Specialist Group on Use of Macrophytes in Water Pollution Control

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CLOSING WATER, NUTRIENT AND ENERGY CYCLES WITHIN CITIES BY URBAN FARMS FOR FISH AND VEGETABLE PRODUCTION

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Fish production in the "city of the future"?

The potential of urban farming to help feed future generations is more and more recognized today. Dickson Despommier, the "father" of the Vertical Farm concept, sums up the key drivers of this development in a comprehensive article published in the New York Times in 2009:

"*Population increases will soon cause our farmers to run out of land. The amount of arable land per person decreased from about an acre in 1970 to roughly half an acre in 2000 and is projected to decline to about a third of an acre by 2050, according to the United Nations. Irrigation now claims some 70 percent of the fresh water that we use. After applying this water to crops, the excess agricultural runoff, contaminated with silt, pesticides, herbicides and fertilizers, is unfit for reuse. The developed world must find new agricultural approaches before the world's hungriest come knocking on its door for a glass of clean water and a plate of disease-free rice and beans. Imagine a farm right in the middle of a major city. Food production would take advantage of hydroponic and aeroponic technologies. Both methods are soil-free and use up to 90 percent less water than conventional cultivation techniques*."

Yet, integrating food production into the built urban environment in general, and into urban water management in special, is a challenge for the "city of the future". Its development will bring significant changes not only to the shape of urban rooftops, but even more so to the way how food production is perceived by urban residents.

This article focuses on the contribution of the Ecological Engineering and the Urban Greening group at ZHAW to develop and implement combined fish and plant cultures into the cities of tomorrow.

From urban farming projects to vertical farms - a brief overview

Architects plan new buildings based on the expected requirements of the future inhabitants – at best. This means, only factors regarding the main purpose of the building are taken into account. Growing food has not been one of them, so far. Therefore, in most cases it is at least very difficult to insert new purposes and functions into urban complexes once they are built.

This is one of the reasons why urban farming, which would require free urban spaces (such as rooftops) to grow food, is still in its very beginnings - however, in the beginnings of a highly promising career. The first companies are about to experience the very high potential both in technical productivity, and in consumer acceptance, which is even more important. A few front-runners shall be named here.

In New York City, USA, BrightFarm Systems, designs rooftop farms to grow premium grade vegetables and fruit, 365 days a year (www.brightfarmsystems.com). Two other companies, Cityscape Farms (http://cityscapefarms.com) and Gotham Greens (http://gothamgreens.com), are about to establish their first rooftop farming systems. The New York "ScienceBarge" (http://www.groundworkhv.org) is another project, aiming to reach a broader public with these ideas.

In Vancouver, Canada, Urban Barns turns abandoned warehouses into agricultural facilities. These buildings have a controlled indoor climate, and are equipped with patented growing machines, yielding "*more food per square foot than a greenhouse*" and produce, according to the authors, much less waste (www.urbanbarns.com).

Urban farming can also be operated as a community-based approach. In 2008, Sweet Water Organics in Milwaukee, Wisconsin, USA (http://sweetwater-organic.com) began the transformation of an abandoned industrial building into a showcase of potential living technologies and urban agriculture. In London, UK, the Farm: London project (http://farmlondon.weebly.com/index.html) follows a similar approach. "

The step from single-floor rooftop gardens and urban barns towards multi-storey, high-rise buildings - the so-called Vertical Farms (VF, http://www.verticalfarms.com) advocated by Despommier – does not seem too big. The vision of VF encompasses an integrated, multi-step-food chain, indoor environment on numerous floors, with an almost completely closed water cycle. It would ideally be run by renewable energy produced right on the site, produce crops, fish and poultry year-round with no agro-chemicals, and close to the consumers. "*The structures themselves would be things of beauty and grace. In order to allow plants to capture passive sunlight, walls and ceilings would be completely transparent. So from a distance, it would look as if there were gardens suspended in space*" (Despommier 2009).

Despite of a great number of creative design sketches listed at www.verticalfarm.com, however, the first of its kind still awaits being built.

These few examples show that there are many on-going projects. Businesses are getting involved and some innovative entrepreneurs see their chance for an interesting investment. Yet, is this really how we want our agriculture to be in the future? It is quite obvious that introducing urban farms in a larger scale would directly affect the needs and preferences of a great part of the population. There are lots of open ethical question. Once the vision becomes more real, a public discussion about them will immediately start.

The technologies for urban farms have more or less been developed. In the following section some examples for research that has been conducted at INRS, will be briefly presented.

Research on recirculating aquaculture and aquaponic at ZHAW Waedenswil
"Aquaponic" is a recent term denoting fish farming ("aquaculture") in combination with plant production on artificial substrates ("hydroponic"). This combination has synergy potential: plants assimilate the nutrients from fish feces, while cleaning the water for its reuse in the fish basins. Bacteria film on artificial substrate enables nitrification of ammonia.

