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Report of the

FAO TECHNICAL TRAINING WORKSHOP ON ADVANCING AQUAPONICS: AN EFFICIENT USE OF LIMITED RESOURCES

Osimo, Italy, 27–30 October 2015

Cover photograph: Woman harvesting tomatoes from a rooftop aquaponic system (©FAO/C. Somerville).

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PREPARATION OF THIS DOCUMENT

This report describes the activities and outputs of the training workshop Advancing Aquaponics: An Efficient Use of Limited Resources, held in Osimo (Ancona), Italy, on 27–30 October 2015.

This report was prepared by Alessandro Lovatelli, Aquaculture Officer, FAO Fisheries and Aquaculture Department, Rome, Italy, and Austin Stankus, FAO Aquaponics Consultant.

The material in the appendixes is reproduced as submitted.

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ABSTRACT

A technical training workshop on advancing aquaponics was held in Osimo, Italy, on 27–30 October 2015. Seventeen participants attended from ten countries of the Near East and North Africa region (Egypt, Jordan, Lebanon, Mauritania, Morocco, Palestine, Tunisia, Saudi Arabia, the Sudan, and the United Arab Emirates). The participants were mainly from government-associated aquaculture research centres. The four-day workshop consisted of lectures, demonstrations and hands-on activities supported by aquaponics experts. This activity was supported under the FAO Regional Initiative on Small-Scale Agriculture for Inclusive Development in the Near East and North Africa and the Major Area of Work on Efficient Resource Use under FAO's revised Strategic Framework. Recommendations were gathered based on participant feedback, and included: (i) education, training and communication; (ii) research and development; (iii) socio-economic and feasibility studies; and (iv) regional and international cooperation.

CONTENTS

ABBREVIATIONS AND ACRONYMS

ANDA	Agence Nationale pour le Développement de l'Aquaculture (Morocco)
ETH Zurich	Swiss Federal Institute of Technology in Zurich
EU	European Union (Member Organization)
FAO	Food and Agriculture Organization
GAFRD	General Authority of Fisheries Research and Development (Egypt)
HPS	high-pressure sodium
JFRC	Jeddah Fisheries Research Center (Saudi Arabia)
KACST	King Abdulaziz City for Science and Technology (Saudi Arabia)
KAP	knowledge, attitudes and practices
KFU	King Faisal University (Saudi Arabia)
LED	light-emitting diode
MALR	Ministry of Agriculture and Land Reclamation (Egypt)
NCARE	National Centre for Agriculture Research and Extension (Jordan)
NENA	Near East and North Africa Region
NFT	nutrient film technique
NREI	Natural Resource and Environment Institute (Saudi Arabia)
PVC	polyvinyl chloride
RAS	recirculating aquaculture system
RECOFI	Regional Committee on Fisheries
SZAC	Sheik Zayed Agriculture Center (United Arab Emirates)
USAID	United States Agency for International Development
UVI	University of the Virgin Islands

BACKGROUND

This practical workshop aimed to support and promote the sustainable development of aquaponics through the active exchange of ideas and regional cooperation among participating countries. The main objective was to support strategic development of aquaponics in the Near East and North Africa (NENA) Region through capacity development of key personnel from each Member. As a result of this training, participants are more prepared to bring the technology back to their home country and support further dissemination. A list of participants, including their affiliations, is included as Appendix 1.

Aquaponics is a symbiotic integration of two mature food production disciplines: aquaculture, the practice of fish farming; and hydroponics, the cultivation of plants in water without soil. These are combined within a closed recirculating system. In a standard recirculating aquaculture system (RAS), the organic matter ("waste") that builds up in the water needs to be filtered and removed so that the water is clean for the fish. In an aquaponic system, the nutrient-rich effluent is filtered through an inert substrate containing plants. Here, bacteria metabolize the fish waste, and plants assimilate the resulting nutrients. The purified water is then returned to the fish tanks. The result is value-added products such as fish and vegetables together with reductions in nutrient pollution into the watersheds.

Aquaponics has the potential for higher yields of vegetables and fish protein with less labour, less land, fewer chemicals and a fraction of the water usage. Being a strictly controlled system, it combines a high level of biosecurity with a low risk of disease and external contamination, while producing high yields without the need for fertilizers and pesticides. Moreover, it is a potentially useful tool to overcome some of the challenges of traditional agriculture in the face of freshwater shortages, climate change and soil degradation. Aquaponics works well in places where the soil is poor and water is scarce, for example in urban areas, arid climates and low-lying islands.

Commercial aquaponics is not appropriate in all locations, and many aquaponic businesses have not been successful. Large-scale systems require careful consideration before financial investment, especially the availability and affordability of inputs (i.e. fish feed, building and plumbing supplies), the cost and reliability of electricity, and direct access to a market willing to pay premium prices for local, pesticide-free vegetables. Aquaponics combines the risks of both aquaculture and hydroponics, and thus expert assessment and consultation is essential. The state of the art is advancing rapidly, and new techniques and technologies, including decoupled designs and automated sensor controls, are being developed to address some of these challenges and support commercial aquaponic development.

In the future, the agriculture sector will need to produce more, with less. Following the principles of efficient resource use to increase the provision of goods and services from agriculture in a sustainable way, synergistic benefits can be realized by integrating separate food production systems, and by reducing inputs, pollution and waste, while increasing efficiency, earnings and sustainability. As one of these efficient and integrated techniques, aquaponics has the potential to support economic development and enhance food security and nutrition through efficient resource use, and it may well become one additional way of addressing the global challenge of food supply in a sustainable way.

The technology and techniques are simple and easy to adopt once demonstrated to the farmers. Aquaponics builds upon several decades of work, and systems have been built successfully throughout the world. Currently, aquaponics serves communities with limited freshwater resources, limited land, and high sale prices of fresh vegetables. Successful aquaponic interventions by FAO have been conducted in Gaza and the West Bank and in Ethiopia. Support for aquaponics was recently highlighted as a target of the Sixth Meeting of the Working Group on Aquaculture of the Regional Commission for Fisheries (RECOFI) in Muscat, Oman.

The technical publication *Small-scale aquaponic food production: integrated fish and plant farming*, recently developed by the FAO Fisheries and Aquaculture Department, is available online[1] and being translated into Arabic to support further aquaponic development in the region.

The specific objectives of the workshop were:

- Develop common knowledge and investigate diversity of aquaponic systems both in the region and globally, highlighting the opportunities of efficient and sustainable production while identifying the risks, costs and other issues that prevent wider implementation, and propose collective action to be implemented locally.
- Support the adoption of aquaponic production in the region, particularly through business plan development and market analysis, technical production modelling and demonstration unit design.
- Document the proceedings of the workshop for dissemination to participants and interested parties.

This activity was supported under the FAO Regional Initiative on Small-Scale Agriculture for Inclusive Development in the Near East and North Africa, and the Major Area of Work on Efficient Resource Use under FAO's revised Strategic Framework.

COUNTRY SELECTION AND PARTICIPANT IDENTIFICATION

Seventeen participants attended from ten countries: Egypt, Jordan, Lebanon, Mauritania, Morocco, Palestine, Tunisia, Saudi Arabia, the Sudan and the United Arab Emirates. The focus countries of the Regional Initiative for Small-Scale Agriculture for Inclusive Development in the Near East and North Africa, namely, Egypt, Lebanon, Morocco, Sudan and Tunisia, were invited. Additional focus countries of the Water Scarcity Initiative, Jordan and Oman, were also were invited. In addition, Saudi Arabia and the United Arab Emirates were invited because of ongoing work with recirculating aquaculture, hydroponics and integrated farming technologies.

The ideal participants for this workshop would have had previous experience in aquaponics, recirculating aquaculture or hydroponics. Moreover, the participants would be in a position to disseminate what they learned to a wider community, for example, an aquaculture or agriculture extension agent or university professional, and these newly trained personnel were expected to be in a position to inform key stakeholders for continued support of aquaponic development. A motivated and well-trained focal point, with the continued support of FAO and provided technical materials, would be instrumental for the extended transfer of aquaponics technology throughout the region.

The integrated nature of aquaponics implies that a successful intervention requires the support of both the Ministry of Fisheries and the Ministry of Agriculture, and therefore it would have been ideal to have one freshwater aquaculture expert and one horticulture expert. However, most of the countries, both the participants were from the Ministry of Fisheries and there was a noticeable lack of horticulture experience.

WORKSHOP PARTNERS

An experienced aquaponics training firm, Acquacoltura Italia Srl, was approached and contracted to facilitate the workshop (www.acquacolturaitalia.com/index.php/en). This company offers effective and expert advice to its clients in the fields of aquaculture, aquaponics and aquarium-sciences, and provides professional services and consultancy specifically for

[1] Somerville, C., Cohen, M., Pantanella, E., Stankus, A. & Lovatelli, A. 2014. *Small-scale aquaponic food production. Integrated fish and plant farming*. FAO Fisheries and Aquaculture Technical Paper No. 589. Rome, FAO. 262 pp. (also available at www.fao.org/3/contents/1dea3c92-1faa-47bb-a374-0cf4d9874544/i4021e00.htm).

technical assistance, vocational training and the design and construction of production plants with a reduced environmental impact. Acquacoltura Italia works in partnership with AquaGuide (www.aquaguide.com), which focuses on research and training in aquaculture and aquaponics, and Irci Spa (www.ircispa.com/en/), which specializes in the production of engineered aquaponic modules (www.irciponic.com) among its business services in technological solutions for the commercial energy sector.

Acquacoltura Italia designs rearing facilities for marine and freshwater fauna and flora that can assume a commercial, restocking or ornamental purpose in national and international territories. It also provides scientific and technological training courses and workshops. This is done through the organization of advanced schools and working stages both at the company's facilities and at specific research centres, universities and other enterprises in Italy and abroad. At the same time, it offers technical assistance and advice contributing towards social and economic development through knowledge transfer.

Acquacoltura Italia's competitive advantage for this workshop was its previous experience in conducting training courses in English for foreign nationals, the technical competence in all aspects of aquaponics and its centralized geographic location. No companies within the NENA Region had the capacity to host this training workshop, although it was recognized during the workshop that developing a network of regional training centres is a priority.

The FAO Service Provider was charged with organizing the regional four-day workshop, which entailed identifying and confirming the venue, making local arrangements for lodging and meals, including securing an adequate meeting venue, and providing all other and relevant logistical support. Moreover, it provided technical inputs to the workshop in collaboration with the FAO Aquaculture Branch, including the agenda, presentations and hands-on training activities. The FAO Service Provider acted as workshop coordinator and facilitator in charge of the overall coordination of the activity.

An independent FAO aquaponics consultant, Mr Austin Stankus, was recruited for his services in conducting this workshop. His inputs to the workshop included the logistical and programmatic preparation, and the drafting of the prospectus and agenda. He conducted a scoping mission for the preparation of the workshop and actively assisted in the delivery of the workshop, including: developing financial and technical spreadsheet calculators and lecture materials, supporting capacity development exercises with participants in order to contribute to increasing feasibility of farm operations and working towards a mutually supportive network of aquaponic practitioners.

The workshop facilitators and trainers included both staff and collaborating partners of Acquacoltura Italia, independent consultants and FAO staff. A list, photograph and brief description of each are included in Appendix 2.

WOKSHOP AGENDA AND PROGRAMME

The four-day workshop consisted of lectures, demonstrations and hands-on activities supported by aquaponic experts, and was hosted by the service provider Acquacoltura Italia. The workshop was designed to be a high-level introduction to aquaponics to highlight the technical requirements of any future aquaponic interventions, whether international, national or private, and included ample opportunity for discussion of regional and national priorities. A valuable group session saw participants create technical designs and draft business plans based on real data from their home countries using an FAO-developed planning tool. Additional time was dedicated to network building, and soft skills including advocacy, training and discussions.

The workshop was broken down as follows:

Day 1 presented an introduction to aquaponics, including: the high-level benefits, opportunities and risks; country reports by each participant; and an initial capacity assessment and expectations exercise. The basic biological and chemical interactions were introduced while anchoring the technology within the global framework of livelihood support and food and nutrition security. The country reports and capacity assessment provided a voice to the participants to understand their expectations and tailor the course over the following days.

Day 2 dealt with in-depth technical training of the functional components of an aquaponic system, namely the fish, plants, water and mechanical components, and was divided between lectures and hands-on activities. This was a challenging day with extensive technical information. Although it was not expected that the participants would become experts, this day was designed to give a detailed overview of the most critical components of an aquaponic system. Overall, it highlighted the need for properly trained operators for aquaponic systems.

Day 3 was a field trip to a larger commercial aquaponic system, where the participants were divided into four subgroups that rotated through intensive hands-on training on key system components. In these small groups, the participants were encouraged to teach/explain the lesson to their group members to buttress the concepts and support soft skills development on how to train others in aquaponics. This day did not introduce new topics and instead used the time to have small working sessions to reinforce the previous theory lessons with active discussions and demonstrations. This also provided a more informal structure that encouraged active question-and-answer sessions and simultaneous translation when needed.

Day 4 focused on commercialization, marketing and financial analysis of small-scale agriculture in general and aquaponics specifically. A keystone aspect of the course was a technical and financial calculator, developed by FAO and presented in Appendix 9, that demonstrates how to correctly size the mechanical components (fish tanks, pumps and grow beds) as well as to estimate the cash flow in terms of recurring costs and production. An example was done with the entire group, and after discussion, the participants divided again into subgroups to do technical sketches and estimate the capital expenditure of an aquaponic system. The financial analysis was based on real data that the participants brought from their home countries.

The full agenda is included as Appendix 3, and the expanded programme as Appendix 4.

The intended technical uptake by the participants was a high-level understanding of the core concepts of aquaponics. These concepts include animal and plant health and production, water quality analysis and management, and technical design parameters, including how to calculate and balance the amount of fish to the number of plants. Moreover, it was expected that participants would learn the key opportunities and risks of aquaponic business development and independently consider the pros and cons of encouraging investment in aquaponics.

The workshop was limited by the short time allotted. Substantial time is required for both theoretical and hands-on practical activities to provide participants with adequate experience. This workshop used the time available efficiently and focused on lectures, demonstrations and participant dialogue to transfer knowledge. The participants acknowledged the success of this method, but unanimously requested a follow-up workshop dedicated to hands-on training activities to build upon the successes seen in this workshop.

A group photograph of all participants and facilitators, selected photographs during the workshop as well as selected press releases are included in Appendixes 10, 11 and 13.

OPENING REMARKS

Opening remarks were presented on behalf of Mr Árni Mathiesen, Assistant Director-General of the Fisheries and Aquaculture Department, and Mr Abdessalam OuldAhmed, Assistant Director-General, FAO Regional Office for the Near East and North Africa. They are included in Appendix 5.

The opening remarks reviewed the global situation of agriculture, including aquaculture in water scarce areas, and the global need to develop innovative practices of local food production that can include aquaponics. FAO has a proposed methodology to support the development of aquaponics. First, and most importantly, aquaponics should only be used in the right locations. Identification of these locations through participatory needs assessment is the first step. Documenting and disseminating the best practices through technical guidelines is also important. Then, facilitating regional networks of experts is crucial for the long-term anchorage of aquaponic development and to share locally appropriate and location-specific techniques. This form of South–South cooperation will reduce the reliance on outside materials and outside experts, and allow aquaponics to develop naturally within this geographic and cultural context.

COUNTRY REPORTS

Each country was invited to prepare a brief presentation to share with the group on the status of aquaponics, recirculating aquaculture and hydroponics in their home countries. The intention was to develop a regional overlook of the status of aquaponic development, identify common opportunities and challenges, and begin to map the key actors in the sector. In addition, each participant was invited to collect market data concerning the costs of aquaponic inputs (fish feed, electricity, etc.) and sale price of products (vegetables, fish) in order to conduct a real financial planning exercise. To support the participants gathering this information, survey forms were circulated before the workshop in both English and Arabic (Appendix 6). A brief summary of each country's report is provided herewith.

