RECIRCULATING FARMS COALITION

From Out of the Blue, Green Farming

May 2013

About Recirculating Farms Coalition

About Us
The Recirculating Farms Coalition is a nationally focused, non-profit collaborative group of farmers, educators, organizations and many others committed to building local sources of healthy, accessible food.

Our Mission
Through research, education and advocacy, we work together to support the development of eco-efficient farms that use clean recycled water without soil as the basis to grow food. We believe these recirculating farms can create stable green jobs and supply sustainably-grown food – fruits, vegetables, herbs and humanely-raised seafood – in diverse communities nationwide, and someday, worldwide.

Our Challenge
Today one of every six people in the U.S. is struggling to buy food. As consumers become savvier, so have their requests increased for clean, safe, local food produced in an eco-friendly way. The U.S. government, in response to the public's growing complaints about our troubled food system, continues to explore various ways to boost domestic food production. Unfortunately, most of the proffered solutions encourage further industrialization and poor quality food. Our challenge is to promote an alternative to this model, one that establishes healthy, sustainable, and local ways to provide food in every community.

Our Vision
We envision a movement toward community-based food production. This can provide safer, better quality food and domestic green job opportunities. A different way of growing, "recirculating farming," is emerging nationwide and can meet these goals.
Our vision is for communities across the country to build recirculating farms as a source of local, healthy fresh food and stable jobs in a green business, and eventually to expand these same benefits globally.

Our Goals
Raise awareness
While recirculating farming has been in practice in various forms for more than 30 years, it is still not a well-recognized alternate method of farming in most areas. Through social and traditional media outreach, educational materials, participation in conferences and public events, the Coalition will help raise awareness about and support for development of recirculating farms.

Be supportive
There are over 200 commercial recirculating farms already operating throughout the U.S., and many others opening. Most farms are small to medium scale and farmers do not have access to significant resources to engage in marketing, advertising, continuing education, etc. All of these aspects can help build a successful green business and clientele. The Coalition will offer various tools for farmers to help grow their farm, their own experience and a healthy food culture.

Be a hub
There is not one entity that acts as a unified voice for recirculating farmers, or helps to coordinate the industry to share successes, challenges and other important information. The Coalition will be a coordinating body – a central place for farmers to connect with one another as well as others interested in recirculating farming – consumers, regulators, scientists and more.

Grow farms and farmers
Growing a healthy, local sustainable food culture requires a different approach to food production – one that works in almost any community worldwide. Recirculating farms, with their versatility in design, closed loop nature and ability to run with limited energy, water and other inputs are ideal for wide application. The Coalition will provide educational resources, research support and training, and eventually funding for farm construction in strategic locations.

Make changes
With an unemployment rate over nine percent, and one in every six people struggling to buy food in the U.S., we need to effect change that helps us to rebuild a strong, sustainable food culture and reconstruct our economy based on stable green jobs opportunities. The Coalition will promote these changes to our existing practices through outreach, education and communications strategies.

To learn more, please visit: http://www.recirculatingfarms.org.

Acknowledgements

Farmer at Hollygrove Market and Farm in New Orleans, Louisiana.

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Executive Summary

Across the country, conversations about food are changing. Rising obesity rates, frequent scares about contaminated food and environmental degradation have made it abundantly clear that our reliance on industrial agriculture is unsustainable. While one of six people living in the United States struggles to put food on the table, vast amounts of fresh produce are lost daily due to spoilage during the often long trek from farm to table. Fast food and the highly processed meal options lining grocery aisles are calorie rich, but nutritionally poor, and can leave us heavier but less healthy. The pervasive use of pesticides and chemical fertilizers can poison our environment and may be causing increases in cancer and a number of diseases. The system is broken – and we know it.

Aquaponic Bibb lettuce growing at Natural Green Farms in Racine, Wisconsin.

We also know ways to fix this. Current concerns with our food culture are driving researchers, entrepreneurs and farmers alike to explore new ways to produce more food using less resources, be environmentally friendly and more versatile. One such approach is called recirculating farming – using water to grow food without soil in a constantly recycling, closed-loop system. This method can raise plants (hydroponics), fish (recirculating aquaculture) or fish and plants together (aquaponics) virtually anywhere. And while growing plants without soil is not new -- it dates back to the hanging gardens of Bablyon – the approach is finding new life on city rooftops, vacant lots and abandoned warehouses as well as in former chicken barns and pastures as a way to produce fresh, affordable food more sustainably. Recirculating farms are empowering communities to control their own food production and creating a viable and exciting new approach to agriculture that can provide green jobs in both rural and urban areas.

The transformation of our food system is needed to feed a growing population without depleting resources for future generations. Recirculating farms are helping with this change. They are space, water and energy efficient and can be used to produce a variety of fresh produce as well as seafood. These farms facilitate a connection between people and their food. "From out of the Blue, Green Farming" reviews each of these issues as well as some of the exciting innovations in the field; finding sustainable and natural ways to feed fish, improving energy efficiency even further, and using farming to achieve social goals as well. Most importantly, it is a call to action to support an economically and environmentally sustainable future in food for us all.

Recirculating farm salad - most of the vegetables were grown using hydroponic and aquaponic techniques.

Introduction

From the Islands of Hawai'i, to the rooftops of New York City, recirculating farms are taking root in communities, bringing locally grown fish and produce to the marketplace, creating green jobs, building edible greenspaces and reinvigorating local food systems.

Microgreens growing at Cabbage Hill Farm Foundation, a non-profit farm with an aquaponic greenhouse in Mt. Kisco New York.

By growing food using continuously cleaned and recirculated water in place of soil, in closed-loop systems, innovative farms can produce food in previously unthinkable spaces, and do so in an array of shapes and sizes. This technology is opening up the door for both urban farming and a rural renaissance, moving back toward smaller scale family farming – just about anywhere – and allowing more food to be grown in an environmentally and economically sustainable way.

