes into biodiesel and animal feed via insect farming. Renewable Energy, 98, 197–202. https://doi.org/10.1016/j.renene.2016.03.022

van Huis, A. (2013a). Edible insects: future prospects for food and feed security. Rome: Food and Agriculture Organization of the United Nations.

van Huis, A. (2013b). Potential of Insects as Food and Feed in Assuring Food Security. Annual Review of Entomology, 58(1), 563–583. https://doi.org/10.1146/annurev-ento-120811-153704

van Huis, A. (Ed.). (2017). Insects as food and feed: from production to consumption. The Netherlands: Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-849-0

van Huis, A., Dicke, M., & van Loon, J. J. A. (2015). Insects to feed the world.

Yen, A. L. (2015). Foreword: Why a Journal of Insects as Food and Feed? Journal of Insects as Food and Feed, 1(1), 1–2. https://doi.org/10.3920/JIFF2015.x001

OPPORTUNITY FOR PUGLIA

WATER MANAGEMENT

Some of most known hypothesis regarding the etymological origin of “Apulia” state that the term originates from “without water” or “thirsty” land (darapri.it, 2017), which is reflected on the fact that Apulia is the Italian region with the lowest rainfall average value (i.e. about 660 mm)(Lopez & Vurro, 2008).

So even in the name itself water has always been an issue for this territory, which is characterised by an inherent lack of bodies of water, and already categorized as a semi-arid; circumstance that stays particularly critical because of its agricultural disposition: Puglia has most of agricultural related business of any other Italian region, with a significant percentage share: 16.8% of the national total (ISTAT, 2013). In Puglia, and in Salento especially, almost the entirety of the plots of land dedicated to agricultural activity are rural with many development barriers and most of its water resources are supplied from groundwater: around 75% is supplied by private well (Lopez & Vurro, 2008; Masciopinto, La Mantia, & Chrysikopoulos, 2008; Regione Puglia, 2014).

Climate change is already affecting the frequency of drought events which may threaten the current stocks of water resources and thus the availability of freshwater for irrigation (Lopez & Vurro, 2008). This happens, not only at a regional level, but it has a national and global scale. In the last years, the occurrence and the magnitude of draughts and water scarcity in Italy it is becoming more and more frequent and severe: pertinent is the current problematic condition, that gained a vast media coverage in the summer 2017, of lake Bracciano, which is the main water resource of the Lazio Region (ISPRA, 2017a).

The region governance already recognizes this as one of the most critical aspect of its agricultural development. In the regional rural development plan (Regione Puglia, 2014) it is clearly acknowledged that the efficient consumption of the water resources in agriculture, which uses 55% of the total availability, is one of the main priority (Priority 5, Area A) in the future regional development.

Therefore, one of the key requirement to improve Puglia’s agricultural landscape is to:

> “Modernize irrigation equipment and techniques (including conventional and non-conventional water storage structures); facilitating productive conversion towards species or cultivars with reduced water needs according to territorial compatibility and through changes in farm plans and farm systems.”
> (Regione Puglia, 2014)

To which the integrated system here proposed completely adheres. The 90% savings, considering equal productivity, that this system provides could be crucial to contrast the impelling issue of Puglia water scarcity, enhancing the overall regional water efficiency, and, at the same time, maintain and further expand Puglia’s competitiveness, at a national and global level, in its main economic sector.

WATER IN PUGLIA

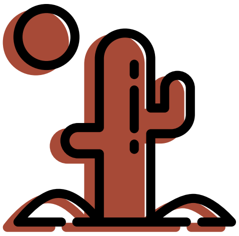
At national level Puglia owns the smallest amount (136 m3/capita/y) of potentially available water. The agricultural (and touristic) vocation of the region is only possible thanks to the local water agency (AQP) that imports water from bordering regions such as Campania, Lucania and Molise. Every year in Puglia around 1.500 Mm3 (Cubic Megametres) of water are consumed of which around 54% (812 Mm3) are dedicated to agricultural activities (while 36% as drinking water 10% for industrial use). This water comes from the 55% from the local regional delicate aquifers. Percentages that rise significantly during water crisis and draughts. The reuse of agricultural (or else) wastewater is still very marginal. Such water crisis and draughts are periodical, and their severity is becoming more worrying year after year.

The extension of Puglia's irrigated land stands at 240.000 ha, equal to 18,6% of the overall UAA, spread on 67.000 farms. The main mean of irrigation is the use of drip irrigation systems, followed by sprinkling (respectively 52% and 32% of the total), which underlines a existent effort to rationalise the agricultural water use in the region.

(Lopez & Vurro, 2008; Regione Puglia, 2014)

Tricase
Marittima,
Lecce Province,
Italy.