Egypt – Egypt is a regional leader in aquaculture, and aquaponics is receiving attention from governmental and private industry levels. On the governmental side, most of the 16 national universities that include an agricultural curriculum have begun to use aquaponics in the classroom, though generally on a very small-scale educational level. The government recognizes the opportunities for aquaponics to expand the agricultural landscape, considering the availability of freshwater and the expanding populations. The governmental research on innovative and integrated aquaculture techniques is supported through research and extension by the General Authority for Fisheries Resources Development (GAFRD), which is part of the Ministry of Agriculture and Land Reclamation (MALR).

Currently, most of the desert aquaculture activities are conducted in flow-through systems, where the aquaculture water discharge is used to fertilize and irrigate agricultural land. There are about 120 intensive farms covering 900 ha of land; the 20 commercial farms produce 6 000 tonnes and the 100 rural farms produce 7 000 tonnes of finfish annually. Tilapia is the major farmed finfish species. There are several farms that have adopted RAS technology, and one of these is commercially producing aquaponic crops.

Bustan Aquaponics is located on the northern edge of Cairo. It follows the style of the University of the Virgin Islands (UVI) for its aquaponic design. Two greenhouses (both net and polycarbonate) with a total area of 1 000 m^2, cover both the fish and vegetable production areas. Six grow beds (1.25 × 30 m each) provide 225 m^2 of vegetable production area using the deep-water culture design. The plant production is fuelled by four fish tanks (8 m^3 each) of tilapia. Initial investment was about USD50 000, and the farm is reported to produce 3–6 tonnes of tilapia and tens of thousands of lettuce heads per year. Lettuce, watercress, arugula, basil, tomatoes and various other vegetables are processed in-house and sold at grocery stores, restaurants and hotels.

Jordan – Jordan has advanced greenhouse horticulture production practices. Hydroponics has been used since the early 2000s in response to water scarcity constraints and import costs. There is an advisory group in Jordan for hydroponic farming, and it is connected with a USAID Powering Agriculture programme and the Hydroponic Green Farming Initiative. The most common hydroponic vegetables are strawberry (50 farms; 75 ha), cucumber (9 farms; 13 ha), ornamental plants (30 farms; about 45 ha) as well as lettuce and herbs (few). Most farms use plastic-covered raised beds with microdrip irrigation under greenhouse / high-tunnel conditions.

Aquaponics in Jordan is very recent and was first introduced in 2012 through a partnership with ETH Zurich sustainability summer schools. Now, there are about 12 domestic / small-scale systems in Jordan, though only half are currently operational. They range in size from 25 to 30 m^2, use tilapia and are often situated on rooftops. One of the designs is called the "freedom machine", with a cost of about USD2 500 and an estimated payback period of 2–4 years. More recently, applied experiments have been conducted by the National Centre for Agriculture Research and Extension (NCARE) of the Ministry of Agriculture in three different locations. Each experimental research project uses single-span plastic greenhouses of about 500 m^2. The design uses in-ground, lined fish pools with rows of volcanic tuff and microirrigation for the plants in a type of "dead-end" hybrid system. In addition, the Bait Ali Hotel in Wadi Rum uses a small aquaponic system designed by Byspokes CIC and located within a 100 m^2 greenhouse to supplement the restaurant's needs and provide educational opportunities.

Lebanon – Aquaculture in Lebanon is almost exclusively centred on the 270 rainbow trout farms located in the Hermel region. Most production is from family-owned and -operated farms, and the techniques include flow-through raceways and ponds. Ancillary support is available including feed and seed production and basic veterinary care, and farmers and buyers are self-organized in marketing cooperatives. However, there is little coordination among the key actors in the aquaculture sector, and while there is high potential, development has been slow.

Hydroponic production became accepted in the early 2000s, mostly focusing on salad production and ornamental flowers. However, there is a high cost of implementation, and uptake has been slow. Aquaponics is very new, and currently only one university includes it in its educational programme – it plans to build a demonstration system to be used for teaching and training.

In 2015, there were three requests for permits for new aquaponic facilities, indicating that there is a small amount of interest within the general public. National legislation governing water use requires the amount of water consumption to be limited and prohibits the introduction of nutrients and contaminated matter into the watersheds. In this regard, aquaponics may have potential as a secondary and tertiary water treatment option for aquaculture effluent.

Mauritania – Currently, there is very little aquaculture or hydroponics in Mauritania.

Morocco – In 2013, aquaculture production in Morocco was estimated at 1 800 tonnes, of which 73 percent was freshwater or diadromous fishes. A recent development initiative has made ambitious plans for aquaculture development by 2020, although it focuses heavily on marine production. In 2004, inland aquaculture produced 685 tonnes, or 40 percent of total national aquaculture production. It was largely dominated by the common carp, accounting for 88 percent of output. All the production was used to restock dammed ponds. Two companies produced carp for the National Office for Potable Water and Combating Dam Eutrophication (Office National de l'eau potable et la lutte contre l'eutrophisation des retenues). One company produced fifty tonnes of rainbow trout, raised semi-intensively in natural and artificial ponds, entirely for the local market.

Several government departments share the management of national aquaculture. The Livestock Directorate at the Ministry of Agriculture, Rural Development and Maritime Fisheries is responsible for enforcing health regulations. The High Commission for Waterways and Forests and Combating Desertification manages and oversees inland aquaculture. Marine aquaculture is managed by the Maritime Fisheries Department, which is also responsible for issuing authorization for all aquaculture projects, and for importing and marketing aquaculture products in close conjunction with the Livestock Directorate. Conversely, the Ministry of Public Works is responsible for issuing permits to occupy the public maritime domain. Government authorities acknowledge that there are many obstacles to developing aquaculture and have been trying to establish an economically viable and biologically stable aquaculture sector for which there is high potential.

The National Agency for the Development of Aquaculture (ANDA) is a public and financially independent institution located in Rabat. ANDA was established in 2011 to promote the development of the aquaculture sector in Morocco. It is one of 16 projects under the Halieutis Strategy, launched in September 2009, to lever growth and job creation in the fisheries industry.

Palestine – Urban and peri-urban agriculture are priority development areas for Palestine considering the high level of food and nutrition insecurity owing to geopolitical history, high cost of imports and limited land and water. Aquaponics has been introduced multiple times through various development partners including FAO. One project was conducted at the Al-Basma Centre in Beit Sahour by Byspokes CIC, which built a small aquaponic greenhouse in 2011. The system was accompanied by three months of training, a side-by-side comparison with soil gardening, and a detailed production record with associated construction costs. The project demonstrated that aquaponics works in the region, but the high daily running costs and the need for highly trained human resources prevented the technology from spreading.

Separately, an aquaponics pilot project was conducted as part of FAO emergency interventions from 2012 to 2013, installing about 143 small aquaponics systems for food-insecure, predominately female-headed households and community establishments in Gaza. The project was initially successful in providing a means for beneficiaries to grow food – particularly for women, because this method allows them to work from within their homes. However, given its nature as an emergency intervention, the project targeted poor and urban families with minimal farming experience. Thus, after the initial inputs provided by the project expired, many families did not have the resources to buy new inputs, a basic farming background to ensure good plant performance, or access to technical support from local, experienced producers. The Gaza experience demonstrates the need to work initially with families who not only possess an entrepreneurial spirit but also have a farming background to ensure that an aquaponics enterprise is profitable and sustainable in the local context.

Reliable and affordable access to inputs, including electricity, fertilizer and fish feed and seed were identified to be major blocking issues to aquaponic development. Imported fingerlings are often stressed or killed during transportation. Moreover, training and human resource development, as well as public awareness, are necessary to keep momentum and build upon past interventions. Overall, in order for aquaponics to be sustainable in Palestine, universities and research centres will need to develop low-cost, locally adapted and more-productive systems at the same time as developing continuing education for interested practitioners.

Saudi Arabia – In Saudi Arabia, aquaponics is driven forward primarily by universities and research institutes. The Natural Resource and Environment Institute (NREI) situated within the King Abdulaziz City for Science and Technology (KACST) is currently developing operating protocols for aquaponic activities. One of the primary research goals is to use saline groundwater to produce both fish and vegetables, including animal fodder. A UVI-style aquaponic system, with 213 m^2 of growing space and 7.5 m^3 of fish tanks within a large greenhouse, was built in the early 2000s, and production data were published, which demonstrated comparative crop and fish yields, and water consumption to similar systems around the world. King Faisal University (KFU) is also conducting research trials into aquaponic production. One private company, EICO-Arabia (Environmental Innovations Contractors) has built a semi-commercial greenhouse in Riyadh that has about 100 m^2 of growing space in a 250 m^2 greenhouse. General awareness of aquaponics is low, and there have been several publicity campaigns.

Inland aquaculture is receiving renewed attention, but owing to a lack of freshwater there has been slow development. The Jeddah Fisheries Research Center (JFRC) of the Ministry of Agriculture is producing fingerlings using RAS technology. This water scarcity has also encouraged the government to take initiatives to reduce water use in conventional agriculture by using high-tech solutions including hydroponics. These initiatives are also being investigated by the KACST and KFU. Several private companies (e.g. Ibrahim Abunayan Farms, Saudi Arabian Hydroponic and Pegasus Agri-tech) are actively producing commercial-scale hydroponic vegetables. Ancillary support to the sector exists through aquaculture labs and feed production companies.

The Sudan – Inland aquaculture in the Sudan dates back to the early 1950s. Freshwater fish culture is primarily based on pond culture of the indigenous species of Nile tilapia. Other local species have been experimented with, but are not widespread or disseminated to farmers. Exotic species such as common carp have been introduced for experimental culture in combination with Nile tilapia, or for use as biological control agents for the eradication of aquatic weeds that infest the irrigation canals of large agricultural structures (grass carp). Freshwater fish culture has not as yet developed into a vertically integrated economic activity, despite the fact that the prerequisites for it are available. Several state and private sector farms are established around the capital and other towns. There is no information about hydroponic vegetable production, and probably there are no aquaponic systems in the country.

Tunisia – Aquaculture in Tunisia grew at an annual growth rate of 20 percent until 2014. Production is about 11 700 tonnes (2014), accounting for almost 10 percent of the total Tunisian fisheries production. Most aquaculture production is marine, with a majority of production coming from European seabass (*Dicentrachus labrax*) and gilthead seabream (*Sparus aurata*). Inland aquaculture is conducted in dams and in geothermal waters. Generally, these are extensive low-cost farming activities and focus on carp, mullet catfish and tilapia. There is limited information about the amount of hydroponics occurring in Tunisia.

The United Arab Emirates – There are two significant aquaponic operations in the United Arab Emirates. The first is a large aquaponic system built by JBA Agritech at the Sheik Zayed Agriculture Center (SZAC). It employs the UVI design and was built under supervision of James Rakocy. Primarily, this was used as a demonstration and teaching system, and has a vegetable production area of about 200 m^2. A separate project was started in 2013 by the private company, Earthen Group, led by Paul Van der Werf, and saw the construction of a 4 500 m^2 greenhouse. Both of these private companies have completed the pilot studies and are currently in the process of expanding.

Aquaculture is expanding in the United Arab Emirates. Much of the aquaculture is marine, and focuses on fisheries enhancement and restocking, but there are freshwater initiatives, focused on tilapia production. Generally, fish are raised in irrigation channels, ponds and tanks as a low-intensity addition to existing farming operations. One notable commercial RAS operation is Emirates AquaTech, the world’s largest caviar farm, located in Abu Dhabi. Similarly, hydroponics is well established in the United Arab Emirates, with several commercial-sized farms and many small farms. Emirates Hydroponics Farm is the longest-established and produces herbs and salads for Abu Dhabi and Dubai. Mirak Agricultural Services is a diversified agricultural company, and partly uses a version of open-field microirrigation hydroponics to produce and export vegetables.

WORKSHOP SATISFACTION SURVEY

Overall, the participants were satisfied with the course, as indicated in the post-workshop satisfaction survey, the results of which are summarized in Appendix 7. The participants indicated overwhelmingly that the instructors were well prepared and helpful. The pre-workshop preparation was sufficient and the objectives were clearly identified.

However, the participants indicated that the pace was too fast and that more time was needed to dedicate to hands-on, practical activities. First, these data suggest that participants were interested, engaged and eager to learn/do more. This underlines the need for a follow-up course for the interested parties that would need to be longer, slower and focus less on theory and more on practical construction and maintenance. A further request was to have a follow-up workshop at a commercial aquaponics facility in a French- or Arabic-speaking country. That said, the expressed purpose of the workshop was to increase the high-level theoretical understanding of aquaponics in order to support the technology transfer rather than training the participants to become experts at construction and maintenance of aquaponic systems.

Concerning the difficulty level, about half of participants indicated that the course was too difficult and the other half that it was too easy, indicating that the level was probably correct.

In addition to the satisfaction survey, a capacity self-assessment was conducted on the first and last days where participants were asked to answer 30 questions on a scale of 1–5; the summarized results of this are presented in Appendix 8. The capacity assessment exercise was designed to assess participants' knowledge, attitudes and practices (KAP) concerning aquaculture, agriculture and aquaponics. Additional questions were asked regarding the organizational arrangements in the participants' institutions to determine what/any actions they could personally take to advance aquaponics. The summarized data show that, on average, the participants' knowledge and attitudes increased in every category. Moreover, these questions helped to guide the discussions, recommendations and flow of the workshop. In fact, in response to the self-assessment on the first day, the workshop gave increased focus to plant production and health (as most participants were already skilled in fish production).

WORKSHOP DISCUSSIONS AND RECOMMENDATIONS

Recommendations were gathered by the workshop facilitators through discussions, direct questions and surveys. In summary, participants requested increased focus on aquaponics, and provided several general recommendations, including to support: (i) education, training and communication; (ii) research and development; (iii) socio-economic and feasibility studies; and (iv) regional and international cooperation.

Education training and communication

Education and training are the key foundations for building up the necessary skills for the production, management and practices for aquaponics, and a trained and engaged pool of human resources is essential to any aquaponic intervention. Some suggestions include:

- Translate and print FAO materials (namely, FAO Fisheries and Aquaculture Technical Paper No. 589 – Small-scale aquaponic food production) into Arabic and French (Appendix 12 contains the full reference).
- Enable education institutions by supporting the addition of aquaponic curricula to existing aquaculture programmes.
- Convene additional and more-intensive training sessions at commercial large-scale aquaponic systems for participants at both the regional and national levels.
- Advocate at ministerial level to include aquaponics within existing legislative frameworks to facilitate licensing and certification.

Research and development

The need for new and/or adapted technologies for aquaponics is important, especially in using the best-adapted fish species and plant varieties that show good production and market demand in a regional context. The research and development could focus on the following aspects:

- Identify advanced greenhouse technologies and infrastructures for new or existing aquaponic facilities adapted to local desert and arid land conditions.
- Identify and characterize select aquatic species suitable for RAS culture in an aquaponic setting with high production potential and market demand.
- Identify and characterize select vegetable and speciality plant crops with high production value and market demand.
- Develop and share technical design criteria and system blueprints using locally manufactured and produced materials.

- Support for the construction, management and data collection and analysis of demonstration centres of commercially viable size situated at national or regional institutions.

Socio-economic and feasibility studies

The purposes of increasing aquaponic development in the NENA region are to provide increased food security and protein sources, provide jobs, create business opportunities and improve livelihoods in the region through the development of aquaponics, and therefore the following actions were suggested:

- Study and document lessons learned from both successful and failed aquaponic ventures in the region and around the world.
- Evaluate the economic feasibility of aquaponic production at small, medium and large scales based on local conditions in a national context.
- Further develop and validate the financial analysis tool developed by FAO that estimates production and costs of aquaponic systems.

Regional and interregional cooperation

Realizing that over the years, regional and inter-regional cooperation has brought considerable benefits to aquaculture development through dissemination of knowledge and expertise, the following recommendations were made:

- Foster information and technical knowledge transfer between areas with more advanced aquaponics and less developed ones.
- Improve regional collaboration and networking of regional and/or national institutions specialized in aquaponics to ensure synergies and exchange of expertise.
- Encourage the establishment of regional organizations for the development of aquaponics through South–South cooperation, training of trainers and study tours.