Peppers grow in a hydroponic greenhouse in Anguilla, in the Caribbean.

This transformation is necessary. Rising obesity rates, malnutrition and hunger, recalls on contaminated foods and environmental degradation are all signs that the industrial-scale, corporate controlled food system currently dominant in the United States is problematic. To meet the food needs of a growing population while protecting both human health and our planet, more sustainable ways to provide food must be employed. Recirculating farms meet that challenge.

The following report outlines the basics of recirculating farms, how they address the many issues in modern food production in the United States, and innovations taking place in this growing industry. Sparked by necessity, but fueled by passion, recirculating farmers are leading the way in community-based food production and sowing the seeds of a sustainable food culture.

What Are Recirculating Farms?

Recirculating farms are closed-loop systems that use constantly cleaned, recycled water in place of soil as the basis to grow food. They can grow just plants or fish, or both plants and fish together in a single system. The cultivation of plants, like fruits and vegetables, without soil is known as hydroponics. Raising fish in tanks on land (rather than in any water body) in this manner is referred to as recirculating aquaculture, or recirculating fish farming. And when the two systems – hydro*ponics* and *aqua*culture – are combined into one, it is called aquaponics.[1] All three types can be located indoors, in a greenhouse, building or other structure, or outside, depending on the climate. Recirculating farms come in a variety of shapes, sizes and styles, but they all have one main theme – continuously recycled water.

Figure 1.1 System Definitions

Name	Definition
Hydroponics	***The soilless cultivation of plants***
Recirculating Aquaculture	***Fish farming in an on-land, closed-loop system (e.g. fish tanks)***
Aquaponics	***Growing plants and fish together in the same closed-loop system, a combination of hydroponics and recirculating aquaculture***

How Recirculating Farms Work

At a recirculating farm, water flows between a growing area and some form of a water filtration system that "cleans" the water before it is returned to the fish and/or plants. Pumps or clever designs that employ gravity keep the water moving. Each system operates differently based on what it is growing, the scale of the farm and the farmer's own preferences. The basic operating design and descriptions of each system type are outlined below.

Hydroponic Systems

In all hydroponic systems, plants grow without soil. They are fed by nutrients dissolved in water and delivered directly to the roots.[2] Some hydroponic systems use beds of sand, gravel or similar materials – called media – to support the plants as they grow. These media beds can be drip-fed or periodically filled with the water and nutrients, then allowed to drain. With either practice, the nutrients and water trickle through the grow beds and then are caught in a collection tank, filtered and then circulated through the system again and again, in a continuous loop. More water and nutrients are added as the plants absorb them.

Some systems use only a minimal amount of media for the plants to grow in, essentially suspending the plants mainly in the nutrients and water. Such systems use the Nutrient Film Technique (NFT). For example, in a raft type system, plants are held in a floating material atop the water and nutrients. The roots of the plants are partially submerged at all times. Additionally, naturally growing beneficial bacteria form a film on the bottom of the raft and

assist with various biological functions. The roots exposure to air as well as the movement of the water ensures that there is enough oxygen present to help the plants absorb nutrients.[3]

Aeroponic towers at Clearwater Farms (now Olde Forge Farm) in New York .

Aeroponic lettuce towers at Hollygrove Market and Farm in New Orleans, Louisiana.

One innovative form of hydroponics is vertical farming, called aeroponics. Aeroponic systems are particularly well-suited for growing a large amount of produce in a small space, because plants grow vertically, arranged on tube-like structures or in cascading baskets or buckets, minimizing the ground space needed. The roots of the plants hang into the center of the tube (or bottom of the baskets/buckets) where water flows or sprays intermittently through the middle, dispensing measured amounts of the nutrient-filled water directly onto the roots. Excess water drains to the bottom and is collected, then recirculated through the system. This method maximizes the amount of oxygen getting to the roots of the plants, helping them to absorb more nutrients.[4]

Recirculating Aquaculture Systems

Recirculating Aquaculture Systems (RAS) raise fish in tanks or some other similar structure and use a water filtration system to continuously "clean" the water for reuse. This is comparable to an aquarium set-up. Water circulates from the fish tank to a series of filters that remove fish wastes and uneaten feed and return clean water to the tank.[5] There are many types of fish, both freshwater and saltwater, being raised successfully in RAS, and the list is constantly expanding. Tilapia, yellow perch, eel and striped bass are common freshwater fish in RAS, while seabream, shrimp, oysters, crabs, bronzini (Mediterranean seabass), cobia, and black seabass are all raised in saltwater RAS. Ornamental fish such as koi, and even goldfish, are popular too.

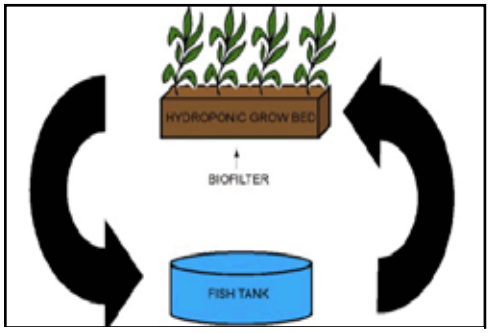
Fish tank. Photo courtesy of Octoform from their Octoblog website: http://info.octaform.com/blog/?Tag=Recirculating%20Aquaculture%20Systems.

In RAS, fish farmers control the quality of the water, enabling them to tailor the conditions to the types of fish they raise. It also means that farmers must closely monitor the composition of their water, especially the amount of dissolved oxygen, pH, and levels of ammonia-nitrite (NH_3). Too high a concentration of NH_3 can be toxic to fish. Both biological filters, like certain plants or bacteria, and mechanical filters remove wastes and transform NH_3 into less harmful compounds. Aerators may also be used to increase the level of oxygen in the water. Fish are fed diets specific to their breed that contain the optimal level of nutrients and proteins to reduce waste and increase health.[6]

Aquaponic Systems

Aquaponics combines hydro*ponics* and recirculating *aqua*culture methods to grow both plants and fish together in one system.

