Reinhold Leinfelder • Alexandra Hamann • Jens Kirstein • Marc Schleunitz (Eds.)

Science meets Comics

Proceedings of the Symposium on Communicating and Designing the Future of Food in the Anthropocene

Jaqueline Berndt • Anne-Kathrin Kuhlemann • Toni Meier • Veronika Mischitz
Stephan Packard • Lukas Plank • Nick Sousanis • Katerina Teaiwa • Arnold van Huis

CH. A. BACHMANN VERLAG

Editors

Reinhold Leinfelder
Freie Universität Berlin
Institute of Geological Sciences
Berlin, Germany

Alexandra Hamann
Cluster of Excellence *Image Knowledge Gestaltung*
Humboldt-Universität zu Berlin
Berlin, Germany

Jens Kirstein
Freie Universität Berlin
Institute of Geological Sciences
Berlin, Germany

Marc Schleuniz
Freie Universität Berlin
Institute of Geological Sciences
Berlin, Germany

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Ein Interdisziplinäres Labor

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Anne-Kathrin Kuhlemann (1979) is Managing Partner of BE Solutions & Blue Systems Design GmbH, supporting clients in developing commercial models for their sustainability innovations – and advising municipalities and regions in utilizing their waste streams as resources for business impetus. She co-founded several companies which implement systemic resource efficiency in creative, scalable business models. In 2010, the magazine *Capital* named her one of the 'Top 40 under 40' of German society.

Anne-Kathrin Kuhlemann

Food Production in the Anthropocene: The Role of AgTech in Urban Spaces

Our daily food consumption is slowly but surely turning into the largest environmental threat. The agricultural sector consumes 70% of the water used by humankind (Fox/Fimeche 2013). The production of meat consumes enormous amounts of water compared to plants. For example, a single kg of beef takes roughly 15,500 liters of water to produce (Fox/Fimeche 2013), as opposed to 2,000 liters for a kilogram of soy (Ercin et al. 2011). Estimates show growth rates of roughly 20% per decade for meat demand – while population growth has slowed to around 10% per decade (Rabobank 2011). Especially the growing middle classes of emerging countries demand for more sophisticated food – in other words, animal proteins. Today, livestock production uses up to 75% of the agricultural land; one third of the cereals produced is fed to livestock (Steinfeld et al. 2006) – which then need up to 30 calories to produce one calorie of meat. Fish would seem an obvious alternative here, as many fish have much better 'feed-conversion-ratios', in other words, they need as little as 1 kg of feed to produce 1 kg of fish (Lane et al. 2014).

However, overfishing has decreased fish populations worldwide by 50% in the past 40 years (World Wildlife Fund 2015). That means we have eaten half the fish from the oceans, plus all the new fish reproduced in 40 years, plus the fish produced in aquaculture, which today makes up half of all fish consumed annually (FAO 2014). And fish only makes up 20% of the animal meat eaten. As a consequence, 70 to 85% of fisheries are at or beyond biological limits. Millions of people, especially those living in coastal areas, depend on fishing for their staple food and livelihoods. 'Modern' aquaculture also comes with many problems, ranging from hormones to environmental impact, such as the destruction of mangroves, or the eutrophication of waters (Lane et al. 2014).

Worse yet, around 40% of all foodstuff never reaches the supermarket (Fox/Fimeche 2013). In future the number of people, and therefore consumers, living in cities and so-called megacities, will rise to 70%. Food production, on the other hand, is located in rural areas. Add globalization and the fact that many of us today ask for all foods all year round (instead of making seasonal choices). As a result, food is being shipped large distances before consumption – and especially in low-income countries, a lot of it perishes en route due

to pathogens, fungi, or insects. But our Western standards (overpurchasing) and perfectionism habits are also a major problem (FAO 2015).

With one billion malnourished people on the planet, in other words 15% of all humankind, we can't afford to lose so much food. 40% wasted food at a value of 750 billion USD sounds like an easy solution to feed even 9 billion. Unfortunately, the answer is not that simple. Besides preservation problems, there is another limitation.