APPENDIX 1

List of participants

Ahmed Saney Eldin M. SADEK
General Manager of Aquaculture Farms General
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A supervisor of GAFRD research farms, especially hatcheries and pilot farms. He also facilitates licensing for private sector and is the Egyptian delegate to the Nile River Basin countries for establishing aquaculture pilot projects.

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A production research specialist with GAFRD, focusing on growout technologies primarily for freshwater finfish and marine shrimp. His research experience includes graduate studies at the Pukyong National University in the Republic of Korea.

Saeb Ghaleb HALLASA
Head of Fish Department
Animal Production Directorate
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Has 25 years of experience working with the Ministry of Agriculture. His primary activities are managing aquaculture projects and offering extension to farmers.

Ussama KATTAN
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An irrigation and plant production specialist working with the Ministry of Agriculture, with many activities in olive oil production and quality. In addition, he follows hydroponics, aquaculture and aquaponic projects.

Imad LAHOUD
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Specializes in agronomy, education, monitor and control, and legislations. His current work ranges from monitoring illegal, unregulated and unreported fishing in the Mediterranean, to facilitating licensing procedures for fisheries and aquaculture activities.

Ahmed TALEB MOUSSA
Chief of Service
Direction de l'Aménagement des Ressources Halieutiques et de l'Océanographie
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Work focuses on the elaboration of fisheries management plans and the introduction of conservation and transformation technologies for fisheries products towards their commercialization and export.

Aicha Alaoui METERAJJI (Ms)
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Work focuses on the coordination of national and international projects in the field of fisheries and aquaculture. Provides supervisory support to project development and implementation.

Nawal ZIRARI (Ms)
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Provides technical support to aquaculture investors throughout all project development stages and farm operations. Monitors all national aquaculture activities. National aquaculture focal point for all integrated coastal projects.

Yaser SHTAYA
Director of Fish Department
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Ramallah, Palestine

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Works predominantly to improve the livelihoods and food security situation through aquaculture, and focuses on improvement on locally produced fingerlings, technical technology transfer and encouraging the consumption of fish.

Angham BANIOWDA (Ms)
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Work focuses primarily on extending fish production technology and agricultural engineering to farmers and producers in the effort to increase food security.

Mohammed Saad HAZZAA
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An aquaculture and agriculture engineering expert focusing on the extension of technologies that reduce the use of freshwater resources. His work varies from management to investment and ranges from marine hatcheries to freshwater biofloc technologies.

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Director of freshwater research at the Ministry of Agriculture. His research focus is in natural resource management and the efficient use of fresh water resources.

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Works with the aquaculture research station with research projects focusing on water quality, breeding and hatchery techniques. Her duties also include the training of university students, extension to farmers and advice to private sector.

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Director of the aquaculture research station and manager of the fish farms. Her duties also include research in fresh water fish production and fish nutrition.

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An aquaculture hatchery specialist. His duties include teaching and extending hatchery technology through seminars and field work, as well as contributing to development of aquaculture strategies.

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A specialist in the reproduction technology of carp, sea bass and sea bream including the production of larval feed. He is currently focusing on introduction of aquaculture in dam reservoirs and recirculating aquaculture systems.

Abdulla Jumaa M. ALJUNAIBI
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Works in various animal production sectors including cow, goat, camel and fish in an effort to increase local production. His work focuses both on increasing the quantity to support market demand as well as ensuring quality and food safety.

APPENDIX 2

List of speakers

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As an associate at Acquacoltura Italia, key duties include the management of the company's aquaponic systems and advanced research on water parameters in aquaponics. His primary research interests include: analysis of the growth of animals and plants in different types of aquaponic systems; research on seeding and first growth of plants using different methods (in collaboration with the Marche Region public agency "Agenzia Servizi Settore Agroalimentare delle Marche") and research and development of innovative agricultural strategies for the farmers and entrepreneurs of the agribusiness local sector.

Massimo BRIANI
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A certified architect and holds a PhD from Florence University. He has been involved with projects co-financed by the European Union in West Africa. Author of publications in the field of sustainable and local development, sustainable development in West Africa, valorization of food processing by-products and green economy. He is Sales and Marketing Manager at Irci SpA, a company specializing in energy efficiency where his duties include analysis of the project, installation, testing and assistance to the industrial fittings. He is a teacher in professional training institutes including: IRFA (Confartigianato), Florence University (Urbanism Department) and Venice University (Cà Foscari).

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As a charter member and scientific manager of Acquacoltura Italia Srl, he has extensive skills and training in aquaculture and aquaponics, including planning and designing, installation and assembly, technical assistance and operations management. He has been part of a 3-year partnership with Marche Polytechnic University for research and innovation in marine aquaponics. He is also a co-founder, charter member and technical and scientific manager of AquaGuide Sas, focused on aquaculture and aquaponics research and training, and Director of Acquacorsi, the only Italian online school for aquaculture and aquaponics training.

Cristian GLORIOSO
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An electronic and telecommunication expert with experience in information technology, computers and mobiles technologies, in the last 10 years Christian has worked in North Europe, Africa and Asia in development projects. He has participated in many projects of social development and health care in rural areas of Guinea Bissau and cooperated in solar electrification and water supply for school and other strategic locations together with NGO, secular and religious organizations and public offices of Bangladesh. For the past year he has been working with Irci SpA and focused on aquaponic technology innovations (Irciponic).

Alessandro LOVATELLI
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A trained marine biologist and aquaculturist with extensive experience in global aquaculture development working with FAO and other international organizations. His area of work focuses mainly on marine aquaculture development, transfer of farming technologies and resource management. He has been active in promoting farming technologies applicable for food production in areas poor in freshwater resources.

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A marine biologist and PhD student. Has worked with a few of the most important commercial fish species (European seabass and seabream) in the Mediterranean area, studying meat quality and food safety. Currently she is involved with Marche Polytechnic University (Università Politecnica delle Marche) in a PhD project, in collaboration with AquaGuide Sas, on marine aquaponics. This projects aims to test system functioning and quality of aquaponic products grown in salt water to take advantage of high-value marine species.

Hillary RIGHINI
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She graduated from Agricultural Science and Technology Specialist Course in Plant Medicine, at the School of Agriculture and Veterinary Medicine, University of Bologna. She spent six months on a project focused on the investigation on the effects of algae and cyanobacteria extracts for the fight against pathogens of plants at the Spanish Center BEA (Banco Español de Algas FCPCT- ULPGC), University of Las Palmas at Canary Islands. She has published several articles about biological control topics on scientific reviews as a component of the Bologna University group. She is an expert of integrated pest management including biological control of pests and plant diseases in aquaponic systems.

Austin STANKUS
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An FAO consultant focusing on integrated approaches to the efficient use of resources towards sustainable intensification of agriculture and improved livelihoods in rural and urban sectors. His studies at the University of Hawaii, USA and work experience were in integrated aquaculture and agriculture systems, specifically aquaponics, agroecology and organic farming, urban forestry mapping and spatial planning using GIS, biocomposting using black soldier flies to recycle food waste as alternative animal feed, and incorporating sustainable agriculture within the education sector as project-based learning for young farmers.

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Co-founder and CEO of Acquacoltura Italia Srl, focused on aquaponics systems, training and assistance, especially in relation to economics and business organization in aquaponics. Fabio is also co-founder of AquaGuide Sas, focused on research and online training regarding aquaculture and aquaponics. He is an expert in management accounting and has supported several Italian companies for the optimization of their inner economic activities. He also has professional experiences in the fields of shipbuilding, mechanical metal companies and service companies.

APPENDIX 3

WORKSHOP AGENDA

Day-1 – **Introduction to aquaponics and country reports (Acquacoltura Italia)**		
09:00 – 09:30	*Registration*	
09:30 – 10:00	Opening address	*Austin Stankus*
10:00 – 10:30	Welcome and brief tour of facilities	*Davide di Crescenzo*
10:30 – 11:00	*Group exercise - expectations*	*Austin Stankus*
11:00 – 12:00	Introduction to aquaponics	*Davide Di Crescenzo*
12:00 – 12:30	Video of aquaponics	*Davide Di Crescenzo*
12:30 – 13:30	*Lunch*	
13:30 – 14:15	Aquaponic system design	*Davide Di Crescenzo*
14:15 – 14:30	Balanced vs. decoupled systems	*Austin Stankus*
14:30 – 15:00	*Coffee break*	
15:00 – 17:30	Presentation of country reports	*All*
17:30 – 18:00	Capacity assessment exercise	*Austin Stankus*

Day-2 – **Water, plants and animals, production and health (Acquacoltura Italia)**		
09:00 – 09:30	System components	*Christian Glorioso*
09:30 – 10:00	Component ratio	*Christian Glorioso*
10:00 – 10:30	*Coffee break*	
10:30 – 11:00	Water: sources and treatment	*Luca Bramucci*
11:00 – 11:30	Biofiltration and cycling	*Christian Glorioso*
11:30 – 12:30	Animal production & health (*lecture*)	*Davide Di Crescenzo*
12:30 – 13:30	*Lunch*	
13:30 – 14:30	Animal production & health (*practical*)	*Luca Bramucci*
14:30 – 15:00	Marine aquaponics (*lecture*)	*Valentina Nozzi*
15:00 – 15:30	Marine aquaponics (*practical*)	*Valentina Nozzi*
15:30 – 16:00	*Coffee break*	
16:00 – 17:00	Plant production & health (*lecture*)	*Hillary Righini*
17:00 – 18:00	Plant production & health (*practical*)	*Hillary Righini*

Day-3 – **Field visits and practical (Rimini farm)**		
Depart – 08:00	Field trip to aquaponic farm - Rimini	
10:00 – 13:00	Group work (*training practical*)	
	System components and design	*Christian Glorioso*
	Fish management practical	*Davide di Crescenzo*
	Water management practical	*Luca Bramucci*
	Plant management practical	*Hillary Righini*
13:00 – 14:00	*Lunch*	
16:00 – 16:30	Review of operational management	*Austin Stankus*

Day-4 **– Commercialization (Acquacoltura Italia)**		
09:00 – 10:00	Commercial-scale production	*Davide Di Crescenzo*
10:00 – 11:00	Marketing	*Massimo Briani*
11:00 – 11:30	*Coffee break*	
11:30 – 12:30	Financial analysis	*Fabio Strappa*
12:30 – 13:30	*Lunch*	
13:30 – 16:30	Group work - demonstration system design and financial analysis (*practical*)	*Austin Stankus*
16:30 – 18:00	Recommendations and closing remarks	*Alessandro Lovatelli*

APPENDIX 4

Workshop expanded programme

Day-1 – INTRODUCTION TO AQUAPONICS AND COUNTRY REPORTS

Opening address (FAO)

Opening address presented on behalf of Mr Árni Mathiesen, Assistant Director-General, FAO Fisheries and Aquaculture Department and Mr Abdessalam OuldAhmed, Assistant Director-General, FAO Regional Office for the Near East and North Africa presented by Mr Austin Stankus.

Welcome address (D. Di Crescenzo)

Introductory remarks by host organization, Acquacoltura Italia Srl including a brief tour of the facilities.

Group exercise / expectations (Participants)

Participants are invited to share their expectations of this course through a facilitated group exercise.

Introduction to aquaponics (D. Di Crescenzo)

Aquaponics has its first greater application 600 years ago with the use of Chinampas, artificial islands created by Aztecs in Mexico able to obtain up to three vegetable crops a year in order to provide fresh food to their ancient capital, the city of Tenochtitlán.

Aquaponics has been rediscovered and is used to rear aquatic animals and cultivate vegetables with the same water. It combines aquaculture (the culture of aquatic animals) with hydroponics (the soilless culture of plants). Aquaponics is based on a multispecies layout where different live organisms interact in a symbiotic environment: animals, vegetables and bacteria.

Aquaculture positives include enhanced control, safety, productivity, ability to grow fish away from water sources. Aquaculture requirements are good water quality, correct temperature, high dissolved oxygen and removal of wastes. Aquaculture negatives include risk of disease, water pollution, and require a stable supply of fish feed.

Hydroponics positives include enhanced control, ability to grow in a small space, less water usage and less physical labour. Hydroponics negatives include increased complication, requirement of electricity and mineral fertilizers.

Aquaponics positives are that it combines the positives of both Aquaculture and Hydroponics. Aquaponics addresses the water pollution of aquaculture by using the effluent as an input for the hydroponics and plants. Also, there is no need for the mineral fertilizers. Aquaponics negatives include the increased complication, compounded risk and need for electricity.

Aquaponic nutrient (nitrogen) cycle: All animals consume protein and excrete ammonia. Ammonia is converted by bacteria into nitrite, and then into nitrate. Ammonia and nitrite are very poisonous to fish; nitrate is not as poisonous. Plants use nitrate as fertilizer to grow. The bacteria are the bridge that connects the fish’s ammonia production to the plant’s nitrate fertilizer requirements.

Mineralization: Other nutrients are also very important for plant growth, especially potassium and phosphorous. These nutrients are released in the solid waste of fish, but plants cannot use these large particles. Again it is the bacteria that break down the large pieces of fish waste into small, charged molecules that the plants can use. It is important that the fish waste is mineralized by bacteria to provide the plants with a complete compliment of nutrients.

Video of aquaponics

A brief set of videos highlighting the scope and breadth of aquaponics demonstrates the versatility and uses of Aquaponics while offering a broader picture.

Aquaponic system design (D. Di Crescenzo)

Aquaponic systems are divided by the technology of water recirculation used and influenced by the type of plant growing module that they use. Each design has positives and negatives. The most common types are: deep water, ebb flow, NFT and wicking beds.

Deep water culture is a large tank of water with a floating polystyrene sheet on top, and the roots hang down into the water. The positives of deep water culture are the ability to grow large amounts of plants in the same space. The tanks can be built with simple materials, buried in the ground or made with hollow-form bricks, and lined with polyethylene sheets. There is an opportunity for automation. This is the best and most common system for large scale commercial plants. The negatives are the heavy weight of the water. The water pump needs to be larger to circulate the water constantly, and it is easy for there to be anoxic, dead spots.

Nutrient Film Technique (NFT) is where plants grow in grow tubes (often PVC pipes) that have a constant, thin layer of water in the bottom. The positives are the very low weight which makes it appropriate for roofs. Then negatives are that it is difficult to control the temperature inside the tubes. Also, if the water stops flowing then the plants can die very fast which makes this inappropriate where electricity is unreliable.

Media beds are the simplest and easiest to understand. Plants grow in an inert medium of clay, cinders, rocks or others. The medium provides support and also a location for the bacteria to live. It is most similar to the soil based gardening, so is very easy to explain. The positive is the combined biofilter which makes balancing the system very easy. The negative is that the media is hard to clean, and can accumulate solid wastes which is a health risk to fish and plants. Most media beds have a reciprocating water height controlled by either siphons or timed pumps, which gives the media high oxygenation good for roots and bacteria.

Wicking beds are a type of media beds that deserves special attention. A secondary container full of a second type of media is ½ buried in a standard media bed. The water is carried by capillary action from the main media bed up into the second media bed. This gives the opportunity to use different media that can support root crops like carrots and storage onions. Also it allows us to fertilize the media without affecting the fish.

Bumina is a special type of media bed where satellite pots line a large fish tank, water is pumped to a header tank and distributed to the satellite pots containing the plants and cascades back to the fish tank. The design is simple to construct, but hard to intensify commercially.

Balanced vs. decoupled systems (A. Stankus)

There are two large divisions within aquaponics, balanced systems and decoupled systems.

A balanced system is the “normal” system, based on the design by James Rakocy at the University of the Virgin Islands. The water is recirculated between the fish to the plants and back to the fish.