The plants and fish have symbiotic relationships – each receiving benefits from the other – and form a mini ecosystem, thriving as they could naturally in the wild.



How aquaponic systems work. Graphic courtesy of Stephen Vincent: http://vino.helldivers.net/?cat=7.


Fish and plants in Colorado Aquaponics' system at the Grow Haus, in Denver Colorado.

Fish in the tanks create nutrients in the water as they live and grow. The nutrient-filled water cycles to plant beds, where the plants absorb the nutrients they need, thus "cleaning" the water. Then the cleaned water is cycled back to the fish tanks, ready for re-use by the fish. These systems allow the growth of plants, fish and beneficial bacteria simultaneously – each of which feeds off of the natural byproducts of the others to create a system that requires few inputs, aside from monitoring water quality, and feeding the fish.[7]

The exact configuration of an aquaponics system depends on the scale desired, but the three essential components include: a fish-rearing tank, a grow-bed for the plants and a pump or other mechanism to move the water between the two. For larger systems, additional filters may be needed to remove more waste.

As mentioned above, when raising fish the major concern is the buildup of ammonia-nitrite (NH_3) and its derivatives, from fish waste, which can be fatal to fish, even in lower concentrations. Aquaponic systems work by introducing nitrifying bacteria, which feed on the ammonia in fish waste to convert it into nitrogen; this is non-toxic to fish and beneficial for the plants.[8] The waste from the fish provides a natural fertilizer and contains 10 of the 13 nutrients plants require to grow.[9] This symbiotic relationship provides a great benefit to farmers because it reduces the equipment needed for filtering water and produces different valuable products in one system.[10]

In most commercial aquaponic operations, the fish and the plants are held separate from one another with pipes or tubes connecting each growing area. Household sized and demonstration systems may use rafts of plants sitting atop the fish tanks allowing the roots to dangle directly into the water with the fish.[11] Many types of plants and fish can grow together. Tilapia is common because they can live in a wide range of pH levels. Yellow perch are also often grown commercially.[12] Leafy greens and herbs, which thrive on higher levels of pH, are common, but many plants grow successfully in aquaponics farms, including: tomatoes, cucumbers, peppers, beets, okra, cantaloupe, carrots, watermelon, squash, bok choy, seaweed, flowers and more.[13]


Pretty tilapia in a tank.

How Recirculating Farms Can Contribute to a Healthy Food Culture

How people relate to food defines their food culture. It encompasses everything from how they eat – whether grabbing a hamburger on the run or taking the time for a sit-down meal with family and friends – to how and where their food was produced. A healthy food culture nourishes both people and our planet. Our food culture relates to our social environment too – can nutritious food choices be made easily and is there a diversity of farming techniques used within a robust regional food system? It includes an agricultural economy that drives green job growth and connects communities both in rural and urban areas.

Sankofa Farmers Market, New Orleans, Louisiana.

Unfortunately, the predominant food culture in the United States today is far from healthy. It is the result of a variety of problems, including a highly concentrated, industrial-scale agricultural system that starkly separates most consumers from the production of their food. The long distance that most food travels to reach consumers is just one indicator of this divide. From farm to plate, the average food product in the United States travels between 1,500 and 2,500 miles.[14] But the disconnect is also evident in the food choices consumers make – like buying processed foods. This in part can be blamed on a lack of diversity in the products available in the marketplace, misleading advertisements and certain government policies that keep the prices of highly processed foods artificially low, making fresh foods expensive in comparison. Since the 1980s, a growing reliance on "convenience" foods – packaged, processed items high in sugar and calories, but low in nutrition – contributed to the tripling of childhood obesity rates. Sixteen percent of today's youth are considered obese.[15] At the same time, food insecurity is prevalent in the United States, meaning people do not have consistent, ready access to healthy foods. As of 2010, 17.2 million households nationally were food insecure.[16] The system is clearly out of balance.

As the symptoms of a broken food system come to light, the call for solutions also increases. By examining the issues with our current agricultural systems, the need to increase urban farming and to restore local food structures becomes clear. Recirculating farms are playing a crucial role in meeting this need and fostering a healthier food culture.

- Issues with Industrial Agriculture

There are numerous concerns with our current reliance on industrial agriculture: environmental damage, mass-produced and genetically altered food, low wages and poor working conditions for many laborers, to name a few. The common agricultural landscape of today is far from the imagery of the idyllic family farm from the past.[17] Beginning in the mid-1900s, advances in mechanization, the development of new chemicals to treat soil and

ward off pests, and certain government policies led to a precipitous drop in the number of farms - from over 6 million crop-farms to an estimated 2.2 million in 2011.[18] The number of small-family commercial crop farms, grossing under $250,000 in production, continues to drop. These operations now account for only 16 percent of production in the United States, down from 36 percent in 1990.[19] Intensive farming operations, reliant on chemical fertilizers, pesticides, vast amounts of water, monocropping (growing a single crop rather than diversifying on a farm) and increasingly the use of genetically modified seeds, have taken their place. Similarly, there was a large decline and concentration in the number of meat and dairy farms. "Factory farming" – raising thousands of animals in confined conditions often using antibiotics, growth hormones and select breeds to speed up production – is now the norm.

Industrial agriculture takes a toll on the environment. Thousands of acres at a time are often turned into plowed fields for a single crop, displacing wildlife and destroying biodiversity.

Cattle feedlot in Texas.