This project aims also to promote an overall increase of innovation approach to the territory's issues, in adherence to the EU rural development policies and akin to the vison outlined by the European Commission in their LEADER approach which designed to produce more profound innovations in local contexts, in fact "it can play an important role in **encouraging innovative responses to old and new rural problems**, and becomes a sort of 'laboratory' for building local capabilities and for testing out new ways of meeting the needs of rural communities".(European Commission Directorate-General for Agriculture and Rural Development, 2006; Labianca, De Rubertis, Belliggiano, & Salento, 2016)



SOIL MANAGEMENT

Soil is increasingly degrading, both in the EU and at global level, (European Commission, 2016) and soil erosion by water is one of the most widespread forms of soil degradation in Europe (Eurostat, 2017).

As mentioned, a great share of the water used by the agricultural sector (75%) in Puglia, comes from private wells, which is the traditional source of water supply in the region. This drawing of groundwater is, unfortunately, considerably uncontrolled and not properly governed, with severe consequences on the progressive salinization of the aquifers and the soil. (Regione Puglia, 2014).

Puglia soil erosion degree (8%, 2016 data) is slightly higher of the national average, also vdue to the high impact of monoculture. Between 2015 and 2016 414 ha of land have been lost, 1 m2 every 5 second. Estimates says that for each inhabitants there is 400 m2 of spent soil and, in Salento especially, numerous municipality have spent soil for 20% of their entire area (ISPRA, 2017b; Regione Puglia, 2014).

The main causes of soil erosion in Puglia are related to salinization and predictably the area more affected are the one dedicated to intensive cultivation and the subsequent use of chemical compounds in spite of organic fertilisers and enhancers (such as quality compost, manure, etc…) (Regione Puglia, 2014).

Therefore, an efficient agricultural productive system that does not use the soil would be crucial in preserving this precious resource, with no issues of salinization or nitrification. Moreover, this integrated system can (and should) be installed on an already exhausted, or otherwise infertile, patch of land. It can also contribute to restoration of the richness of the soil itself by increasing its organic matter composition, thanks to the possibility of producing organic fertilizers, derived from the mineralization of the organic waste generated inside the system (Somerville & FAO, 2015).

SOIL IN PUGLIA

Puglia’s territory is spread on a surface equal to 1.954.090 ha, which correspond to the 6,46% of the entire national surface. It is composed by mainly plain land and low hills, with very few mountainous relief. In the plain area are situated the majority of its municipality (70%) while the rest are on the hills (27%) mountains (3%) areas. To agriculture activities is devoted a great share (83,2%) of its territory.

The UAA in Puglia, in 2010, was, in 2010, equal to 1.285.290 ha, in particular 51% of this land is dedicated to arable crops, 8% to pasture and livestock, and 41% to woody plants. Even if, the highest share of land is reserved to yearly crops, permanent crops, namely olive trees and vines, have the greatest economic impact. Urban areas represent 4,6% of the territory.

Areas that are vulnerable to nitrate contamination are stretch across a surface of 89.359% ha, around 4,6% of the overall region. Nonetheless monitored nitrates levels in acquifer are stablily beneath the legal threshold of 50mg/l NO3. (Regione Puglia, 2014)

Salento
Countryside,
Lecce Province,
Italy.

SAFEGUARDING BIODIVERSITY

Soil can be considered a non-renewable source and, among its various function, it is fundamental in supporting biodiversity.(Eurostat, 2017)

Thus, soil management is essentia; in contrasting biodiversity erosion. Along with soil erosion other cause of this loss of biodiversity are global climate change, intensive agriculture and the decrease of commecral relevance of more traditional crops. Estimates say that half of world's biodiversity has been lost in the past 40 years (Shmelev, 2017).

The south of Italy is still a centre of diversity for several crops but modern cultivars are progressively replacing them and invaing their landscape. In the Salento area, Tremendous genetic erosion is evident since the 1980 and widespread in the past 25 years (Laghetti et al., 2005, 2008), therefore the region is trying to safeguard its botanic richness. A portal, "biodiversitapuglia.it", has been established to help catalogue and monitor local cultivars; 14 crops have been found to be at risk of genetic extinction ("Il progetto BiodiverSO," 2017). Furthermore, in the regional Rural Development Plan (Regione Puglia, 2014) for 2104-2020, the preservation of biodiversity has been made one of the priority (Priority 4): to preserve, restore and enhance the agricultural ecosystems. It is stated that:

> "The agricultural areas represent and important factor in the conservation of the biodiversity, because they are potentially capable to provide an analogue function as natural forest and fallow do. "

Also, growing attention is given to consumer demands, which are increasingly going toward the selection of goods produced with sustainable and safe methods.

The system proposed, mixing agriculture and aquaculture appears an interesting solution to this compelling issue, as it could preserve biodiversity and, at the same time, raise productivity (Pantanella, 2010).