Our group's research on aquaponic systems started in1994, when Tilapia was used in a pilot constructed food chain to recycle nutrient-rich fertilizer water from tomato hydroponics. In 1998, triploid *Tilapia* were used in a polyculture setup (wastewater-fed aquaculture) to convert nutrients from biogas-effluent to fish biomass (Staudenmann & Junge-Berberović 2003, Graber & Junge-Berberović 2008). In 1999, *Oreochromis niloticus* were bred and produced in a pilot installation of a tropical greenhouse, which today is a working aquaponic system (www.tropenhaus-wolhusen.ch). From 2002 to 2004, triploid *O. niloticus* from Thailand and a natural strain of Tilapia from Lake Turkana, Kenya, were used in the pilot aquaponic research facility at the INRS campus, which continues to be operated. Offspring *Tilapia* are distributed to interested Swiss farmers on request.

Figure 1: Aquaponic model setup as a showcase at exhibitions.

In 2004, the work focused on aquaponic systems in greenhouses as a secondary income for Swiss farmers, looking at fish as well as plant production (Graber & Junge-Berberovic 2009). In two outdoor systems, rainbow trout *(Oncorhynchus mykiss)* and brook trout *(Salmo trutta fario)* were raised in trials under alpine conditions. To define the technology of recirculating in-door aquaculture, three groups of Eurasian perch *(Perca fluviatilis)* were raised in an aquaponic system (Graber & Welti 2008). International cooperation with Uganda started in 2009 with the aim of developing new feed formulations for Nile tilapia based on locally available and low-cost feed ingredients. In 2010, research on pike-perch *(Sander lucioperca)* started and will be continued to develop technologies to easily breed and produce this very interesting new aquaculture species.

A practical handbook on *Tilapia* culture (in German, to be published 2011), the founding of a Swiss forum for aquaculture (www.fischforum.ch, started on Nov. 24, 2010) and a new aquaculture education course (1 week, starting 2011) are outcomes of this work.

Urban farming in European cities – open questions

The logical next step in Switzerland will be to set up at least one pilot facility on a rooftop. Designed by closely following the principles of Ecological Engineering, it should demonstrate the feasibility of the concept under real world conditions in a city. The pilot should work as research and demonstration site, and should attract planners, architects and investors as well as the broader public.

Where will this pilot site be situated? Technically spoken, fish - especially tropical species - require warm water. A suitable site would therefore be a building that produces a lot of excess heat (a server farm? a shopping mall? a factory?). A production site will also depend on the availability of water, since even in recirculating fish culture, a certain share of the water needs to be regularly replaced with fresh water. Here, a combination with rainwater harvesting and management should be the target. Furthermore, running the rooftop farm CO_2-free and with renewable energies will enhance credibility and keep its ecological footprint small.

Once in operation, technical issues such the quality of the produce, pest control with natural antagonists, the optimization of the system and possible scale-up issues will have to be addressed. Design issues, especially focusing on how to reach a stable, multifunctional system (the greenhouse as air conditioner for the entire building?)

Another upcoming issue is the integration of urban agriculture into cities from the perspective of urban design. An interesting approach can be found in the book "Continuous Productive Urban Landscapes CPULs: designing urban agriculture for sustainable cities" (edited by A. Viljoen). The book argues for the creation of networks of productive open space as essential elements within the spatial planning of cities, and introduced the 'CPUL' concept into the international design discourse. Its influence is evidenced in international exhibitions hosted by leading research institutions, e.g. the Canadian Centre for Architecture (Actions Exhibition, Montreal 2008-9 & Graham Foundation, Chicago, 2009-10) and Netherlands Architecture Institute (Edible City, 2007), and it is widely cited.

Ecological Engineering at the INRS of ZHAW Waedenswil, Switzerland

The Zurich University of Applied Sciences (ZHAW) is a center for education, applied research and know-how transfer, with about 7'400 students in many different degree programs (www.zhaw.ch). The Institute of Natural Resource Sciences (INRS, www.iunr.zhaw.ch) offers a complete education for Bachelors and Masters of Science in Natural Resources Sciences. Currently (2010), 421 students are registered in these programs.

Research at INRS focuses on the sustainable use of natural resources in both urban and rural areas. Solutions are developed in collaboration with a network of national and international partners. The aim is to harmonize economic, social and ecological aspects of natural resource management. INRS is located at a wonderful garden site overlooking Lake Zurich and has a permanent staff of 126 (31 lecturers, 36 Research Associates, 43 Assistants, 16 technical).

The Ecological Engineering group (EE-group) at the Centre of Ecological Engineering (www.cee.zhaw.ch) has six collaborators. Since 1993, the EE-group has successfully managed applied research projects in the field of nature orientated wastewater treatment, aquaculture, aquaponic and phytoremediation. The projects were carried out together with the business community and public management, and were funded by various Swiss funding agencies (e.g., the Swiss National Science Foundation (SNSF), and by Swiss government agencies (such as the Swiss EPA). The EE-group also offers courses in Ecology, Limnology, and Ecological Engineering for Bachelor students at the INRS.

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