A decoupled system is different. It is also called a “dual-loop” system. It is a standard RAS system (fish tank to filter back to fish tank). The solid waste is diverted into a mineralization tank. Each day some of the fish tank water, 5 percent, is also given to the mineralization tank, and the fish tank is resupplied with fresh, clean water. From the mineralization tank, the nutrient rich water goes through a one-way valve to the hydroponics portion. This is a standard recirculating hydroponics system (reservoir to plants to reservoir). At no point does water from the plants go back to the fish.

The benefits of a decoupled system are that you can add aquaponics to an existing RAS with minimal changes. Both systems can be run independently. If disease or pests occur, the systems can be separated and treated without hurting the other system. In essence, two separate systems can be built and managed, connected by a one-way pipe.

The negatives of a decoupled system are increased water management, more complicated plumbing, more tanks, and more control valves.

Presentation of country reports

Participants from each country (1 presentation per country), are asked to introduce themselves and presents the state of aquaponics in their home country. These presentations follow the summary report questions circulated to the participants, including questions about the level of aquaponics knowledge, development of RAS technologies, and major stakeholders. The purpose is to develop a broader understanding about aquaponics in the region, and to identify similarities and differences among the group and within the sector.

Group assessment exercise (A. Stankus)

Knowledge, Attitudes, Practices – An individual exercise where each participant is asked to complete a distributed worksheet that answers a series of questions about the participants' current state of knowledge, attitudes, and practices. Results are used to guide further workshop activities.

Day-2 – PLANTS AND ANIMALS, PRODUCTION AND HEALTH

System components (C. Glorioso)

Fish tank is where the fish live. It should be a normal shape that allows water movement and easy cleaning, be covered with netting to prevent the fish from jumping out, and be in indirect sunlight.

Sump is the lowest point in the system – water always flows downhill into the sump. The sump is not strictly necessary, but it makes water management and filtration easier.

Mechanical filter is used to separate the solid wastes, the most important aspect of RAS and Aquaponics. Common types include a swirl filter, baffle filter, drum filter or mesh screen.

Grow bed is where the plants live. It is important to have the correct size, good aeration and no leaks. Media materials should be lightweight and porous, but not float.

Water pump should be large enough to circulate the water 1–2 times every hour. A pre-filter prevents obstructions from damaging the pump.

Air pump should be large enough to provide 5–8 ppm of dissolved oxygen in all parts of the fish tank at all times. Well placed air stone diffusers ensure there are no "dead" spots with low DO.

Component ratio (C. Glorioso)

The fish and the plants need to be balanced. If there are too many fish, then there is an accumulation of nutrients and the plants and fish both suffer. If there are too many plants, there are insufficient nutrients and the plants do not grow well. If the biofilter is too small, there will be insufficient bacteria to convert the ammonia, and the fish will suffer. There are two main ways to balance an aquaponics system. The Feed Rate Ratio or Water Volume Ratio + Stocking Density.

The Feed Rate Ratio states that every 50–80 grams of fish food that enters the system per day can fertilize 1 square metre of plant growing area. The amount of feed suggests the biomass of fish required.

The Volume Ratio + Stocking Density is an estimation that for every 1 unit of water of fish tank, you can fertilize between 2–4 units of grow bed. This assumes a standard stocking density. These demonstration systems use this method because the stocking density is set by Italian regulation.

Water: sources and treatment (L. Bramucci)

There are several common sources of water: municipal water, rainwater, surface water and well water. All new sources of water should be tested before use in an aquaponic system.

Main water parameters to check on a regular basis include: temperature, dissolved oxygen, carbon dioxide, pH, ammonia, nitrite, nitrate, hardness, and alkalinity. In addition, initial chemical analysis should include microbiological and chemical contaminants including chlorine and heavy metals.

Hard water (water with high levels of calcium carbonate) can be treated with phosphoric acid before being added to the system. Water with potential of microbial contamination can be sand filtered and exposed to treatment with ultraviolet light. Water with chlorine can be oxygenated for 24 hours to promote degassing.

Living organisms in an Aquaponic system affect the water chemistry. Fish release carbonic acid and lower the pH; nitrification by the bacteria releases nitric acid and lowers pH.

Biofiltration and cycling (C. Glorioso)

The biofilter takes a long time to fully process the daily ammonia produced by the fish. The time required is at least 6 weeks, but can be as much as 3 months. Bacteria will be inhibited at ammonia concentrations higher than 4 ppt. Warm temperatures help the bacteria cycle faster, and bacteria do not work well below 15 degrees Centigrade.

It is helpful to do nitrogen and pH testing often during the cycling process and to graph the results. This will give an indication of how far along the cycling process the system is.

Fishless cycling is a good way to jump-start the biofilter. Instead of using fish as the source of ammonia, urea can be used. The nitrifying bacteria will colonize the biofilter and convert the urea into nitrite and finally nitrate. This prevents the stress and death of fish when they are stocked into an immature system.

The most common error is impatience – adding too many fish too fast can kill the fish. Wait for the biofilter to be fully cycled before fully stocking the fish. It is better to stock very slowly. Also, be sure that the biofilter is large enough.

It is important to pay attention to balance the aquaponic system, for example avoid transplanting only a few vegetables and introducing too many animals in a short time. Greater volumes of water are more balanced and have more stable aquatic parameters.

Animal production and health (lecture**)** (D. Di Crescenzo)

The key characteristics for choosing the right species to rear include: temperature range, the ability to live in crowded conditions, and fast growth. Also, it should be neither territorial nor cannibalistic; be adaptable to different methods of raising; able to be reared in polyculture; and exhibit a high survival rate and be resistant to diseases.

The most common species reared in aquaponics are: tilapia, carp, koi carp (ornamental species), trout, catfish, barramundi, jade perch, blue gill (sunfish), crayfish, freshwater prawn (*Macrobrachium*). In salt water it is possible to rear seabass, seabream, penaeid shrimp and *Solea* spp.

Good water quality will ensure health fish and high growth rates. Strong, healthy fish living in clean, un-crowded conditions with adequate oxygen is the best defence against disease – support the immune system of the fish by providing a healthy environment and good food.

It is important to keep a steady standing crop of fish in the systems. To replenish harvested fish, choose either to resupply from a hatchery or to breed fish on-site. Hatchery fish can add to cost, and you need an additional biosecurity control to prevent incoming disease. On-site breeding adds to the labour costs and requires more expertise.

One example of breeding is based on the common tilapia, which will breed when provided with correct stocking density, male to female ratio, in a tank with substrate on the bottom in warm temperatures (24 °C).

It is important observe the behaviour and the physical features of animals every day and every time you feed them. A healthy fish swims normally, with all fins erect, and exhibits normal colours and markings; has a good appetite; doesn't show signs of stress or has not damaged fins; breathes normally and does not gasp at the surface.

Preventive healthcare is based on the observation of the following features: biology of species; feed; water quality; quarantine; cleaning of the system; and disinfection. Sanitation practices for tank facilities include: regularly remove wastes (faeces, uneaten food, etc.); weekly clean the facility; place hand-washing areas at the entrance of the facility and in the working hot spots.

Ensure proper biosecurity by using: nets against birds; fences against wild animals; disinfectants such as bleach (sodium hypochlorite at 5%) against harmful bacteria and microorganisms. Be cautious to avoid using chemicals that are dangerous to the fish or plants, or are prohibited.

A hospital tank should be available to remove diseased fish out of the main system for treatment.

No chemical treatments can be used in the main system because it will hurt the bacteria and the plants necessary for aquaponics. Anyway it is possible to use some organic substances such as common salt that are well known for their ability to protect the animals from the action of some parasite organisms, but always in a separate treatment tank.

Animal production & health (practical**)** (L. Bramucci)

The practical section and hands-on activities include the practice of: proper feeding technique; measuring the main water parameters; selection, capture and reintroduction (acclimation) of animals; the preparation and proper use of quarantine and salt bath treatment. The objective of these exercises is increased comprehension of the management of animals in the tank regarding the quality of water, introduction of individuals after quarantine and acclimation, feeding and correction of water conditions regarding pH.

Marine aquaponics (lecture**)** (V. Nozzi)

Salt water (marine) aquaponics is similar to freshwater aquaponics, but there are limitations imposed by the marine environment. Salinity, defined as the amount of salt in water, has an effect on the regulation of the amount of water inside a fish (osmoregulation), and it can lead to stress. It is important to monitor the water parameters of the salt water, and there are differences in the effect of pH and unionized ammonia.

Choose appropriate crops and varieties. The best plants to grow in salty water are: algae, Salicornia, beet greens, sea kale, and tomatoes. Salinity can sometimes increase the quality of fruits. In many places marine fish have high market demand, but limited vegetables can grow in salt water.

It is possible to adapt some fish species from marine (salt) water to fresh water. Most fish can live at 7–10 ppt of salinity, and it is essential to adjust the salinity slowly.

There are some commercial opportunities for ornamental marine species.

Marine aquaponics (practical**)** (V. Nozzi)

The practical section and hands-on activities include the practice of: preparation of synthetic salt water solution, use and calibration of a refractometer, water quality measuring and review of how to acclimate fish.

Plant production and health (lecture**)** (H. Righini)

Suitable species in aquaponics: salads, tomatoes, cucumbers, beans, peppers, cabbages, beets, green onions, herbs, ornamental plants and many more. Root crops are possible, but difficult.

The environmental parameters such as light, temperature and humidity, wind, aquaponic method, water quality and nutrients determine the health and production of fish. Each plant has a specific tolerance and acceptable range, and sometimes protected culture areas are required.

Deep water culture is best for large scale production of salads, greens and herbs. It does not support very large plants as well. NFT is also best for small, fast growing plants. Media systems are good for taller plants that need more support such as tomatoes or peppers.

Plants grow well in aquaponics because: no crop-weed competition; less effort necessary to extend the roots; and the constant availability of water and food.

Understanding the uses and function of the essential nutrients (N, P, K, Ca, Mg, S, Fe, Mn, B, Zn, Cu, Mo) can aide in identifying and rectifying nutrient deficiencies. pH can affect the availability of the nutrients, and the best range for plants is from 5.5–7.0.

High throughput of plants requires a system to ensure efficient seeding, transplanting, grow-out and harvest. It is important to have a good supply of seedlings ready to be planted into the system; continual harvesting and replanting will ensure that the levels of nutrients into the water are relatively constant. Two seed starting choices are available: seeding directly on the grow bed or a nursery area where to grow the seedlings; temperature and humidity are fundamental for the rapid growth of the seedlings. It is strongly recommended to avoid using plants started in soil or from an independent nursery

A healthy plant is visually recognizable: swollen and erect parts of the body; green leaves and no tissue alterations (such as curling, discolouration, dry parts, etc.); well-developed and healthy roots; absence of signs of rot; the fruits are colourful.

Nutrient deficiencies occasionally occur in aquaponics, especially potassium and iron. To correct, first ensure a correct balance of fish to plants, complete fish waste mineralization, and then consider supplementation. Potassium and calcium can be added during pH correction using carbonates, iron can be added as a chelate, and liquid kelp can supply micronutrients.

Integrated pest management is the combination of several methods to manage problems owing to insects and includes: environmental control; insect barriers; insect traps; fungicides and beneficial organisms.

Chemicals products for disease prevention and pests and disease control cannot be used because they endanger the fish and bacteria. Examples of biological methods against pests and fungus include the use of predaceous and parasitoid insects (*Adalia bipunctata*, *Aphidius ervi*) and natural products composed by: antagonistic microorganisms of fungi; plant extracts; seaweeds, bacteria etc.

Plant production & health (practical**)** (H. Righini)

The practical section and hands-on activities include the practice of: seeding, transplanting and harvesting; identification of diseases, pests and nutrient deficiencies and their treatment options.

Day-3 – OPERATIONAL MANAGEMENT AND HUMAN RESOURCES

Field trip to aquaponic farm in Rimini

The practical section and hands-on activities are based on work in small groups and include 4 modules: system components and design, fish management, water management and plant management. Each module reviews and reinforces lessons from Day-2. Participants are asked to take turns explaining each module to their group with the support of the facilitator to practice teaching aquaponics. Objectives of the tour are to practice doing and teaching the daily management of a mid-size aquaponic system and to highlight the importance of human resource training.

Module 1: *System components and design* – Major components are identified and discussed, and full day of management and data collection, including training, daily management tasks such as cleaning, checklists and log book data entry.

Module 2: *Fish management* – Management of fish includes proper techniques and methods of feeding; harvesting; stocking; observing and treating for disease.

Module 3: *Water management* – Water management includes full water quality testing and adjustment of key parameters. Correction of the pH of water using acid or base substances.

Module 4: *Plant management* – Plant management includes seeding, transplanting, harvesting, checking and observing plants to identify and diagnose insect pests, diseases and nutrient deficiencies and methods for correcting and treating each.

Operational management (A. Stankus)

Human resources are a critical pillar of any aquaponic farm and employees and managers need to be well trained. Practical management and record keeping are essential for the correct operation of an aquaponics system. It is important for management of the health of plants and fish, for tracking and predicting production and labour costs, and for safety and certification during inspection.

Day-4 – COMMERCIALIZATION

Commercial-scale production (D. Di Crescenzo)

There is a difference between commercial production and small scale production. Commercial production can realize gains from the efficiency of scale, but the investment increases. Aquaponics changes from small to large – it is not always linear. Large designs must be designed in such a way to take advantage of these differences. Many commercial aquaponic farms exist, but many farms have failed.

A pilot system is important to make before a full commercial site is developed– to develop market, work out the bugs, and bring in investors.

Village aquaponics is a good solution for the creation of a big commercial plant, dividing the cost of installation, management and work between several persons in a community.

The use of covered aquaponic systems allows a better control on the environmental parameters and for biosecurity purpose. Greenhouses are important in temperate climate, and the proper equipment should be chosen. It may be necessary to bring in a specialist in controlled environment agriculture to ensure that the equipment, fans, air movement, shade, humidity, lights are appropriately chosen and installed.

Energy consumption could be a significant cost. Some strategies to reduce consumption include timed pumping, temperature control with passive heating/cooling, positioning of greenhouse, solar, small strategies, types of grow light (neon, high pressure sodium (HPS), and light emitting diode (LED)).

Marketing (M. Briani)

It is important to understand the market demands, market location, produce production and sales prices, transportation and storage logistics. This market analysis must be done before designing a commercial system. The idea is not 'how much can I grow' but it is "how much can I sell?"

Product differentiation, certification and law – it is important to understand and follow local regulations. As one example, in the European Union (EU), it is not possible to have biological certification for hydroponics, but in USA can be organic. EU regulations for nitrate levels in salad and herbs are discussed in terms of how it affects system design.

Niche markets vs. commodity: commodity is selling lettuce by the kilo which is very hard to compete with industrial-scale agriculture. Niche marketing is identifying a gap in the market demand that can be filled by an aquaponic system.

The 4 Ps of applied marketing: Product, Price, Place and Promotion. How to sell better following the direct marketing and the sale on site. Aquaponic marketing directives. The strategic actions in order to reach more customers. Creation of a professional product presentation and of a customer portfolio. Online communication is a must today.

Financial analysis (F. Strappa)

Management control allows the owner/operator to continuously assess the situation in terms of cash-flow and production.

Investment (capital) costs include the cost of items related to the initial investment with particular reference to items related to the fish, vegetables and plant facility. Management (recurring) costs of a commercial plant include continuing expenses such as electricity, labour and water. Cash flow is an analysis of the income and expenditure according to the financial budget developed economic and related considerations. Profit is when there is positive cash flow – or more income than expenditure. Return on investment is the time until the investment costs are paid off, which requires positive cash flow.

Risk management is an assessment and set of precautions to prevent that the unforeseen may lead to significant shifts in the budget and problems in production.

Economic budget of a commercial plant includes the analysis of cost and revenue forecasts.

Efficiency ratio is an evaluation and analysis measured by the ratio of the results achieved and resources used.