The ubiquitous use of pesticides ensures that nothing else takes root and any wildlife that could be harmful to crop growth is often eliminated in the farm area or at least controlled. As soil is depleted of nutrients, large amounts of fertilizers are needed to maintain production. The fertilizer can be quickly lost to rains in farms without many types of plants growing to provide root structure and hold soil. It runs into local watersheds and can cause massive problems both locally and downstream. The heavy concentration of fertilizer coming from farms into the Mississippi River for example, is thought to be contributing to a large area of low-oxygen – or "dead zone" – in the Gulf of Mexico where little life can survive. As fertilizer runoff enters the waterway and fuels the growth of oxygen-absorbing algal blooms, large swaths of the Gulf become deprived of oxygen and thus uninhabitable for other wildlife, including fish.[20] Pesticide use poses a risk to both the environment and human health as the chemicals enter the air and waterways, and can remain as a residue on foods. Animals, targeted or not, may become sick and die from ingesting the toxins.[21] Similarly, many pesticides can harm people too - contributing to the risk of cancer, complicating existing health concerns or creating new ones.[22]

Industrial agriculture also uses significant amounts of water. Currently, 70 percent of fresh water worldwide is used for agriculture. As the population continues to rise, so does the demand for this dwindling, vital resource.[23]

Energy costs in most forms of agriculture are also high. Beyond transporting food to market, we use enormous amounts of energy to run tractors and other farm equipment and produce fertilizers and other farm chemicals.[24] It is estimated that the United States agricultural sector uses "10 non-renewable fossil fuel calories to produce only one food calorie," making it a highly inefficient process.[25]

Recirculating Farms - Making A Change

Recirculating farms can be used to achieve a number of social and economic goals. Following are highlights of recirculating farm applications.

Commercial: Commercial scale recirculating farms are popping up all over the United States. The ability of hydroponics, aquaponics and recirculating aquaculture to deliver high-quality, safe and sustainable foods is poised to help meet the growing consumer demand. There is also a trend of for-profit recirculating farms operating as social enterprises designed to benefit their communities. For example, the for-profit Sweet Water Organics in Milwaukee also operates the Sweet Water Foundation. [26]

Non-profit: Non-profits are employing recirculating farms to enhance local food security, provide job training and promote economic development. Growing Power, Inc. with operations in both Milwaukee and Chicago is one example.[27] Many faith-based groups are also incorporating the use of aquaponics in their mission work, like Morningstar Fishermen in Dade City, Florida.[28]

Hobby and self-support: Scalability makes recirculating farms ideal for home and hobby use to produce fresh food in a small amount of space. A number of do-it-yourself websites and support groups as well as companies providing home-sized systems exist to help individuals start their own gardens.

International Development: Worldwide, aquaponic systems are being designed to allow construction from locally-sourced and low-cost materials. This helps to increase food security and promote economic growth in developing countries. A partnership is currently underway between the University of Wisconsin Madison, Sweet Water Organics Foundation and Growing Networks for a pilot aquaponics project in Kerala, India.[29] In Westmorland, Jamaica, the U.S. Agency for International Development is teaching students to construct and run aquaponic systems.[30]

Government Supported Economic Development: Recirculating farms can support economic development in a number of ways, like direct job creation, or teaching students the basics of science, technology, engineering and math. These benefits have been acknowledged through government partnerships with public and private entities to promote research and development of recirculating farms throughout the United States. From research at the Conservation Funds' Freshwater Institute funded by the U.S. Department of Agriculture to reworking zoning laws to allow for the development of a rooftop hydroponic garden in New York, government can play an important role in securing the future for recirculating farms.[31]

Service Businesses: Recirculating farming is inspiring entrepreneurship. For small businesses and individuals wanting fresh fish and produce, but without the time or know-how to manage an aquaponic system themselves, companies such as Aquaponic Modular Production Systems (AMPS) in New Orleans, LA have sprung up to install and make regular site visits to maintain individual systems.[32]

In the Classroom: Aquaponic systems are ideal for teaching students basic ecology and teachers are embracing them nationwide.[33] In Pennsylvania, "Creek Connections" a partnership between Allegheny College and a number of local elementary schools created a school curriculum for aquaponics.[34] The Milwaukee Aquaponics Expertise Development Initiative is a similar concept in Wisconsin.[35] In 2012, the University of Wisconsin also introduced a full-length aquaponics class, open to students and the public.[36]

Community Supported Agriculture (CSA): In a CSA program, people invest in a farm by purchasing a "share." In return, they receive a box of produce or other goods from the farm regularly. Recirculating farmers are embracing this model to deliver local food year-round in communities. One example is Garden Fresh Farms near St. Paul, Minneapolis.[37]

Job Training: Aquaponics can teach valuable job skills. In Indiana, the Pendleton Juvenile Correctional Facility teaches aquaponics to 12-19 year old boys to promote basic skills such as the importance of promptness and reliability on the job, as well as farming.[38] In Buffalo, NY the Massachusetts Avenue Project has successfully trained hundreds of youth from low-income areas in recirculating farming.[39]

Additionally, the social impacts have been felt across the spectrum as labor abuses run rampant in much agricultural production. Many positions are underpaid and overworked and laborers have little recourse to protect their rights. Migrant workers in particular are vulnerable to abuse.[40]

Also, rural communities, with economies almost entirely based on farming, have suffered from the consolidation of the agriculture industry; the infrastructure to process and distribute food is less needed and the jobs from those disappearing specialties have dried up as well.[41]

Despite what seems like an array of new products, industrial agriculture practices and concentrated corporate control of the food system has lead to loss of choices for consumers. Only a few varieties of many fruits and vegetables are available today in most areas. For example, in 2000, iceberg lettuce made up 73 percent of all the lettuce planted in the United States and two types of apples make up 50 percent of the apples available at most grocery stores. A quick survey of processed foods also reveals that most have corn, wheat, soy or one of their derivatives as major ingredients.[42] The appearance of choice, then, is really just that between a few key ingredients with slight variations.

Most produce available is now chosen for its ability to withstand the long journey between the field and plate. Still, on average, 50 percent of produce is lost to spoilage.[43]

Given these issues, a transformation in how food is produced and delivered to consumers is needed. Increasing urban farming to bring fresh produce directly to population centers and reinvigorating local food systems will help address some of the major concerns.