Degradation of soil affects one third of Earth's land surface and 40% of all arable land today (Arsenault 2014). Over the past 150 years, half of our topsoil has been lost due to erosion, compaction, loss of soil structure, nutrient degradation, loss of carbon, and soil salinity (World Wildlife Fund 2016). At the current rate, we have about 60 years of topsoil left (Arsenault 2014). Due to growing populations and consumption, natural resources have become object to speculation, the land being used for mining, buildings, and streets rather than farming. And most likely, climate change will provoke extreme weather conditions, reducing crop yields on the arable land that remains – which will lead to increasing food prices and more people seeking refuge from poverty and hunger.

To sum up, the challenge is immense: With tastes changing, we need to produce 50% more food from soil producing up to 30% less with oceans at more than their limit (World Bank 2016).

Sustainable solutions need to address all three challenges – and should make use of urban spaces as part of the solution. There are dormant areas, empty buildings, or unused basements and rooftops which can be used for small-scale food production that can still be profitable. According to calculations by Fraunhofer Institute (Keuter/Krause 2011), Germany could produce all vegetables it consumes on 36,000 ha of German rooftops.[1]

Innovations in the area of food production are lately summarized as *AgTech*, agricultural technology. This encompasses all sorts of areas, ranging from drone-controlled tractors to printed hamburgers. Specifically the challenge of making use of the limited areas available in cities and maximizing crop yields has seen a recent boom in novel approaches – and quite a bit of investor finance.

1 Germany needs 120,000 ha of vegetable production; Fraunhofer assumes higher annual yields in rooftop greenhouses. Even better, roughly 250 m^2 are needed to produce and process 50 tonnes of fish p.a. Germany consumes roughly 1.3m tonnes of fish, so 2% of all rooftops would theoretically be sufficient to cover the entire German demand for fish.

Fig. 1: Design of urban rooftop greenhouse with integrated vertical farming

Done right, food production using urban spaces can fulfill numerous criteria:

- Conservation of resources
- (Almost) free of emissions
- Copying natural ecosystems
- No use of drugs, pesticides, fungicides, insecticides, hormones
- Combining sustainability with efficiency
- Powered by renewable sources (biomass, solar)
- Production close to consumption

Let me present some examples of what is already being implemented today.

There is a wide range of non-commercial projects and initiatives around community gardening. Groups of neighbors or other people use undeveloped and rundown spaces to cultivate fruits and vegetables, and many of these gardens are a sight to sore eyes in the city gray. Dozens of cities around the world are host to beautiful and inspiring examples of this, which play a valuable role in our societies, connecting people, preserving seeds of traditional varieties, and building and strengthening communities and neighborhoods. Lacking a business model, nearly all of these initiatives rely on the involvement of committed individuals. Yet, without financial sustainability, many projects are of a temporary nature. There have been waves of community gardening in the past, Germany saw much of that in the 1970s. So despite the service community gardening does to our cities, it does not play a role in solving the food crisis.

Several companies around the globe have begun implementing commercial rooftop farming. Nearly all produce greens and vegetables, many in summer season, some all year round in greenhouses, delivering restaurants and retailers in their neighborhood. Other companies cultivate greens inside buildings such as empty factories and underground spaces or containers using LEDs and controlling climatic conditions. Here again, greens are the focus, often even medicinal plants or micro-greens, as fast growth and high prices are needed to cover the cost of the high-tech production.

And the past years have seen a boom in home-growing hydroponic systems. These are small-scale, remote-controlled, automatically fed, watered, LED-lighted plant growing systems, many of which engage consumers by displaying vitality data of the plants on mobile phones, very much creating a tamagotchi effect for city dwellers. But compared to the price, they are inefficient and produce very little.

All three examples tend to require artificial fertilizers – and none of them produce meat, which is still the major challenge. A hybrid solution (producing animals AND plants) that has been hyped recently is *Aquaponics*.