Group exercise (practical system design**)**

A hands-on practical group activity that uses a spreadsheet calculator (provided) and participants local financial variables (i.e. cost of fish feed and sale price of vegetables) in order to design a theoretical aquaponic demonstration system that could be built at the participants home station. The spreadsheet calculator provides the very basics of a financial analysis, which is then hand-sketched on graph paper. Sketches include sizes and position of each component, including the fish tank, grow bed, sumps and pumps. This exercise shows the relationship between financial variables, relative costs, and serves as a final review of the course. Participants have materials to show to colleagues and co-workers upon return. Groups are invited to present to entire class to practice lobbying and explaining aquaponics.

Course conclusion

Course evaluation (15 minutes) – a survey used to determine participants' satisfaction with the course as well as a second survey to indicate changes knowledge and attitudes about aquaponics.

APPENDIX 5

FAO welcoming remarks

The following FAO opening address, reproduced here in its entirety, was presented on behalf of Mr Árni Mathiesen, Assistant Director-General, FAO Fisheries and Aquaculture Department, and Mr Abdessalam OuldAhmed, Assistant Director-General, FAO Regional Office for the Near East and North Africa on the occasion of the workshop *Advancing aquaponics: an efficient use of limited resources*, 27–30 October 2015 in Osimo (Ancona), Italy.

Ladies and Gentlemen,

On behalf of Mr Árni Mathiesen, Assistant Director-General of the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO), and Mr Abdessalam OuldAhmed, Assistant Director-General, FAO Regional Office for the Near East and North Africa (FAO-RNE), it is my pleasure to welcome you here today. Some of you have travelled a long distance, and we thank you for your effort for what we hope will be a valuable experience for furthering the development of aquaponics in the Near East and North Africa Region (NENA).

To begin, we should remember why we are here. We face global challenges in the near future: namely that a finite natural resource base must sustain a growing population in a complex and changing world where agriculture faces an unprecedented confluence of pressures. The population is increasing, hungry for more and better food, yet even now there are hundreds of millions of undernourished people on our planet. Many natural resources, including soil and freshwater, are already overexploited, and a changing climate will add further stress to this precarious situation. Within this context, we have complex social dynamics, institutional and governmental capacities that influence the long-term success and impact of development interventions, both national and international.

To combat these global concerns, FAO has undergone a strategic restructuring focusing on five priority objectives, in order to make a more agile and streamlined institution capable of tackling the global concerns through interdisciplinary and cross-sectoral actions. These priorities are: 1) help eliminate hunger, food insecurity and malnutrition; 2) make agriculture more sustainable and productive; 3) reduce rural poverty; 4) enable inclusive and efficient food systems; and 5) increase resilience from disasters.

Though aquaponics addresses several of these priorities, our main focus here is Strategic Objective Number 2 (SO2), i.e. to make agriculture, forestry and fisheries more productive and sustainable. To do more, with less. Furthermore, this regional activity is under the auspices of the Regional Initiative on Small-Scale Agriculture of the NENA region in collaboration with the FI Aquaculture Branch (FIRA) and also contributes to the FAO Strategic Objective 3 (SO3) - Reduce Rural Poverty.

This workshop will focus on one of the Objectives' major streams of work: supporting innovative practices and the adoption of new technologies. We will be primarily focusing on enhancing Efficient Resource Use through aquaponics. At the same time we will address complimentary principles of protecting natural resources, improving livelihoods and increasing resilience.

One of the most pressing issues is the availability of freshwater resources, recognizing that nearly two billion people depend on agriculture in arid areas, and that global climate change is increasing the risk of desertification around the world. This is a regional workshop, for the Near East and North Africa region, where water scarcity is a genuine concern.

The revised Strategic Framework of FAO is further tailored to regional initiatives, developed through consultation with stakeholders through a long participatory process to understand some of the most important issues facing the region. Here, we understand that finding options to thrive in water scarce areas is a key goal, important to all arid areas, and essential to NENA. Also, support for small-scale farmers is a key opportunity to improve the way of living of family farmers who are critical in the global food production system. The point is, that FAO has asked the countries, regions and Member states what are the most important priority areas for the development of food security and nutrition.

Aquaponics is one of these integrated technologies that addresses some of the outlined constraints. The next four days will be spent talking about the technical details, with an experienced team of FAO consultants and collaborating partners.

In the simplest terms, aquaponics is the combination of hydroponics and aquaculture. By combining these two separate systems, we are able to use the wastewater from the fish to fertilize the plants. This integration increases efficiency. This is the key opportunity provided by aquaponics.

FAO has a proposed methodology to support the development of aquaponics. First, and most importantly, aquaponics should only be used in the right locations. Identification of these locations through participatory needs assessment is the first step. Documenting and disseminating the best practices through technical guidelines is also important - kindly note that FAO has recently published a technical manual on small-scale aquaponic food production that each participant will take home. The manual is also available online, free-of-charge, and has now been translated into Arabic. Then, facilitating regional networks of experts is crucial for the long-term anchorage of aquaponic development. It is important for us, for you, to forge connections among yourselves and others in the region to share locally-appropriate and location-specific techniques. This form of South-South Cooperation will reduce the reliance on outside materials and outside experts and allow aquaponics to develop naturally within this geographic and cultural context.

Then, it is important to consider building demonstration units. These units are generally built at universities, institutes or government aquaculture research centres - but also medium-size businesses often open their doors to demonstrate aquaponics to the wider community. These demonstration sites should be located somewhere stable with institutional memory, and then used to research and adapt the general aquaponic technologies to locally important fish and plant species. Moreover, these sites serve as education and training centres, often targeting young students and entrepreneurs, to develop the capacity of the farmers who should be provided with simple implementation materials to build production systems of their own.

Aquaponics works, but different scales should be used for different purposes. Medium to large demonstrations centres, such as the one at the University of the Virgin Islands, are used to teach, research and develop sound financial investment strategies. Small systems using simple materials and simple techniques are used for family and village level interventions using low-risk and low-expenditure techniques, key for development in rural areas.

The impact of aquaponics is to produce both fish and vegetables, together and efficiently, using minimal inputs. Aquaponics is an option for farmers with limited access to land and water to have a chance to grow food. No fertilizers or chemical pesticides are required. And overall it provides small-scale farmers the potential to earn a supplementary income, and for commercial farmers to create a viable business.

In addition, aquaponics provides an opportunity for women and youth to be involved in the production of fish and plants, and the daily tasks are labour-saving. It is an opportunity to promote education, and can be done in a safe and secure way inside the home on the balcony or rooftop at a small-scale.

Aquaponics provides a method to grow fish as a source of protein. Choosing a wise selection of crops for a small-scale system can add to a family's dietary diversity and alleviate the burden of micronutrient deficiencies by adding nutritious crops to the diet in a cost-effective way.

But one must be cautious. Aquaponics seems too good to be true. There is a history of unscrupulous people who explain all of the benefits of aquaponics, but fail to highlight the risks. An aquaponic system requires electricity to operate the pumps and thus cannot work unless there is a reliable source of power. Aquaponics is most appropriate where land is expensive, water is scarce, and soil is poor. Otherwise, in areas suitable for agriculture, the introduction of aquaponics may be too complicated, or just unnecessary. In urban environments where no or very little land is available, aquaponics provides families with a means to grow crops on small balconies, patios or on rooftops. In areas where there is a potential to build a network among several households using aquaponics, it is easier to purchase fish stock, feed, and seed plants in bulk and at a cheaper price and can thereby lead to opportunities for commercialization. A market that is willing to pay premium prices for nutritious, high-quality and residue-free produce is required for a large-scale commercial system.

There are challenges that should be addressed and discussed over the following days. Aquaponics requires dependable electricity, reliable access to fish seed, plant seed and good quality water. The farmers and workers need to be trained and engaged. Finally, any commercial aquaponics venture requires a feasibility study, sound financial planning and significant technical expertise before it can be seriously considered.

With these challenges in mind, there are lessons worth sharing from FAO's aquaponic experience in Gaza.

In the early 2000s, FAO implemented an emergency food production project funded to increase both food and nutrition security in this region. The project installed approximately 70 aquaponics systems in food insecure, predominately female-headed, households.

The project was initially successful in providing a means for the women to grow food. However, after the initial inputs ran out, many families did not have the cash to buy new inputs, a basic farming background to ensure good plant performance, or access to technical support from local, experienced producers. The Gaza experience demonstrates the need to initially work with families who possess both an entrepreneurial spirit and a farming background. Further, these small-scale family framers needed a local technical base and regional network to provide on-going support and extension.

The main goal of this workshop is to open a dialogue with you. We ought to share with one another why we are here. What we hope aquaponics can do for us and for the people we represent, and what reservations and concerns we have. Of course, you will receive an opportunity for a hands-on, intensive technical training where you will go through every detail of aquaponics. By the end, we hope that you will have acquired the knowledge, experience and materials to share what you have learned with your research centres and the farmers so that together we can use aquaponics in our collective struggle against hunger.

This conversation is much longer than a single workshop, so let us keep in touch through a regional network so that we can continue to share and learn from each other. We would like to hear from you what further needs are envisaged to support aquaponic development, and especially how FAO can provide that support, whether it is through technical assistance or other means. Over the next few days, we will record your recommendations, and the report and share with our Members to better guide our future activities.

And so, I extend my heartfelt welcome to all of you. Thank you for coming and we look forward to collaborating and supporting you in future endeavours that may include aquaponics development in your respective countries.

APPENDIX 6

Country survey forms

Each country was asked to give a short presentation on the first day regarding the level of aquaponic development in their home country. For this, a 2–4 page written summary was requested in addition to the 5–10 minute presentation.

Each participant was invited to design a model aquaponic system on the final day. The exercise was to imagine that the participant would actually build a demonstration system upon their return to their home country. Each choose an actual location (university, department of fisheries, aquaculture training centre, etc.) that would be convenient for training industry professionals and students. The following questionnaire was circulated in anticipation of the workshop to collect actual market prices (electricity cost, crop sale price, etc.) to support the financial analysis. These data were fed into an Excel model which was used to estimate production and revenue based upon local conditions.

Both the survey forms are presented herewith in both original English and an unofficial Arabic translation.

Summary report (*English form*)

TECHNICAL TRAINING WORKSHOP ON ADVANCING AQUAPONICS: AN EFFICIENT USE OF LIMITED RESOURCES

Country summary report

Each participant is kindly requested to prepare a 2–4 page report regarding the current state of aquaponics, if any exist, in their home country. However, summaries should include not only the state of aquaponic development, but information on recirculating aquaculture and hydroponics. Some important information to include would be:

Aquaponics

- General awareness of aquaponics in university and extension programmes.
- Number of universities with aquaponic systems.
- Number of commercial aquaponic companies.
- General awareness of aquaponics at the government level.
- General awareness of aquaponics in the general public.
- Availability of information regarding aquaponics.
- Significant blocking issues to aquaponic uptake and development.
- Relevant companies, institutions, universities or other organizations that are practicing aquaponics.
- Level of business interest for investment on new agricultural technologies.

Recirculating aquaculture (RAS)

- Level of awareness of RAS at university level.
- Level of use of RAS in commercial production.
- Level of awareness of RAS at government level.
- Availability of information regarding RAS.
- Relevant companies, institutions, universities or other organizations that are practicing RAS.
- Availability of fish fingerlings and fish feed.
- Availability of veterinarians and fish health professionals.

Hydroponic production

- Level of awareness of hydroponics at university level.
- Level of use of hydroponics in commercial production.
- Level of awareness of hydroponics at government level.
- Availability of information regarding hydroponics.
- Relevant companies, institutions, universities or other organizations that are practicing hydroponics.
- Availability of nutrient solutions and equipment.

Summary report (*Arabic form*)

ورشة عمل تدريبية فنية حول تطوير الاستزراع المائي السمكي والنباتي: استخدام كفؤ لموارد محدودة

موجز التقرير الوطنى

يرجى من كل مشارك إعداد تقرير من 2 إلى 4 صفحات حول الوضع الحالي للاستزراع المائي السمكي والنباتي، واذا ما كان موجودا فى بلده. ومن ناحية أخرى يجب ان تشمل المواجيز ليس فقط الوضع الحالي لتنمية الاستزراع المائي السمكي والنباتي، ولكن أيضا معلومات حول اعادة تدوير تربية الأحياء المائية والزراعة فى الماء. بعض المعلومات الهامة التى يجب تضمينها هي:

الاستزراع المائي السمكي والنباتي

- التوعية العامة بالاستزراع المائي السمكي والنباتي فى الجامعات وبرامج الارشاد.
- عدد الجامعات التى بها نظم الاستزراع المائي السمكي والنباتي.
- عدد الشركات التجارية للاستزراع المائي السمكي والنباتي.
- التوعية العامة بالاستزراع المائي السمكي والنباتي على مستوى الحكومة.
- التوعية العامة بالاستزراع المائي السمكي والنباتي بين عامة الجمهور.
- اتاحة المعلومات الخاصة بالاستزراع المائي السمكي والنباتي.
- العقبات الأساسية أمام الأخذ بالاستزراع المائي السمكي والنباتي وتنميته.
- الشركات المعنية، المعاهد، الجامعات أو المنظمات الأخرى التى تمارس الاستزراع المائي السمكي والنباتي.
- مستوى الأعمال التجارية الحريصة على الاستثمار فى التقنيات الزراعية الجديدة.

إعادة استخدام الماء داخل وحدة الاستزراع المائي

- مستوى الوعى بإعادة استخدام الماء داخل وحدة الاستزراع المائي.
- مستوى إعادة استخدام الماء داخل وحدة الاستزراع المائي في الانتاج التجاري.
- مستوى الوعى بإعادة استخدام الماء داخل وحدة الاستزراع المائي على مستوى الحكومة.
- اتاحة المعلومات الخاصة بإعادة استخدام الماء داخل وحدة الاستزراع المائي.
- الشركات المعنية، المعاهد، الجامعات أو المنظمات الأخرى التى تمارس إعادة استخدام الماء داخل وحدة الاستزراع المائي.
- اتاحة الأسماك الصغيرة وتغذية الأسماك.
- وجود الأطباء البيطريين والمتخصصين في صحة الأسماك.

انتاج الزراعة فى المياه

- مستوى الوعى بالزراعة فى المياه على المستوى الجامعي.
- مستوى استخدام الزراعة فى المياه في الانتاج التجاري
- مستوى الوعى بالزراعة فى المياه على مستوى الحكومة
- اتاحة المعلومات الخاصة بالزراعة فى المياه.
- لشركات المعنية، المعاهد، الجامعات أو المنظمات الأخرى التى تمارس الزراعة فى المياه.
- اتاحة الحلول المغذية والمعدات

Questionnaire (*English form*)

TECHNICAL TRAINING WORKSHOP ON ADVANCING AQUAPONICS

DEMONSTRATION AQUAPONIC UNIT QUESTIONNAIRE

Please imagine that you will be building a demonstration aquaponic system upon your return to your home country. Choose an actual location (university, Department of Fisheries, aquaculture training centre, etc.) that would be convenient for training industry professionals and students, and answer the following questions. These answers will be used during the workshop to develop a technical design and business plan based on the local species, conditions and constraints.