- Need for Urban Farming

Urban agriculture is defined as the "growing, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities."[44] Sustainable urban farming can help address environmental and social impacts of industrial agriculture, while meeting some of the unique challenges presented by city life. Urban farms can revitalize communities, create green jobs and bring fresh food to areas where there is little available.

Mr. Okra, a mobile vegetable vendor in New Orleans, Louisiana.

Transportation and energy costs associated with farming can immediately be cut by bringing the production of fruits, vegetables – and even fish – closer to where many consumers call home. According to the 2010 census, over 80 percent of the population of the United States – or nearly 250 million people - live in an urban area.[45] Growing food closer to where people live also increases consumer choices. Instead of decisions about what to grow being based on whether or not an item will withstand a 1,000-mile journey, choices can be made based on local tastes and needs. Indeed, diversity is key for many urban farmers. The benefits of using a recirculating farm model, which eliminates most of the environmental concerns with our current agriculture system, are discussed in-depth below.

Urban farming can revitalize communities both physically and economically. Unused or abandoned areas, including vacant lots, old warehouses, and rooftops can be transformed into vibrant edible green spaces. Even paved lots or industrial areas with soil unfit for growing food can become productive spaces once more through recirculating farming techniques, as the systems are self-contained and require no soil.

Economically, urban farming presents communities with an opportunity for sustainable development and growth. Multiple business models exist for bringing food to the marketplace and generating revenue from urban farms – from farmers markets to supplying local grocery stores and restaurants. Farms may also be created to teach leadership and job skills in areas where opportunities are scarce and there is a lack of healthy, fresh food, further strengthening the community. Money spent on food produced within the community stays in and supports the community.[46]

Locating farms in urban areas addresses food insecurity as well. Seventy-five percent of "food deserts" – areas without easy access to a grocery store – in the United States are in urban areas.[47] [48] A number of factors led to the decline of supermarkets in many struggling

communities. Those stores that are left may carry less of a selection and charge higher prices.[49] For example, in New Orleans, LA, following Hurricanes Katrina and Rita in 2005, there was an obvious lack of food stores. Today, nearly eight years later, there are just over 20.[50] This means that in New Orleans, a city of approximately 343,829 people, the average grocery store serves nearly 16,000 people, which is twice the national average.[51] The food stores that do exist are generally in higher income neighborhoods, forcing those who live in lower-income surrounding areas to travel on unreliable and slow public transportation to get to these stores. Adding insult to injury – most of the products in these stores are also high priced – in an effort to offer unique gourmet items to a nearby clientele willing and able to pay for them and to meet their operating costs in an expensive location. Not surprisingly, New Orleans was labeled the worst food desert in the United States in a September 2011 study.[52]


Aeroponic towers on the roof of Rouses Supermarket, Baronne Street, New Orleans, Louisiana.

Urban farms can introduce new sources of fresh, healthy food for such food-limited communities, functioning in place of or in addition to grocery stores. Building strong local food systems increases access to a wider variety of products and benefits urban and rural communities alike.

- Building Local Food Systems

A food system is made up of all the processes and actors that are involved in producing, distributing, consuming and disposing of food. Currently, the United States food system is almost exclusively national and even international in scope, though this is changing and local food systems are on the rise again. The qualifying criteria for "local" food often depends on how densely populated an area is. The geographic radius of "local" may be considered anywhere between 100 miles to 400 miles, though there is no universally agreed upon definition.[53] Still, no matter the distance, a major defining feature of local food systems is local control, where food is often produced by smaller scale, independent businesses that are owned and operated within the community they serve. This creates a level of connection and accountability to consumers not found in national and global food networks. Farmers' markets, community supported agriculture and farm stands are hallmarks of local food systems. People know where their food comes from and often


Kevin Morgan-Rothschild of AMPS NOLA watering plant starts for the aquaponic demonstration system at Hollygrove Market and Farm in New Orleans, Louisiana.

who grew it. Increasingly, supermarkets and even large grocery chains are carrying and promoting "locally produced foods,"[55] although some customers may find purchasing food from chain stores against the spirit of supporting a local food system. Farm-to-school programs are also increasing nationwide, bringing fresh foods directly from farms to cafeterias and supporting both children's health and local farmers.[56]

Building local food systems also presents new opportunities for rural communities. As demand increases for regionally produced food, so does the need for revitalization of infrastructure to process and distribute goods for local markets.[57] Marketing directly or shortening the supply chain to consumers brings more jobs and money back into farming communities.[58]

By building local food systems, society can lessen its dependence on industrial agriculture, reconnect people with their food and create new economic opportunities for both rural and urban communities. Recirculating farms offer new and exciting ways to meet these goals and to help establish a healthier food culture.

What Does Your Garden Grow? (50 examples)

Numerous varieties of plants and fish can be grown in recirculating farms. Here is list of what farmers are most commonly reporting to grow successfully either in personal use or commercial settings – and by no means is this list exhaustive![54]

Red bell pepper and carrots in hand from Boswyck Farms, a hydroponic garden in Bushwick (Brooklyn) New York. Photo courtesy of Dulce Fernades.

- Aloe Vera
- Basil (Sweet green, purple, curly leaf and Thai)
- Beets
- Bell Peppers
- Bok Choy
- Broccoli
- Brussels sprouts
- Cabbage
- Cantaloupe
- Carrots
- Cauliflower
- Celery
- Chamomile
- Chiles
- Chives
- Cilantro
- Coriander
- Cucumber
- Duckweed
- Eggplant
- Garlic
- Ginger
- Honeysuckle
- Jasmine
- Kale
- Kohl Rabi
- Leeks
- Lemon grass
- Lettuce
- Lima Beans
- Medicinal Herbs
- Mint
- Onions
- Parsley
- Peas
- Radishes
- Rainbow Chard
- Rhubarb
- Sage
- Snow Peas
- Spinach
- Strawberries
- Summer Squash
- Swiss Chard
- Taro
- Tomato – many varieties
- Watercress
- Watermelon
- Wheatgrass
- Zucchini

Benefits of Recirculating Farming

Recirculating farms are growing in popularity due to their numerous benefits over many current industrial agricultural practices. The systems are closed-looped and eco-efficient. They are space efficient and scalable, utilize energy and water wisely, can be inexpensive to build and are adaptable to a wide range of settings.