A good example is the case of "mugnoli", a particular cultivar of broccoli (Brassica oleracea var. italica), which can be considered, as stated in Laghetti's (2005) work on this crop, as "an early step in the evolution of broccoli". This surviving crop, present in only a small portion of Salento, is proof of the region biodiversity richness. A particular problem that local growers face, is the natural contamination, through natural pollination, of other broccoli cultivar.

> "Its [of" mugnoli"] typical flower colour is white; sometimes in the field some plants with yellow flowers appear as a token of the genetic introgression from extraneous Brassica spp.; during the seed production all the single selected plants are covered by a net to avoid undesired genetic introgression but, in any case, traditionally, farmers eliminate plants with yellow flowers."
> (Laghetti et al., 2005)

By hypothetically using the suggested aquaculture agricultural system to grow this particular crop, such issue stops being relevant, as the soilles indoor (in the greenhosue), controlled cultivation, will protect the crops from external contamination and, at the same time, safeguard its survival, by assuring its efficient production.

REFERENCES

darapri.it. (2017). Origine nome Puglia. Retrieved November 1, 2017, from http://www.darapri.it/vinidipuglia/originenomepuglia.htm

European Commission. (2016, June 8). Soil - Environment - European Commission. Retrieved November 13, 2017, from http://ec.europa.eu/environment/soil/index_en.htm

European Commission, & Directorate-General for Agriculture and Rural Development. (2006). The Leader approach: a basic guide. Luxembourg: EUR-OP.

Eurostat. (2017, September). Agriculture statistics at regional level. Retrieved from http://ec.europa.eu/eurostat/statisticsexplained/

Il progetto BiodiverSO. (2017). Retrieved November 14, 2017, from http://biodiversitapuglia.it/il-progetto-biodiverso/

ISPRA. (2017a). Analisi e valutazione dello stato ambientale del Lago di Bracciano riferito all’estate 2017 (Rome). Retrieved from http://www.isprambiente.gov.it/files2017/notizie/Relazione_ISPRA_Bracciano_18ottobre2017.pdf

ISPRA. (2017b). Consumo di suolo, dinamiche territoriali e servizi ecosistemici (No. 226/2017). Rome: ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale. Retrieved from http://www.isprambiente.gov.it/files2017/pubblicazioni/rapporto/RapportoConsumoSuolo2017_0615_web.pdf

ISTAT. (2013). 6° Censimento Generale dell’Agricoltura - ATLANTE DELL’AGRICOLTURA ITALIANA. Rome: ISTAT - Istituto nazionale di statistica. Retrieved from https://www.istat.it/it/files/2014/03/Atlante-dellagricoltura-italiana.-6%C2%B0-Censimento-generale-dellagricoltura.pdf

Labianca, M., De Rubertis, S., Belliggiano, A., & Salento, A. (2016). Innovation in rural development in Puglia, Italy: critical issues and potentialities starting from empirical evidence. Studies in Agricultural Economics, 118(1), 38–46. https://doi.org/10.7896/j.1531

Laghetti, G., Martignano, F., Falco, V., Cifarelli, S., Gladis, T., & Hammer, K. (2005). “Mugnoli”: a Neglected Race of Brassica oleracea L. from Salento (Italy). Genetic Resources and Crop Evolution, 52(5), 635–639. https://doi.org/10.1007/s10722-005-8511-4

Laghetti, G., Pignone, D., Cifarelli, S., Martignano, F., Falco, V., Traclò, B. R. G., & Hammer, K. (2008). Agricultural biodiversity in Grecìa and Bovesìa, the two Griko-speaking areas in Italy. Plant Genetic Resources Newsletter, (156), 57–61.

Lopez, A., & Vurro, M. (2008). Planning agricultural wastewater reuse in southern Italy: The case of Apulia Region. Desalination, 218(1–3), 164–169. https://doi.org/10.1016/j.desal.2006.08.027

Masciopinto, C., La Mantia, R., & Chrysikopoulos, C. V. (2008). Fate and transport of pathogens in a fractured aquifer in the Salento area, Italy: FATE AND TRANSPORT OF ACQUIFER PATHOGENS. Water Resources Research, 44(1). https://doi.org/10.1029/2006WR005643

Pantanella, E. (2010). New aquaponics research in Italy. Aquaponics Journal, (56), 25–27.

Regione Puglia. (2014). Italy - Rural Development Programme (Regional) - Puglia. Regione Puglia.

Shmelev, S. (Ed.). (2017). Green Economy Reader (Vol. 6). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-38919-6

Somerville, C., & FAO. (2015). Small-scale aquaponic food production: integrated fish and plant farming. Food and Agriculture Organization of the United Nations.

gianlorenzo.desantis@gmail.com
https://www.linkedin.com/in/gianlorenzo-de-santis/