Aquaponics systems have been around for thousands of years. From the ancient world, systems have been passed on that enabled a natural cycle of fish and plant cultivation. Aquaponics describes a method of rearing fish in aquaculture and combining this with the cultivation of agricultural crops. Today, these are most often grown in containers with substrates such as foamed clay or gravel and receive water enriched with nutrients from fish excretions. These substrates generally fulfill a support function, salads are often produced just in water. Regulation of nutrients for optimal growth of the plants is achieved by separating the water cycles between fish and plant production and adding artificial fertilizer for the plants as needed. Aquaponics is argued to be more systemic than traditional agriculture.

However, food production is only truly sustainable if it consistently mimics ecosystems, in other words actually cascading resources, and drastically reduces the land usage per head. That is why a Berlin team has developed a system they call *Aquaterraponics* which leads the water full cycle and reintroduces soil as an element for healthy and integral plant growth. The method uses all material flows and excess nutrients to grow plants (including duckweed and algae, both of which are extremely rich in proteins). The biomass that cannot be used in this way is fed to insects, which serve as feed and another vital source of protein for the fish. In this system, a significant amount of the feed needed can be self-produced, and all

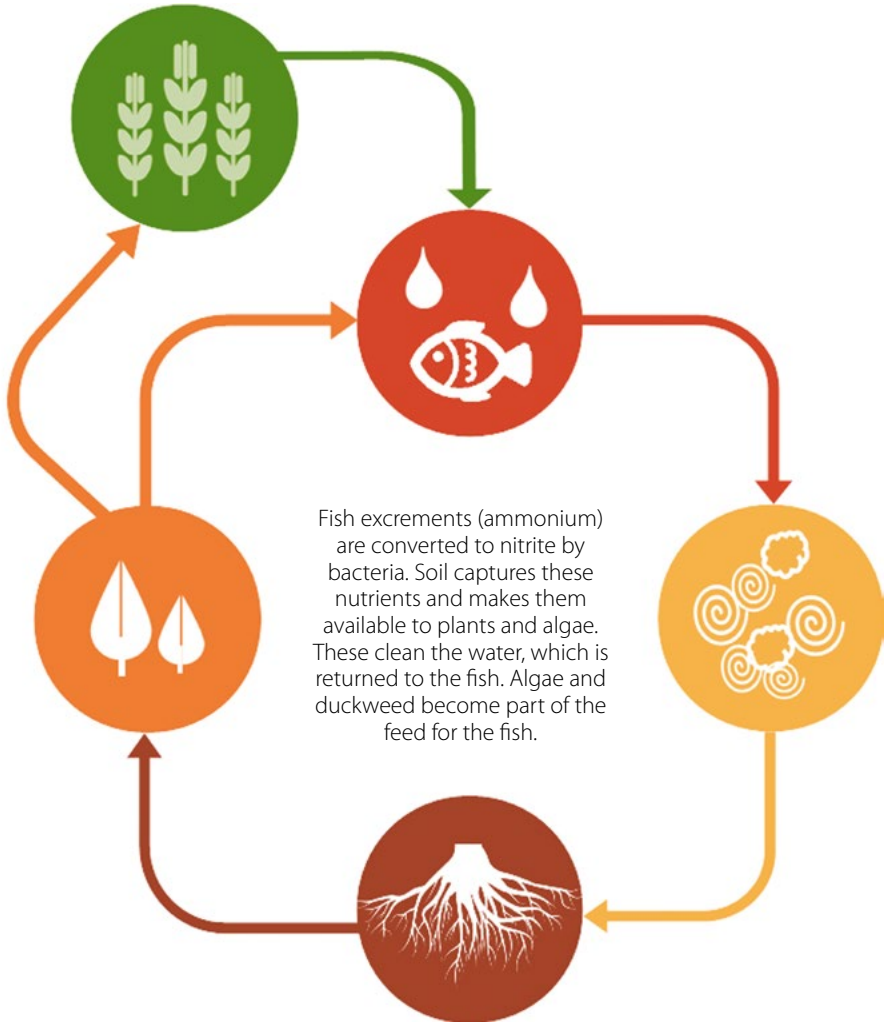

Fig. 2: Schematic illustration of biology in aquaterraponic system

fish meal eliminated from fish production. This is not just ecologically sensible – it also reduces the cost pressure that the fish market has seen due to soaring fish meal prices.