Closed Loop

Most recirculating farms are self-contained, closed-loop systems. This helps control diseases and parasites, allowing recirculating farms to grow food without the regular use of antibiotics and other drugs or chemicals. Water supply is still a possible route of pathogen entry, so water used in recirculating farms is often disinfected first or the water is obtained from a source that does not contain fish or invertebrates that could be pathogen carriers (rain, spring or well water are common sources).[59]

Plants from recirculating farms – including aquaponic systems – can be certified organic in accord with United States Department of Agriculture (USDA) standards (there is no United States organic certification process currently in place for fish, though the National Organic Standards Board, an advisory body to the USDA, has been discussing this for many years).

Being self-contained and closed-loop also means that these farms can be located just about anywhere. They are not restricted to being near bodies of water to discharge waste and replenish water within the system, because waste can be reused or captured and water is constantly recycled. This makes recirculating farm techniques particularly promising for bringing fresh fish, as a healthy and sustainable source of protein, to communities where there would otherwise be little access.

Growing food without soil also addresses some of the major challenges of traditional urban farming – soil availability and contamination. Due to decades of industrial production and pollution, soil in urban areas may be contaminated with lead or other heavy metals.[60] Or, areas that could be used for farming may be awkwardly shaped, small, paved or rocky. Buying and bringing in clean soil to grow can be very expensive, and creating new soil through composting can take a long time. Recirculating farms remove the soil component and can be configured to fit, and grow food, nearly anywhere. And one other benefit – no weeding! Water based systems grow what is planted – making constant weed removal unnecessary.

Eco-Efficient

Eco-efficient means, "creating more goods and services with ever less use of resources, waste and pollution."[61] It is a way of doing business and creating systems that takes the entire life-cycle of a product into consideration, finding innovative ways to use wastes created by one process in another.[62] As discussed above, aquaponic farming is a prime example of eco-efficiency as two systems are combined where the waste from one process (aquaculture) is used to fuel the other (plant growth) and fish benefit from the water filtering capabilities of the plants. All recirculating farm models have the capacity to produce a large volume of fish, plants or both in a small space. The constant reuse of water and minimal discharge of wastes makes them highly eco-efficient, producing more, with less going into the system and less waste coming out. Recirculating aquaculture systems, even when not coupled with

hydroponics in aquaponics, may also capture and reuse fish wastes in a number of ways, such as for fertilizer on soil-based plants or turned into methane gas for fuel to power parts of the farm system.[63]


Mini aquaponic system.

Contributing to the eco-efficiency of aquaponics systems is that use of most chemicals is highly discouraged by design. Pesticides that treat plants could contaminate the water, killing the fish. Any drugs used on the fish – for example to enhance their growth or to combat parasites and diseases – could similarly harm the growth of plants. When control is needed, natural methods of pest and disease management can be used, like a natural predator system (sometimes called integrated pest management), where another organism is introduced into the system, creating traps and barriers to keep certain pests out.

At the University of the Virgin Islands Agricultural Experimentation Station, an outdoor aquaponics system, they control caterpillars by introducing bacteria that only deters the caterpillars. Growing fish and plants together may also introduce some beneficial bacteria to the root systems of plants that make them more resistant to common plant diseases.[64] This combination of producing more food with less waste and pollution as well as an avoidance of chemical pesticides makes recirculating farms highly eco-efficient.


Hydroponic lettuce and other vegetables and herbs grow in a hydroponic greenhouse in Anguilla, in the Caribbean.

Space Efficient and Scalable

Recirculating farms are very space efficient, and capable of producing large amounts of food in a small area. They vary greatly in size and purpose. A personal set-up may require only a few square feet for a rain barrel, tank and rafts to raise fish and vegetables for a family, while a larger commercial farm may occupy tens of thousands of square feet. Many operations start small and scale up over time.

Evo Farm in Mar Vista, California currently operates in a 500-square-foot greenhouse, with three 250-gallon tanks for catfish and vertically stacked rafts of plants where over 50 types of lettuce as well as Asian green beans, basil and tomatoes grow.[65] The University of Virgin Islands Agricultural Experiment Station hosts an aquaponic research facility in an outdoor system on one-eighth of an acre, or 5,445 square feet, with plants growing on floating rafts and four 2,000 gallon fish tanks. The system produces 11,000 pounds of tilapia and 37,800 heads of lettuce annually. Nelson and Pade,

a maker of aquaponic systems, offers indoor commercial models that range from 4,000 square feet to nearly 11,000 square feet. Depending on the model, these systems produce anywhere between 28,000 to 112,896 heads of lettuce annually and between 2,200 and 5,294 pounds of fish.[66] In New Orleans, a group called Aquaponic Modular Production Systems (AMPS) is using aeroponic growing methods, allowing them to raise 44 plants within 6 square feet.[67] In contrast, the average single head of iceberg lettuce must be planted 8 to 12 inches apart, generating only up to 9 heads of lettuce in a horizontal, 6 feet long, soil-based row.[68]

Aeroponic towers powered by solar panels on the roof of Bell, Book and Candle in the West Village, of New York City.

Production levels in recirculating aquaculture systems are also often higher than those in other forms of fish farming. Year-round growth is possible due to the controlled environmental conditions.[69] Some recirculating farms can produce market-sized fish in just nine months, compared to the 15 to 18 months it often takes for fish raised in other systems to reach market size.[70]

This space efficiency and scalability of recirculating farms makes them suitable for a variety of settings – personal, educational and commercial – and ideal for producing food close to market.