Category	Question	Answer	Unit
Location	Nearest city, name of country		--
	Land tenure (taxes, rent - if any)		$/year
	Is the land level and ready for building		--
	Distance to nearest urban area with > 50 000 people		km
Climate	Average air temperature in summer		°C
	Average air temperature in winter		°C
	Average humidity in summer		%
	Average humidity in winter		%
	Elevation from sea level		metres
	Total rainfall per year		mm
	Number of days with rain per year		days
Water	Access to irrigation quality water on site? (circle answer)	Yes / No	--
	What is source of water at location? (rain-fed, well, municipal)		n/a
	pH of the water?		--
	Cost of water per cubic metre?		US$/$m^3$
Electricity	Access to electricity at site? (circle answer)	Yes / No	--
	Cost of electricity per kilowatt*hour?		US$/kWh
	Number of hours of electricity at site?		hours

Category	Question	Answer	Unit
Aquaculture	Are there any freshwater aquaculture farms near the site?	Yes / No	--
	Local freshwater aquaculture species (list at least 3), especially the ones you want to grow?	1.	--
		2.	--
		3.	--
	Farm-gate/market sale price of each species? (provide both if available)	1.	US$/kg
		2.	US$/kg
		3.	US$/kg
	Cost of fingerlings of each species? Indicate unit price and species name	1.	US$/fish
		2.	US$/fish
		3.	US$/fish
	Cost of fish feed per kilo?		US$/kg
Horticulture	Access to seeds?	Yes / No	--
	Access to hydroponic nutrients?	Yes / No	--
	Local and popular vegetables (list at least 3), especially the ones you want to grow?	1.	--
		2.	--
		3.	--
	Farm-gate/market sale price of each vegetable? (provide both if available)	1.	US$/kg
		2.	US$/kg
		3.	US$/kg
	Is there a market for certified organic produce?	Yes / No	--
Supplies and Equipment	Access to PVC pipe, connectors, and fittings?	Yes / No	--
	Access to water pumps?	Yes / No	--
	Access to air pumps, air-stones?	Yes / No	--
	Access to greenhouse supplies? (shade-cloth, nursery trays, potting mix, etc.)	Yes / No	--
	Access to fish tanks	Yes / No	--
Labour	Average hourly or daily (please specify) wage for labourer		US$/hr
Additional Notes			

Questionnaire (*__Arabic form__*)

ورشة عمل تدريبية فنية حول تطوير الاستزراع المائي السمكي والنباتي

استبيان وحدة اظهار مزايا الاستزراع المائي السمكي والنباتي

من فضلك تخيل أنك ستبنى نظام لإظهار مزايا نظام الاستزراع المائي السمكي والنباتي عند عودتك لوطنك. اختر موقع حقيقي (جامعة، هيئة للثروة السمكية، مركز تدريب لتربية الأحياء المائية، الخ.) وأن يكون مقنعاً لصناعة تدريب المهنيين والطلبة، وأجب على الأسئلة التالية. هذه الأسئلة ستستخدم خلال ورشة العمل لتطوير تصميم فنى وخطة عمل ترتكز على الأصناف المحلية والظروف والمعوقات.

العنصر	السؤال	الاجابة	الوحدة
الموقع	أقرب مدينة، اسم الدولة		--
	ملكية الأراضى (الضرائب، الايجار – إن وجد)		**دولار/سنة**
	هل مستوى الأرض يصلح وجاهز للبناء		--
	المسافة إلى أقرب منطقة حضارية مأهولة بأكثر من 50000 نسمة		**كم**
المناخ	معدل درجة حرارة الطقس فى الصيف		**درجة الحرارة**
	معدل درجة حرارة الطقس فى الشتاء		**درجة الحرارة**
	نسبة الرطوبة فى الصيف		**%**
	نسبة الرطوبة فى الشتاء		**%**
	الارتفاع عن مستوى سطح البحر		**متر**
	إجمالي سقوط الأمطار كل سنة		**ملليمتر**
	عدد الأيام التى تسقط فيها الأمطار كل سنة		**يوم**
المياه	فرص الحصول على مياه الري جيدة النوعية بالموقع؟ (ضع دائرة حول الاجابة)	نعم / لا	
	ما هو مصدر المياه بالموقع؟ (مطرى، بئر، بلدى)		
	مؤشر حموضة المياه؟		-
	تكلفة المياه لكل متر مكعب منها؟		**دولار أمريكى/ متر مكعب**
الكهرباء	فرص الحصول على الكهرباء بالموقع؟ (ضع دائرة حول الاجابة)	نعم / لا	-
	تكلفة الكهرباء لكل كيلو وات ساعة؟		**دولار أمريكى/ كيلو وات ساعة**
	عدد ساعات وجود الكهرباء بالموقع؟		**ساعات**

العنصر	السؤال	الاجابة	الوحدة
تربية الأحياء المائية	هل هناك أية مزارع لتربية الأحياء المائية بالمياه العذبة بالقرب من الموقع؟	نعم / لا	-
	أصناف زراعة الأحياء المائية بالمياه العذبة المحلية (ضع ثلاثة على الأقل بالقائمة)، وخصوصا الأصناف التى ترغب فى زراعتها؟	.1	-
		.2	-
		.3	-
	سعر البيع بالسوق لكل صنف/ سعر البيع عند باب المزرعة؟ (اذكر كل منهما اذا كان ذلك متاحا)	.1	**دولار أمريكى/ كيلوجرام**
		.2	**دولار أمريكى/ كيلوجرام**
		.3	**دولار أمريكى/ كيلوجرام**
	تكلفة الأسماك الصغيرة لكل صنف؟ قم بالاشارة إلى سعر الوحدة واسم الصنف؟	.1	**دولار أمريكى/ صنف الأسماك**
		.2	**دولار أمريكى/ صنف الأسماك**
		.3	**دولار أمريكى/ صنف الأسماك**
	تكلفة تغذية الأسماك لكل كيلو؟		**دولار أمريكى/ كيلوجرام**
البستنة	الحصول على البذور؟	نعم / لا	-
	الحصول على مغذيات الزراعة المائية؟	نعم / لا	-
	الخضراوات المحلية والشعبية (ضع 3 على الأقل)، وخصوصا تلك التى ترغب فى زراعتها؟	.1	-
		.2	-
		.3	-
	سعر البيع عند باب المزرعة وبالسوق لكل نوع من الخضراوات؟	.1	**دولار أمريكى/ كيلوجرام**
		.2	**دولار أمريكى/ كيلوجرام**
		.3	**دولار أمريكى/ كيلوجرام**
	هل هناك سوق للإنتاج العضوي الموثق؟	نعم / لا	-
الامدادات والمعدات	الحصول على انابيب البولي، الموصلات والتركيبات؟	نعم / لا	-
	الحصول على مضخات المياه؟	نعم / لا	-
	الحصول على مضخات الهواء؟	نعم / لا	-
	الحصول على لوازم البيوت الخضراء؟ (........)	نعم / لا	-
	الحصول على أحواض الأسماك	نعم / لا	-
العمل	معدل أجر العامل فى الساعة أو اليومي (يرجى التحديد)		**دولار أمريكى/ ساعة**
ملاحظات إضافية			

APPENDIX 7

Participant satisfaction survey

A workshop satisfaction form was circulated on the last day of the workshop that was designed to quantify how well the expectations of the participants were met. The form and analysis are included herewith.

Satisfaction form

WORKSHOP EVALUATION QUESTIONNAIRE

Participant name (*optional*): .... Country: ....

Instructions:
Please circle your response to the items below. Rate aspects of the workshop on a 1–5 scale:

1 = "*Strongly disagree*" or the lowest, most negative impression
3 = "*Neither agree nor disagree*" or an adequate impression
5 = "*Strongly agree*" or the highest, most positive impression

Your feedback is most appreciated. Thank you.

Circle your response to each item
1 = strongly disagree | 2 = disagree | 3 = neither agree nor disagree | 4 = agree | 5 = strongly agree

	Workshop content					
1.	I was well informed about the objectives of this workshop	1	2	3	4	5
2.	This workshop lived up to my expectations	1	2	3	4	5
3.	The content is relevant to my job	1	2	3	4	5
	Workshop design					
4.	The workshop objectives were clear to me	1	2	3	4	5
5.	The workshop activities stimulated my learning	1	2	3	4	5
6.	The activities gave me sufficient practice and feedback	1	2	3	4	5
7.	The difficulty level was appropriate	1	2	3	4	5
8.	The pace was appropriate	1	2	3	4	5
	Workshop instructors (facilitators)					
9.	The instructors were well prepared	1	2	3	4	5
10.	The instructors were helpful	1	2	3	4	5
	Workshop results					
11.	I accomplished the objectives of this workshop	1	2	3	4	5
12.	I will be able to use what I learned in this workshop	1	2	3	4	5
13.	The workshop was a good way for me to learn this content	1	2	3	4	5

14. How would you improve this workshop (check all that apply)

- ☐ Provide better information before the workshop
- ☐ Clarify the workshop objectives
- ☐ Reduce the content covered in the workshop
- ☐ Increase the content covered in the workshop
- ☐ Include more practical / hands-on activities
- ☐ Include less practical / hands-on activities
- ☐ Make activities more stimulating
- ☐ Improve workshop organization
- ☐ Make workshop less difficult
- ☐ Make workshop more difficult
- ☐ Slow down the pace of the workshop
- ☐ Speed up the pace of the workshop

15. What other improvements would you recommend in this workshop?

....

....

....

16. What is least valuable about this workshop?

....

....

....

17. What is most valuable about this workshop?

....

....

....

18. Any other comments, concerns and follow-up recommendations

....

....

....

Participant satisfaction survey – Satisfaction analysis

The data from the satisfaction form were tallied and are presented in the following table:

	Average n=16	Standard deviation
Workshop content		
1. I was well informed about the objectives of this workshop	4.7	*0.5*
2. This workshop lived up to my expectations	4.3	*0.6*
3. The content is relevant to my job	4.1	*0.7*
Workshop design		
4. The workshop objectives were clear to me	4.8	*0.4*
5. The workshop activities stimulated my learning	4.6	*0.5*
6. The activities gave me sufficient practice and feedback	4.0	*0.9*
7. The difficulty level was appropriate	4.2	*0.6*
8. The pace was appropriate	3.7	*1.1*
Workshop instructors (facilitators)		
9. The instructors were well prepared	4.5	*0.6*
10. The instructors were helpful	4.9	*0.3*
Workshop results		
11. I accomplished the objectives of this workshop	4.1	*0.6*
12. I will be able to use what I learned in this workshop	4.3	*0.7*
13. The workshop was a good way for me to learn this content	4.6	*0.5*

14. How would you improve this workshop (check all that apply)	**COUNT of responses**
☐ Provide better information before the workshop	10
☐ Clarify the workshop objectives	7
☐ Reduce the content covered in the workshop	0
☐ Increase the content covered in the workshop	10
☐ Include more practical / hands-on activities	15
☐ Include less practical / hands-on activities	0
☐ Make activities more stimulating	7
☐ Improve workshop organization	2
☐ Make workshop less difficult	4
☐ Make workshop more difficult	3
☐ Slow down the pace of the workshop	7
☐ Speed up the pace of the workshop	2

APPENDIX 8

Knowledge, attitudes and practices (KAP)

Form and analysis

An informal capacity analysis was done with the participants on the first and last day of the course. The objective was to understand the targeting of the invitations, the impact of the course and the opportunities for future endeavours. The two forms are almost identical, with a small difference about institutional arrangements in regards to aquaponics. The two forms are presented below, followed by a numerical analysis and discussion.

KAP form (before)

Participant name (*optional*): .... Country: ....

Instructions:
Please circle your response to the items below. Rate your current level of current level of understanding and/or comfort on a 1–5 scale:

1 = “*Strongly disagree*” or the lowest, most negative impression
3 = “*Neither agree nor disagree*” or an adequate impression
5 = “*Strongly agree*” or the highest, most positive impression

Your feedback is most appreciated. Thank you.

Circle your response to each item

1 = strongly disagree | 2 = disagree | 3 = neither agree nor disagree | 4 = agree | 5 = strongly agree

Aquaculture	
1. I understand and can explain freshwater fish production (breeding, on-growing, harvest)	1 2 3 4 5
2. I understand and can explain key aspects of fish feeding (feed conversion ratio, growth rate, feed selection)	1 2 3 4 5
3. I understand and can identify water parameters required for good fish production (pH, T, DO, TAN, NO_2, NO_3, KH)	1 2 3 4 5
4. I understand the importance of mechanical filtration and can describe different types of filters	1 2 3 4 5
5. I understand and can explain the importance of biological filtration and the nitrogen cycle	1 2 3 4 5
6. I am comfortable designing a Recirculating Aquaculture System (less than 20 000 litres)	1 2 3 4 5
7. I am comfortable recognizing and treating common fish diseases	1 2 3 4 5

Agriculture	
8. I understand and can explain the basic anatomy of a plant	1 2 3 4 5
9. I understand and explain the nutrient requirements of plants	1 2 3 4 5
10. I understand and can explain and major aspects of Integrated Pest Management	1 2 3 4 5
11. I am comfortable identifying nutrient deficiencies in plants	1 2 3 4 5
12. I am comfortable identifying insect pests on plants	1 2 3 4 5
13. I am comfortable propagating seedlings, transplanting, harvesting, storing agricultural crops	1 2 3 4 5
14. I understand the importance of market analysis for commercial agriculture	1 2 3 4 5
15. I am comfortable adjusting the pH of water using acids/bases	1 2 3 4 5
Aquaponics	
16. I understand and can explain the theoretical balance between the number of fish and the number of plants in an aquaponic system	1 2 3 4 5
17. I understand and can explain the critical components of an aquaponic system (fish tank, sump, water pump, etc.)	1 2 3 4 5
18. I am comfortable performing water quality analysis	1 2 3 4 5
19. I understand and can explain the key opportunities of aquaponics for sustainable food production	1 2 3 4 5
20. I understand and can explain the key constraints/challenges of aquaponics	1 2 3 4 5
21. I currently use aquaponics while preforming my professional duties	1 2 3 4 5
22. I currently use aquaponics in my private/personal garden	1 2 3 4 5
Training and capacity development	
23. I understand the importance of trained human resources specializing in aquaponics	1 2 3 4 5
24. I am comfortable teaching aquaponics to farmers, students and entrepreneurs	1 2 3 4 5
Advocacy	
25. I believe that aquaponics deserves increased investment from the government	1 2 3 4 5
26. I believe that aquaponics should be taught in universities and schools	1 2 3 4 5
27. I believe that more research is needed in aquaponics	1 2 3 4 5

28. I believe that a regional network of experts and practitioners would support aquaponic development	1 2 3 4 5

KAP form (after)

Participant name (*optional*): .... Country: ……………..................

Instructions:
Please circle your response to the items below. Rate your current level of current level of understanding and/or comfort on a 1–5 scale:

1 = "*Strongly disagree*" or the lowest, most negative impression
3 = "*Neither agree nor disagree*" or an adequate impression
5 = "*Strongly agree*" or the highest, most positive impression

Your feedback is most appreciated. Thank you.