Add to this the possibility of operating these systems with renewable energy, but also utilizing residual heat from district heating wherever possible. A modular container system makes it possible to move parts of the production to other locations or expand without lengthy administrative processes. And despite its complexity, Aquaterraponics systems can be operated profitably on comparatively little space, roughly 1,000 m^2 is enough – an area that can often be found within cities or in their absolute vicinity. The aim of Aquaterraponics is uncompromising sustainability that is financially viable.

Aquaterraponics can produce fish for 1,800 Europeans and vegetables and fruits for 90 on every 1,000 m^2 of space. That is roughly ten times the regular space productivity for plant produce and one third of the space needed compared to conventional meat production. In Germany, 2,500 m^2 of agricultural land is needed per head to produce our food – most of this space is 'imported'. Planet-friendly would be 1,300 m^2. Using Aquaterraponics on unused spaces to grow our animal protein and vegetables, this number can be achieved, even if milk, eggs and cereals are still produced as they are today. Of course, this is a theoretical calculation, but it shows the potential the right AgTech methods can have producing on urban spaces. The reduced impact of less logistics and less wasted food, as the harvest reaches consumers within miles rather than days in airplanes, ships and trucks, is not even included in that calculation.

Naturally, every technology can be misused or applied 'wrongly'. A high level of biodiversity is preferable and important to maintain the stability of Aquaterraponics systems, since plants need to strengthen and protect their so-called companions (beneficial species) rather than pesticides. More monocultures and genetically manipulated varieties would not be a desirable path – not least since old varieties of tomatoes, salads, and herbs have proven to flourish better in the Aquaterraponics near-natural ecosystem than new breeds. Not least, the aim must be to keep solutions as low-tech as possible to reduce investment costs – and create jobs instead.

Over the past century, our cities have forgotten how to integrate different functions: Working, living, and production have become separated into distant areas, we spend a lot of our time commuting from one to the other. During the time of the wall, West Berlin was different, as space was so limited that special programs encouraged the stacking of functions into a harmonic system. At least food production should be able to rediscover that way of city life, when implemented sustainably it can even reduce emissions and improve quality of life. Inhabitants become aware again of agriculture and food production, giving them more importance than before. High quality (freshness!), transparency, and renewable energy become features that are demanded rather than wishful thinking.

When food production moves back into the cities, both existing structures as well as new buildings can be used – and city development should be thought in a way to integrate this element of our lives into the vicinity of our living quarters, rather than banning it to industrial estates. Cities that harmonize sleeping, recreation, work, and transport, and generate a balance of these functions, generate a multitude of benefits for their inhabitants.

How do we get to a world where urban spaces are utilized in such a manner? There are three approaches:

- Rules and regulations
- Education & consumer campaigns (changing behaviors)
- Business models without collateral damage

I personally believe in the latter as a driver towards fast change, with numerous social entrepreneurs today simply waiting for opportunities to emerge.
Healthy ecosystems supply us with an abundance of healthy foodstuffs. We all should appreciate food and its producers more. Those who bring their groceries home climate neutral by bike or on foot and know how and where it was produced can savor fish and meat again with a clear conscience.

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Dr. Katerina Teaiwa was born and raised in Fiji and is of Banaban, I-Kiribati, and African American descent. She is Associate Professor in the School of Culture, History and Language, College of Asia and the Pacific at the Australian National University in Canberra. She is also President of the Australian Association for Pacific Studies. From 2011 Katerina has been a Research Fellow in *the Framing the Global Research and Publication Project* at the Center for the Study of Global Change at Indiana University. She is the author of *Consuming Ocean Island: Stories of People and Phosphate from Banaba* (Indiana University Press 2015).

Dr. Teresia Teaiwa is an award winning scholar and mentor, and the founder of Pacific Studies at Victoria University of Wellington. She is currently Director of Va'aomanu Pasifika which includes Pacific Studies and Samoan Studies. A practising poet, Dr. Teaiwa is also researcher and author of numerous articles and book chapters on history, art, politics, gender and militarism in Oceania. She interviews a variety of Pacific women activists, authors and artists on her *microwoman blog* (microwoman.wordpress.com).