Solar panels atop Growing Power, in Milwaukee, Wisconsin.

Energy Efficient

Different recirculating farms require varying amounts of energy to move water through the system, dependant on design and equipment. Recirculating farms often use new innovations and techniques to lower energy demands. The main component requiring energy in a recirculating farm is a pump to keep the water moving. Heating units, grow lights and aerators may also be needed depending on the type of farm, its location and what is being raised.

At Skidaway Institute of Oceanography, Dr. Richard Lee, an emeritus professor of oceanography, uses geothermal chilling and solar heating to regulate the temperatures in his farm. Geothermal chilling taps into naturally occurring factors to alter the temperature of water in the farm. To achieve temperature reduction, water from the system flows through a closed-loop pipe running down to water underground and back up to the surface (no water is exchanged between the facility and the groundwater). The groundwater is approximately 64.5° F and the contact of the cool water on the outside of the pipe reduces the heat of the water in the pipe, so that the fish tanks can maintain temperatures between approximately 79° F and 82.5° F during the hot Georgia summers.[71] Similarly, solar heating is also used, by


Methane flame generated from repurposed fish waste from a recirculating aquaculture system in Baltimore, Maryland.

running pipes carrying water from the farm through black plastic sheets that transfer the heat they absorb from the sun to the water in the pipes. Using this method, the farm had temperatures between approximately 70° F and 77° F in the winter when air temperature was not above 60° F.[72] Using solar heating has been found to reduce conventional energy requirements by 66 to 87 percent, depending on the regional climate where the recirculating farm is located.[73]

Wind energy has also been tested as a means to power certain aspects of a recirculating farm, with increasing success.[74]

Some farms can operate on solar energy. They may use battery back-ups, or tie into an urban power grid to sell the energy produced to the local utility and then receive credit that is applied to reduce or eliminate their own power bills.

In other examples, Cabbage Hill Farm Foundation in Mt. Kisco, New York used waste vegetable oil donated from local restaurants as fuel to power a furnace that then heated the farm's water. The repurposed vegetable oil was preheated in a large tank and filtered prior to its use to fuel the furnace. The furnace heated a coil in the fish tanks, warming the water.[75]

Dr. Yonathan Zohar, Director at University of Maryland Biotechnology Institute's Center of Marine Biotechnology (COMB), can reuse waste captured from fish tanks to produce energy in the form of methane gas that can then power a generator to run parts of the system.[76]

Many of these approaches have proven viable on a small scale, and testing is under way as to whether they can be used for larger-scale projects. Research is being done at the United States Department of Agriculture's Agricultural Research Service (ARS) to determine the specific energy requirements for various aspects of recirculating farm technology and how to get the most efficient function with the least amount of energy.[77]


Large rain catchment.

Water Efficient

Water efficiency in agriculture is becoming even more important as freshwater resources become scarcer. Traditional agriculture use currently accounts for 70 percent of freshwater consumption worldwide. Recirculating farms are highly water efficient, producing more food than many other farming methods, using less water. Because water is constantly cleaned and recycled throughout the farm, only minimal water loss occurs through waste removal, evaporation, and absorption by the plants. Ideally, systems operate with replacement of about one percent of total water volume daily.[78]

In comparison to other agriculture techniques, much less water is needed in recirculating farms to produce the same amount of food. For


Single barrel used to catch rainwater.

example, it is estimated that a head of lettuce grown through soil-based agriculture requires 15.9 gallons of water. At the University of the Virgin Islands Agricultural Experiment Station mentioned above, they can produce one head of lettuce with only 7.6 gallons of water – nearly half the amount of that needed in soil-based growing. And the water in the UVI system is being used to produce another product at the same time – fish. This system requires a daily water addition of 1–1.5% of the total system's volume.[79]

Maximizing water re-use and minimizing waste makes recirculating farms an ideal way to produce food in arid climates. In fact, in 2011 construction of what will reportedly be the world's largest aquaponics system in the United Arab Emirates was announced. The Baniyas Centre will be made up of two 4,000 square meter (43,056 square feet) greenhouses, one for fish and the other for plants, connected by a series of pipes to transfer the water. At full capacity they will produce up to 300,000 heads of lettuce annually and about 220 tons of fish.[80] Aquaponics is particularly good for raising both fish and plants in dry areas or in greenhouses, because the removal of wastes by the plants further decreases any water loss due to filtration in fish farming.[81] Other arid countries in the Gulf, such as Qatar and Saudi Arabia, are also looking to recirculating farms as a solution to improve food security.[82]

Fuel Efficiency

Recirculating farms do not employ the heavy machinery often used in industrial agriculture, such as tractors and crop dusters, thus greatly reducing the amount of fuel used per pound of food produced. Also, the use of synthetic fertilizers, pesticides, and herbicides, which require great amounts of energy to create,[83] are often unnecessary: Products grown in recirculating farms can achieve faster growth rates than with other forms of agriculture due to the efficiency in biological processes promoted in the farms, natural pest management is often employed and with no soil, there are no weeds!

Most importantly, locating farms in or near the communities where food will be consumed decreases the vast amounts of fuel expended in preservation and transport. This makes both economic and environmental sense. In addition to less carbon emissions, there is a reduction in costs associated with shipping and refrigeration, savings that can be passed on to consumers making fresh food more affordable.

Many advances are being made to increase the overall energy efficiency (and thus fuel efficiency) of recirculating farm systems to compliment the already-existing benefits.

Affordable

Recirculating farms are relatively inexpensive to start-up and maintain. They can also be designed to meet the needs of a particular community or market. As a business progresses, the farm can be enlarged by adding more plant growbeds and fish tanks, while maintaining both proper balance for a healthy system and the most ideal production level. Small personal use systems can be built for about one hundred dollars and entrepreneurs can establish a

small commercial-sized aquaponic farm for just over $40,000. The University of the Virgin Islands' aquaponics operation was constructed and fully outfitted for $40,490 (not including labor).[84]


Aquaponics system at Growing Power in Milwaukee, Wisconsin.