Circle your response to each item

1 = strongly disagree | 2 = disagree | 3 = neither agree nor disagree | 4 = agree | 5 = strongly agree

Aquaculture	
1. I understand and can explain freshwater fish production (breeding, on-growing, harvest)	1 2 3 4 5
2. I understand and can explain key aspects of fish feeding (feed conversion ratio, growth rate, feed selection)	1 2 3 4 5
3. I understand and can identify water parameters required for good fish production (pH, T, DO, TAN, NO_2, NO_3, KH)	1 2 3 4 5
4. I understand the importance of mechanical filtration and can describe different types of filters	1 2 3 4 5
5. I understand and can explain the importance of biological filtration and the nitrogen cycle	1 2 3 4 5
6. I am comfortable designing a Recirculating Aquaculture System (less than 20 000 litres)	1 2 3 4 5
7. I am comfortable recognizing and treating common fish diseases	1 2 3 4 5
Agriculture	
8. I understand and can explain the basic anatomy of a plant	1 2 3 4 5
9. I understand and explain the nutrient requirements of plants	1 2 3 4 5
10. I understand and can explain and major aspects of Integrated Pest Management	1 2 3 4 5
11. I am comfortable identifying nutrient deficiencies in plants	1 2 3 4 5
12. I am comfortable identifying insect pests on plants	1 2 3 4 5

13. I am comfortable propagating seedlings, transplanting, harvesting, storing agricultural crops	1	2	3	4	5
14. I understand the importance of market analysis for commercial agriculture	1	2	3	4	5
15. I am comfortable adjusting the pH of water using acids/bases	1	2	3	4	5
Aquaponics					
16. I understand and can explain the theoretical balance between the number of fish and the number of plants in an aquaponic system	1	2	3	4	5
17. I understand and can explain the critical components of an aquaponic system (fish tank, sump, water pump, etc.)	1	2	3	4	5
18. I am comfortable performing water quality analysis	1	2	3	4	5
19. I understand and can explain the key opportunities of aquaponics for sustainable food production	1	2	3	4	5
20. I understand and can explain the key constraints/challenges of aquaponics	1	2	3	4	5
Training and capacity development					
21. I understand the importance of trained human resources specializing in aquaponics	1	2	3	4	5
22. I am comfortable teaching aquaponics to farmers, students and entrepreneurs	1	2	3	4	5
Advocacy					
23. I believe that aquaponics deserves increased investment from the government	1	2	3	4	5
24. I believe that aquaponics should be taught in universities and schools	1	2	3	4	5
25. I believe that more research is needed in aquaponics	1	2	3	4	5
26. I believe that a regional network of experts and practitioners would support aquaponic development	1	2	3	4	5
Institutional arrangement					
27. Aquaponic extension (research and farmer training) would be covered by my current job description	1	2	3	4	5
28. Aquaponic extension (research and farmer training) would be covered by my organizations mandate	1	2	3	4	5

KAP analysis

	Before		After	
	Avg. n=15	***SD***	**Avg.** n=16	***SF***
Aquaculture				
1. I understand and can explain freshwater fish production (breeding, ongrowing, harvest)	4.0	*1.4*	4.3	*0.8*
2. I understand and can explain key aspects of fish feeding (feed conversion ratio, growth rate, feed selection)	3.9	*1.1*	4.4	*0.7*
3. I understand and can identify water parameters required for good fish production (pH, T, DO, TAN, NO2, NO3, KH)	4.1	*1.0*	4.4	*0.6*
4. I understand the importance of mechanical filtration and can describe different types of filters	3.7	*1.1*	4.3	*0.7*
5. I understand and can explain the importance of biological filtration and the nitrogen cycle	4.1	*1.1*	4.3	*0.7*
6. I am comfortable designing a Recirculating Aquaculture System (less than 20 000 litres)	3.1	*1.3*	4.1	*0.8*
7. I am comfortable recognizing and treating common fish diseases	2.4	*1.4*	3.3	*1.2*
Agriculture				
8. I understand and can explain the basic anatomy of a plant	2.6	*1.5*	3.4	*1.1*
9. I understand and explain the nutrient requirements of plants	2.4	*1.5*	3.7	*1.0*
10. I understand and can explain and major aspects of Integrated Pest Management	2.1	*1.3*	3.6	*1.1*
11. I am comfortable identifying nutrient deficiencies in plants	2.2	*1.3*	3.2	*1.2*
12. I am comfortable identifying insect pests on plants	2.1	*1.3*	3.3	*1.1*
13. I am comfortable propagating seedlings, transplanting, harvesting, storing agricultural crops	2.4	*1.2*	3.6	*0.9*
14. I understand the importance of market analysis for commercial agriculture	2.6	*1.3*	3.8	*1.0*
15. I am comfortable adjusting the pH of water using acids/bases	2.6	*1.4*	4.0	*0.8*
Aquaponics				
16. I understand and can explain the theoretical balance between the number of fish and the number of plants in an aquaponic system	2.1	*1.2*	4.0	*0.8*
17. I understand and can explain the critical components of an aquaponic system (fish tank, water pump, etc.)	3.1	*1.4*	4.0	*0.7*

18. I am comfortable performing water quality analysis	3.2	*1.3*	4.1	*0.8*
19. I understand and can explain the key opportunities of aquaponics for sustainable food production	2.9	*1.2*	3.8	*0.8*
20. I understand and can explain the key constraints/challenges of aquaponics	2.7	*1.4*	3.5	*1.0*
21. I currently use aquaponics while preforming my professional duties	1.5	*0.9*		
22. I currently use aquaponics in my private/personal garden	1.6	*1.1*		
Training and capacity development				
23. I understand the importance of trained human resources specializing in aquaponics	4.2	*0.8*	4.5	*0.6*
24. I am comfortable teaching aquaponics to farmers, students and entrepreneurs	3.2	*1.4*	4.1	*0.8*
Advocacy				
25. I believe that aquaponics deserves increased investment from the government	4.4	*1.0*	4.6	*0.6*
26. I believe that aquaponics should be taught in universities and schools	4.4	*0.9*	4.9	*0.3*
27. I believe that more research is needed in aquaponics	4.5	*0.9*	4.9	*0.3*
28. I believe that a regional network of experts and practitioners would support aquaponic development	4.4	*0.9*	4.8	*0.4*
Organizational				
29. Aquaponic extension (research and farmer training) would be covered by my current job description			4.3	*0.7*
30. Aquaponic extension (research and farmer training) would be covered by my organizations mandate			4.3	*0.7*

KAP discussion

In every single question the participants improved based on this self-assessment. Overall, this further emphasises the success of the workshop, but there are interesting trends in these data, including the targeting, the skills gaps and the future directions.

The targeting of this workshop was well done, and indeed most participants considered that extension of aquaponics would fall within their current job description and within the mandate of their organization. Even so, few of the participants were currently using aquaponics in their private nor professional capacity and therefore clearly benefited from this training. Also, it is clear from the differences in the initial capacity between aquaculture and agriculture that almost all participants were aquaculture experts with limited or no understanding of basic horticultural practices.

There were clear skills gaps in the horticulture practices as indicated to the responses of questions 8–15.

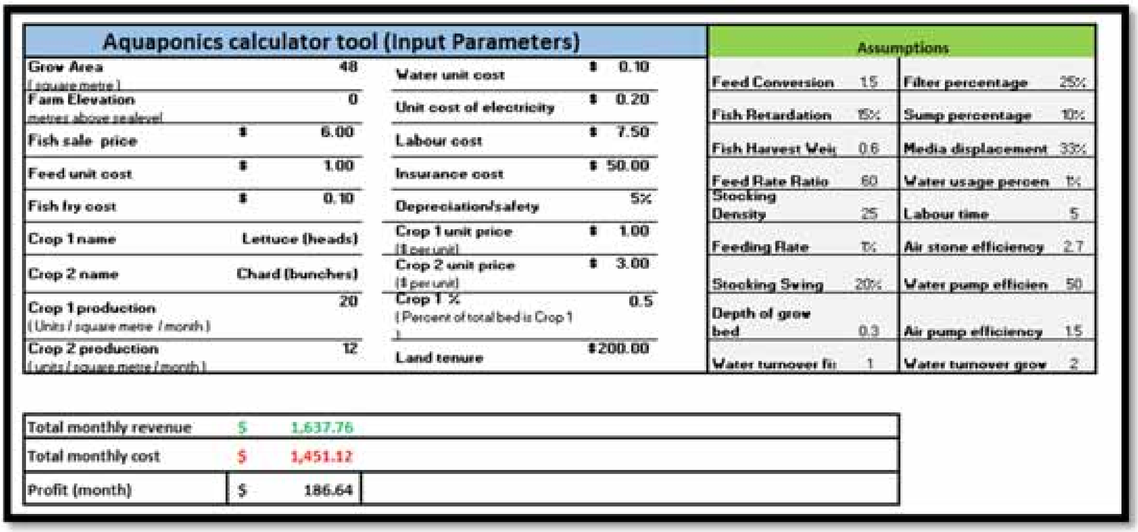
APPENDIX 9

Calculator (explanation and screenshots)

Purpose and introduction

FAO is developing a spreadsheet model of aquaponic systems. The two purposes are to 1) reinforce theoretical lessons of an aquaponic course, and 2) estimate cash-flow, running costs and production volume in a model aquaponic farm. As a teaching tool, this calculator reviews the key equations and calculations that are required to design an aquaponic farm. The user can follow through the built-in logic inside the model to understand how the production is calculated. This offers an opportunity for the practical use of the core concepts taught in the workshops, and moves the participant from a classroom setting into actually planning a model farm.

Secondly, by estimating cash flow in a simple way the participant sees a demonstration of the importance of adequate market research, proper targeting of aquaponic interventions and niche marketing. It is important to note that this calculator is in no way intended to replace full business plan development or the work of professional consultants and builders. Instead, it is intended to show why proper planning is essential to a successful intervention. The calculator is currently (January 2016) in *beta* development and is being released for testing to verify the calculations and add missing components. As of writing the calculator does not calculate capital expenditure nor return on investment.



Aquaponics calculator tool (Input Parameters)

Grow Area (square metre)		48	Water unit cost	$	0.10
Farm Elevation metres above sealevel		0	Unit cost of electricity	$	0.20
Fish sale price	$	6.00	Labour cost	$	7.50
Feed unit cost	$	1.00	Insurance cost	$	50.00
Fish fry cost	$	0.10	Depreciation/safety		5%
Crop 1 name		Lettuce (heads)	Crop 1 unit price ($ per unit)	$	1.00
Crop 2 name		Chard (bunches)	Crop 2 unit price ($ per unit)	$	3.00
Crop 1 production (Units / square metre / month)		20	Crop 1 % (Percent of total bed is Crop 1)		0.5
Crop 2 production (units / square metre / month)		12	Land tenure		$200.00

Assumptions

Feed Conversion	1.5	Filter percentage	25%
Fish Retardation	15%	Sump percentage	10%
Fish Harvest Wei	0.6	Media displacement	33%
Feed Rate Ratio	60	Water usage percen	1%
Stocking Density	25	Labour time	5
Feeding Rate	1%	Air stone efficiency	2.7
Stocking Swing	20%	Water pump efficien	50
Depth of grow bed	0.3	Air pump efficiency	1.5
Water turnover fi	1	Water turnover grow	2

Total monthly revenue	$	1,637.76
Total monthly cost	$	1,451.12
Profit (month)	$	186.64

Description of components

First, the user inputs variables that include: the growing area, the crop choices, the cost of water, cost of electricity and sale prices of fish and vegetables. These input parameters can be developed through online research, farm visits or expert opinion.

Second, the user examines the "assumptions" which are prefilled for the user. These assumptions are the technical parameters of the aquaponic system, including: feed conversion ratio, feed rate ratio, feeding rate, stocking density, water turnover rates, displacement and electrical efficiency. The assumptions can be easily changed by the user, which is encouraged based on local experience or feedback from demonstration/pilot units. The prefilled values are based on literature research, expert consultation and experience.

Aquaponics calculator tool (Input Parameters)					
Grow Area (square metre)		48	Water unit cost	$	0.10
Farm Elevation metres above sealevel		0	Unit cost of electricity	$	0.20
Fish sale price	$	6.00	Labour cost	$	7.50
Feed unit cost	$	1.00	Insurance cost	$	50.00
Fish fry cost	$	0.10	Depreciation/safety		5%
Crop 1 name		Lettuce (heads)	Crop 1 unit price ($ per unit)	$	1.00
Crop 2 name		Chard (bunches)	Crop 2 unit price ($ per unit)	$	3.00
Crop 1 production (Units / square metre / month)		20	Crop 1 % (Percent of total bed is Crop 1)		0.5
Crop 2 production (units / square metre / month)		12	Land tenure	$	200.00

Assumptions			
Feed Conversion Ratio	1.5	Filter percentage	25%
Fish Retardation Facto	15%	Sump percentage	10%
Fish Harvest Weight	0.6	Media displacement	33%
Feed Rate Ratio	60	Water usage percent	1%
Stocking Density	25	Labour time	5
Feeding Rate	1%	Air stone efficiency	2.7
Stocking Swing	20%	Water pump efficiency	45
Depth of grow bed	0.3	Air pump efficiency	1.5
Water turnover fish	1	Water turnover grow bed	2

Each time one of the input parameters or assumptions is changed, the output also changes. The output is a grouped set of response variables. The high level groupings are "Revenue", "Cost" and "Profit" in order to underscore the importance of financial planning. These two high level groupings can be expanded to provide itemized cash flow as well as design parameters.

The revenue is divided into volume and sales prices of the fish and two crops.

The costs are broken into the costs of feed, water, electricity, fingerlings, labour and running costs.

Within the feed group the daily and monthly weight of feed is also calculated.

Within the water group the sizes of each tank, including the fish tank, sump, filters and grow beds is calculated.

Within the electricity group the energy consumption of the water and air pumps is calculated, as well as the required flow rates.

Overall the breakdown of the costs demonstrates their relative importance. The calculations of component sizing is designed to lead to an accurate understanding of the total system size, and helps the participant to cost and source the correct materials.

Total monthly revenue	$	1,637.76		
Lettuce (heads) revenue	$	*480.00*	*Lettuce (heads) production*	*480*
Chard (bunches) revenue	$	*864.00*	*Chard (bunches) production*	*288*
Fish revenue	$	*293.76*	*Fish production (kilos)*	*49*
			Fish production (#)	*82*

Total monthly cost	$	1,451.12		
Feed costs	$	86.40	Feed usage (kilos)	86
Daily Feed		2880		
Biomass of fish (average)		288		
Biomass of fish (max)		346		
Water cost	$	0.85	Water usage (litres)	8493
Water volume total		28310	Water weight (tonnes)	28
Water Volume (fish tank)		13824	Number fish tanks	1
Water Volume (filter)		3456		
Water Volume (sump)		1382		
Water Volume (grow bed)		9648		
Electricity cost	$	123.82	Electricity usage (kWh)	619
Water pump energy consumpt		338		
Water flow rate (fish)		18662		
Water flow rate (plants)		4824		
Water pump energy demand		470		
Air pump energy consumptio		281		
Oxygen demand by day		2880		
Oxygen demand per hour		120		
Number of Airstones (sea level)		44		
Number of Airstones (at farm altit		44		
Air Volume delivered at depth		440		
Air Volume at pump outlet (0 m de		585		
Air pump energy demand		390		
Fish costs	$	8.16		
Insurance costs	$	50.00		
Depreciation cost	$	81.89		
Land tenure	$	200.00		
Labour cost	$	900.00	Number of workers	0.8
Labour burden (8-hr days)		15		
Labour burden (hours total)		120		

Calculations

The following section walks through the mathematical logic embedded within the spreadsheet.

Steps (costs):

Feed weight and fish biomass

1. Grow area × Feed Rate Ratio = Daily feed
2. Daily feed × 30 × Feed unit cost = **Feed costs (month)**
3. Daily feed ÷ Feeding rate = Biomass of fish (instantaneous average) **unit conversion*
4. Biomass of fish (average) × Stocking swing = Biomass of fish (max)
5. Biomass of fish (max) ÷ Stocking density = Water volume (fish tank)

Water volume, water usage, water weight, fish tank sizing, filter sizing

6. Water volume (fish tank) × Filter percentage = Water volume (filter)
7. Water volume (fish tank) × Sump percentage = Water volume (filter)
8. Water volume (fish tank) × Grow bed volume × media displacement = Water volume (grow bed)
9. ∑Water volume (fish tank, filter, sump, grow bed) = Water volume total
10. Water volume total × Water usage percent = Water usage **unit/time conversion*
11. Water usage × Water unit cost = **Water cost (month)**
12. Water volume total => Water weight tonnes **unit conversion*

Energy consumption (air and water only), pump size

13. ∑Water volume (fish tank, filter, sump) × Water turnover fish = Water flow rate (fish)
14. Water volume (grow bed) × Water turnover plants = Water flow rate (plants)
15. ∑Water flow rate (fish, plants) × Water pump efficiency = Energy demand (water pump)
16. Daily feed = Oxygen demand by day
17. Oxygen demand by hour × Air stone efficiency = number of air stones (sea level) **unit conversion*
18. Number of air stones (sea level) * [1 +(Farm elevation × 0.0133333)] = Number air stones (farm)
19. Number of air stones (farm) × 9.9 = Air volume delivered at depth
20. Air volume delivered at depth × 1.33 = Air volume at pump outlet
21. Air volume at pump outlet × Air pump efficiency = Energy demand (air pump)
22. ∑Energy demand (water pump, air pump) × unit cost electricity = **Electricity cost (month)**

Fish costs

23. Feed usage × Feed conversion ratio = Fish production (kilo)
24. Fish production (kilo) ÷ Fish harvest weight = Fish production (#)
25. Fish production (#) × Fish fry cost = **Fish costs**

Labour costs

26. Grow area × labour time = labour burden **unit conversion*
27. Labour burden (hours) x labour cost (per hour) = **Labour cost**

Fixed costs (Insurance, depreciation, tenure

28. *Carried down from input variables

Steps (revenue):

Vegetable crop, production and revenue

1. Grow area × Crop production per area = Crop 1 production
2. Crop 1 production × Crop unit price = **Crop 1 revenue**
3. *repeat for Crop 2

Fish production and revenue

4. Feed usage × Feed conversion ratio = Fish production (kg)
5. Fish production (kg) × Fish sale price = **Fish revenue**
6. Fish production (kg) ÷ Fish harvest weight = Fish production (#)

Limitations

The calculator is limited in three ways, one significant and two manageable with further development. The most significant limitation is the balance between flexibility and prescriptiveness. In order to calculate accurately, the model must dictate a certain set of design choices. For example, two crops are grown in either media bed or deep water culture, a filter and a sump are used, and all calculations are done monthly. This was identified as an issue of concern during a second aquaponic workshop held in Indonesia because it could not accurately reflect the culture of batch harvesting nor the bumina-method of aquaponics. Increased flexibility of the model can be contained with more back-end/hidden coding, but would make its use more complicated. At the same time, there is an argument for a more prescriptive approach that indicates the exact design criteria. Once the user has entered the input parameters the model would provide an actual line-drawing and estimate costs of construction. This will be useful for investors to calculate return on investment and for farmers looking for exact design blueprints. However, it will be impossible to capture all possible permutations of an aquaponic farm and will limit the adaptability and creativity. Moreover, choosing the design based on location specific materials and limitations is the most important step in the planning process which means that the calculator is already presupposing. In this regards it is proposed that the main calculator should remain flexible, and an associated secondary tool could provide capital expenditure on the most common and recommended systems, based on a modular greenhouse system using standard and tested technologies.

The second problem is technical and manageable. The set of variables called "assumptions" change for every farm, in every location. Currently these assumptions are averages based on literature research, expert opinion and experience. However, they are biased based on where the research was done, typically in Australia, Europe and the United States of America (USA). Therefore, regionally specific parameters will need to be calculated, and pilot projects will need to ground-truth and verify those assumptions. In addition, more expert consultation will be needed. The model will need to be tested against existing farms to verify how well it predicts observed production and consumption values.

The third problem is related, but deserved special attention. The labour costs calculation can cause bias within the system based on the high leverage of the variable. The labour, in reality, needs to be calculated very carefully to include marketing, human resources, distribution and ancillary tasks. As the farm grows, so will the need for these additional resources. At the same time, as the farm grows so do the opportunities for automation in the seeding, transplanting, harvesting and packaging and thus the labourers decrease. No study has ever quantified the labour burden of an aquaponic farm based on the size, and therefore it is difficult to make a scalable variable. In this regards this labour parameter will need dedicated attention during any pilot studies and should be the focus of further research.

APPENDIX 10

Group photograph

Group photo of the FAO technical training workshop on "*Advancing Aquaponics: An Efficient Use of Limited Resources*" held in Osimo (Ancona), Italy, from 27–30 October 2015.

Standing (*left to right*): Mohammed S. Alghamdi (Saudi Arabia); Ussama Kattan (Jordan); Mohammed Saad Hazzaa (Saudi Arabia); Youssef Abdaoui (Tunisia); Abdulla Jumaa M. Al-Junaibi (United Arab Emirates); Ahmed Taleb Moussa (Mauritania); Ahmed Saney Eldin Sadek (Egypt); Angham Baniowda (Palestine); Imad Lahoud (Lebanon); Alessandro Lovatelli (FAO); Nawal Zirari (Morocco); Austin Stankus (FAO); Saeb Ghaleb Hallasa (Jordan); Aicha Alaoui Meterajji (Morocco); Mahassin Elhassan (Sudan); Fabio Strappa (Acquacoltura Italia Srl); Hend Sheilhidris (Sudan); Barbara Macchitella (Acquacoltura Italia Srl); Davide Di Crescenzo (Acquacoltura Italia Srl); Massimo Briani (Irci SpA).

Kneeling (*left to right*): Khalil Rahali (Tunisia); Mohammed Abdel Aty Mahdy (Egypt); Yaser Shtaya (Palestine).

APPENDIX 11

Selected photographs of the workshop

Participants inspecting plants during a plant health practical for signs of insect damage and disease

Participants examining fish during demonstration of health monitoring and growth measurement

Participants measuring water quality of aquaponic water during practical demonstrations of the nitrogen cycle

Participants in classroom during the theoretical portion of the workshop

Group photo during practical session in front of greenhouse

Participant Imad Lahoud presenting his design of a theoretical aquaponic system design during group work

©FAO/Acquacoltura Italia

A family-sized aquaponic unit, showing noteworthy vegetable production of tomatoes, strawberries and zucchini, in a small area as seen during a demonstration session

©FAO/Acquacoltura Italia

Participant collecting fish from an aquaponic fish tank during a hands on session on fish health management

©FAO/Acquacoltura Italia

Participants taking turns to practice teaching and explaining plant health to their group members during a practical session

©FAO/Acquacoltura Italia

Participant examining the undersides of the leaves of a pepper plant to inspect for insect infestations, and demonstrating the proper use gloves to prevent contamination

©FAO/Acquacoltura Italia

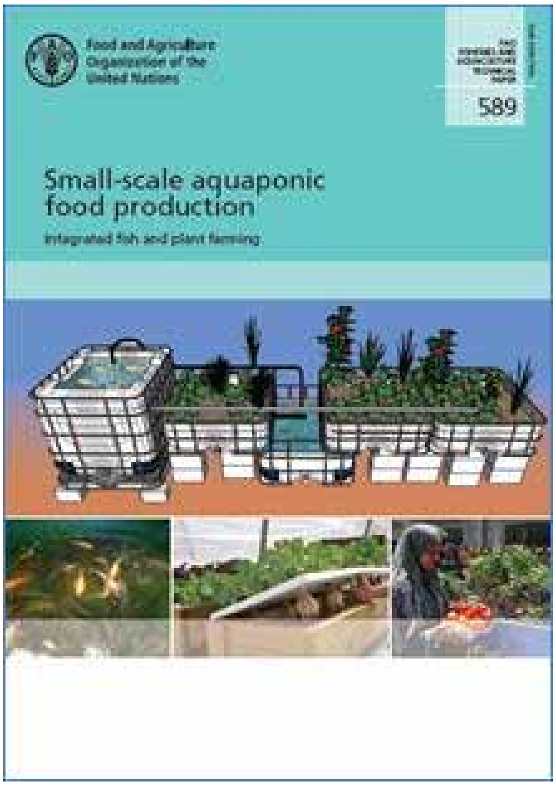
Participants in the classroom during the theoretical portion of the course

©FAO/Acquacoltura Italia

A participant receiving his Certificate of Completion during the final and closing session of the training workshop

APPENDIX 12

FAO aquaponics manual



Somerville, C., Cohen, M., Pantanella, E., Stankus, A. & Lovatelli, A. 2014.

Small-scale aquaponic food production: Integrated fish and plant farming.

FAO Fisheries and Aquaculture Technical Paper No. 589. Rome, FAO. 262 pp.

Aquaponics is a symbiotic integration of two mature disciplines: aquaculture and hydroponics. This technical paper discusses the three groups of living organisms (bacteria, plants and fish) that make up the aquaponic ecosystem. It presents management strategies and troubleshooting practices, as well as related topics, specifically highlighting the advantages and disadvantages of this method of food production. This publication discusses the main theoretical concepts of aquaponics, including the nitrogen cycle, the role of bacteria, and the concept of balancing an aquaponic unit. It considers water quality, testing and sourcing for aquaponics, as well as methods and theories of unit design, including the three main methods of aquaponic systems: media beds, nutrient film technique, and deep water culture. The publication includes other key topics: ideal conditions for common plants grown in aquaponics; chemical and biological controls of common pests and diseases including a compatible planting guide; common fish diseases and related symptoms, causes and remedies; tools to calculate the ammonia produced and biofiltration media required for a certain amount of fish feed; production of homemade fish food; guidelines and considerations for to establishing aquaponic units; a cost-benefit analysis of a small-scale, media bed aquaponic unit; a comprehensive guide to building small-scale versions of each of the three aquaponic methods; and a brief summary of this publication designed as a supplemental handout for outreach, extension and education. Aquaponics is an integrated approach to efficient and sustainable intensification of agriculture that meets the needs of water scarcity initiatives. Globally, improved agricultural practices are needed to alleviate rural poverty and enhance food security. Aquaponics is residue-free, and avoids the use of chemical fertilizers and pesticides. Aquaponics is a labour-saving technique, and can be inclusive of many gender and age categories. In the face of population growth, climate change and dwindling supplies of water and arable land worldwide, developing efficient and integrated agriculture techniques will support economic development.

The manual can be downloaded from the following web link (***English version***):
http://www.fao.org/3/a-i4021e/index.html

The manual can be downloaded from the following web link (***Arabic version***):
http://www.fao.org/3/a-i4021a/index.html

APPENDIX 13

Selected press releases and news clips

Source: Corriere Adriatico – 27 October 2015
Published in a local newspaper, this short article describes the aquaponic technology, the overview of the workshop and the partnership between FAO and Acquacoltura Italia.

L'impresa di Osimo Stazione

Acquacoltura Italia e Fao Una partnership speciale

IL PROGETTO

Osimo

Un'azienda osimana nell'olimpo della cooperazione internazionale grazie ad un corso di formazione organizzato con le Nazioni Unite. Una collaborazione prestigiosa di livello mondiale quella presentata ieri in conferenza stampa tra la Fao e Acquacoltura Italia, realtà leader in Italia, con sede ad Osimo Stazione, nel settore dell'Acquaponica, il trattamento di concimazione naturale, ecosostenibile, che coniuga l'allevamento di specie acquatiche con la coltura dei vegetali senza l'utilizzo di terra. La Fao ha deciso di stabilire una partnership speciale con la società osimana scegliendola come service provider nell'ambito di un progetto che verte su un corso di formazione internazionale per la promozione delle tecniche dell'Acquaponica nei Paesi in via di sviluppo. La dinamica realtà imprenditoriale osimana da oggi a venerdì realizzerà nella propria sede di via Merloni corsi di formazione intensiva rivolti a venti alti funzionari governativi che giungono da Nord Africa e Medio Oriente. Nello specifico da Mauritania, Libano, Sudan, Giordania, Arabia Saudita, Palestina, Egitto, Marocco, Tunisia. Davide Di Crescenzo, direttore scientifico di Acquacoltura Italia, ha sottolineato in conferenza come l'obiettivo di questa iniziativa sia quello di "dare un piccolo contributo alle Nazioni Unite nella lotta contro la povertà insegnando ad alti funzionari di Nord Africa e Medio Oriente, i quali a loro volta trasmetteranno le nozioni a imprenditori e agricoltori e alle famiglie del luogo su come sviluppare impianti di Acquaponica in terreni aridi per renderli coltivabili".

Il delegato Fao, Austin Stankus, ha spiegato che "Acquacoltura Italia è l'azienda di maggiore esperienza da noi conosciuta, possiede adeguata preparazione e spazi adeguati". "Questa partnership per noi rappresenta un vero e proprio riconoscimento al lavoro svolto negli anni e conferma la bontà di un'idea avuta in anticipo sui tempi", ha commentato Fabio Strappa, amministratore unico di Acquacoltura Italia.

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Source: Il Resto del Carlino – 27 October 2015
A brief announcement was published that indicated that the workshop, hosted by Acquacoltura Italia and facilitated by FAO, was taking place. It highlighted the cutting edge nature of aquaponics.

PARTNERSHIP TRA ACQUACOLTURA E LA FAO

AL VIA una partnership internazionale tra l'azienda osimana Acquacoltura e la Fao. L'organizzazione delle Nazioni unite ha scelto la ditta di Osimo leader nel settore dell'acquaponica per il primo corso di formazione internazionale che si apre oggi. Quattro giornate per insegnare ad allievi d'eccezione, funzionari dei governi del Medio Oriente e Nord Africa, le tecniche di un settore all'avanguardia per la sostenibilità delle colture.

Di Crescenzo, D. (17 December 2015). ***L'acquaponica italiana scelta dalla FAO (Food and Agriculture Organization)*** [video file].

Retrieved from: https://www.youtube.com/watch?v=0wNYnBlGHQM&feature=youtu.be

A six minute video originally broadcast on the Italian television channel TVRS on 31 October 2015. The video shows interviews with Acquacoltura Italia and Austin Stankus (FAO Consultant) and an overview of course facilities and the workshop goals. Video is in Italian.

Di Crescenzo, D. (31 October 2015). ***Primo workshop internazionale di acquacponica ufficiale della FAO organizzato ad OSIMO (AN)*** [video file].

Retrieved from: https://www.youtube.com/watch?v=BlgJ1R2dSbE

A two minute video originally broadcast on the Italian television channel RAI TGR MARCHE on 30 October 2015. Video shows participants during both practical and theoretical sessions, interviews with FAO Aquaculture Officer, Alessandro Lovatelli, and highlights the aquaponic systems used during the workshop. Video is in Italian.

Baldini, Silvia (19 November 201). ***Acquaponica, batte nelle Marche il cuore dell'agricoltura del future.***

Retrieved from: http://www.mlmagazine.it/acquaponica-batte-nelle-marche-il-cuore-dellagricoltura-del-futuro/

A 1 500 word article from an online and printed magazine, presented in an answer and question format, regarding the workshop and aquaponics in general. It provides an overview of the opportunities and challenges of aquaponics, the background and the participants, and demonstrates some the possible future directions.

Acquaponica, batte nelle Marche il cuore dell'agricoltura del futuro

Pubblicato il: 19 novembre, 2015   Autore: Silvia Baldini   0 Commenti

Un modulo di Acquaponica realizzato sotto serra in Italia

***Allevare pesci per coltivare prodotti agricoli**: sembra un'utopia, invece è una realtà ben consolidata. **E' il sistema dell'Acquaponica, che consente di coltivare vegetali senza utilizzare la terra, ma l'acqua**. Proprio **nelle Marche è nata e cresciuta la società leader in Italia nella progettazione e nella fornitura di impianti di questo tipo, Acquacoltura Srl**. L'amministratore **Fabio Strappa** ci ha spiegato i progetti in corso, da quelli con la Fao fino all'agrobusiness in Ghana e nei paesi in via di sviluppo, per aiutare le popolazioni a produrre risparmiando le risorse idriche.*

Da quanti anni è operativa Acquacoltura Italia srl e come si è sviluppato il suo business?

"La società è operativa dal 2012 ma l'impegno dei soci fondatori nel settore dell'Acquaponica era già iniziato nel 2009. Abbiamo in questi anni portato avanti un'attività di ricerca che si è poi riversata nella realizzazione di impianti con caratteristiche e affidabilità tali che possono permettere una produzione ottimale, nel rispetto delle normative vigenti. **Siamo diventati in questi anni il punto di riferimento sul**

This publication is the report of the FAO technical training workshop on advancing aquaponics held in Osimo (Ancona), Italy, on 27–30 October 2015. Seventeen participants attended from ten countries of the Near East and North Africa region (Egypt, Jordan, Lebanon, Mauritania, Morocco, Palestine, Tunisia, Saudi Arabia, the Sudan, and the United Arab Emirates). The participants were mainly from government-associated aquaculture research centres. The report summarizes the knowledge and provides guidance to Members on the process of advancing aquaponic development. This document contains a comprehensive record of the workshop proceedings. The four-day workshop consisted of lectures, demonstrations and hands-on activities supported by aquaponic experts. Recommendations were gathered based on participant feedback, and included: (i) education, training and communication; (ii) research and development; (iii) socio-economic and feasibility studies; and (iv) regional and international cooperation. This activity was supported under the FAO Regional Initiative on Small-Scale Agriculture for Inclusive Development in the Near East and North Africa and the Major Area of Work on Efficient Resource Use under FAO's revised Strategic Framework.

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