Some farmers are designing their systems from pieces that can be found at almost any hardware store, eliminating the need for and thus saving money on special equipment. Others are even experimenting with materials that can be grown on the farm or nearby, reducing both shipping and replacement costs.

Operating costs vary depending on the type and scale of the farm, but may include fish fingerlings, fish feed, seeds, growing media, electricity, staffing and maintenance.[85] Additionally, because the systems use water as a primary medium to grow food, soil is not necessary. In many communities, soil may be too contaminated, paved, rocky, or otherwise not fit to grow food. In these instances, farmers may buy and truck in or make healthy, enriched soil through composting. Either way, there is a significant expense associated with buying or creating soil. The lack of soil also means no weeds, further reducing time and costs associated with preventing and removing invasive plants.

Versatility

The recirculating farms' design and efficiency benefits make these systems highly versatile. They can be located virtually anywhere, from tropical climates to arid deserts to temperate regions and be scaled for personal or commercial use. They are also useful to reach a number of goals, including economic development, food security and environmental conservation.

In Brooklyn, NY, for example, the largest-to-date rooftop garden (100,000 square feet) is being built to showcase hydroponics in an industrial waterfront revitalization effort. The farm will create jobs, produce local food and assist with storm water management – helping to control as much as 1.8 million gallons of storm water.[86]


Creating soil through vermi (worm) composting at Growing Power in Milwaukee, Wisconsin.

Recirculating farms can also be integrated with traditional farming techniques. For example, Growing Power, in Milwaukee, WI, uses aquaponics as part of a larger "community-food-hub" that produces everything from produce to honey to soil through composting.[87] Scalability, space efficiency and low-cost make recirculating farms a viable solution to increasing the availability of healthy, fresh food.

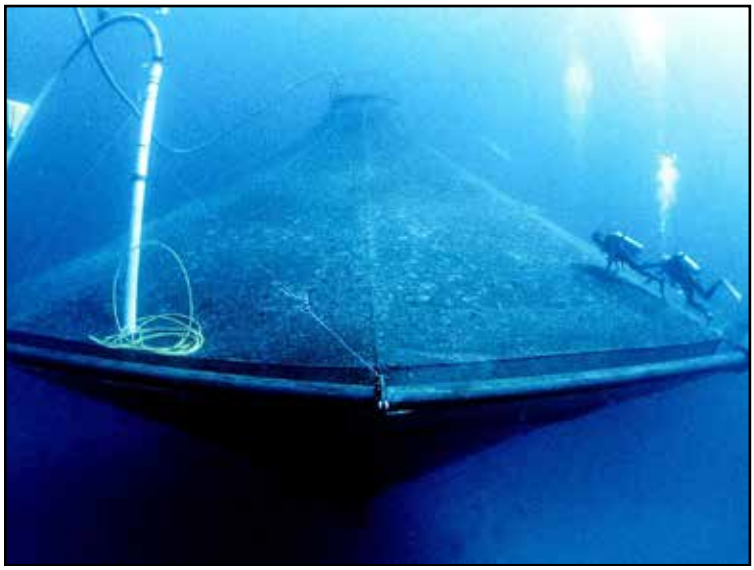
Recirculating farms can grow a variety of fish and plants, either together or in separate systems. Academic research and experiments by entrepreneurs is constantly expanding the types of food grown in these systems.

Tilapia swim in a tank in the basement of The Plant, an indoor urban farm housed in a repurposed meat packing building in Chicago, Illinois.

Fish

Recirculating farms can raise both saltwater and freshwater fish. Some of the most popular commercial freshwater fish currently include tilapia, yellow perch and catfish. But the list of aquatic species being researched and grown in recirculating systems is constantly broadening to include: crabs, sea bream, branzini, cobia, red drum, black seabass, bivalves (oysters, mussels, clams), soft corals, assorted flatfish (like flounders), lobster, nautilus, rainbow trout, striped bass, assorted shrimp and prawns and even salmon.[88]

Sustainable Fish Farming



Open ocean aquaculture cage with divers, photo courtesy of NOAA library: http://www.photolib.noaa.gov/index.html.

Just as recirculating hydroponics and aquaponics can be used as sustainable methods of growing vegetables, fruits, herbs flowers and other plants, recirculating aquaponics and aquaculture systems can be employed as a way to raise fish in an eco-friendly and humane manner. Recirculating fish farms are fully contained, unlike open water fish farms that raise fish in floating net pens or cages in the ocean, rivers or other bodies of water, where fish wastes, excess feed, antibiotic and chemical treatments and parasites and diseases pass directly into the surrounding environment. Recirculating farms capture and often reuse waste, recycle water, can better control the environment for the fish – drastically reducing the incidence of disease and stress and eliminating parasitic and disease transfer between wild and farmed fish. This equates to less need for antibiotic treatments to keep fish healthy. It also removes the threat to wild fish that escaped farmed fish can pose. When farmed fish escape from net pens or cages, they may interbreed with wild fish and disrupt the genetic fitness of the population. They may also outcompete wild fish for food, habitat or mates.[89] Land based, closed containment systems located far from waterways virtually eliminate this risk.[90] As the need for fish farming increases, recirculating farms are one of the most ecologically sound ways to bring more fish to a variety of markets and minimize stresses on wild fish.


Hydroponic vegetables.

Plants

The list of the types of plants that can be grown in recirculating farms is also expanding rapidly. Systems can be specifically designed to produce a variety of fruits, vegetables, flowers, herbs and more by using shallow or deep water growbeds, vertical towers, and many other creative options. Leafy greens, tomatoes, cucumber, eggplant, okra, strawberries, melons, pharmaceutical plants and even root crops like beets and carrots are successfully growing in recirculating farms.[91] In saltwater systems, algae and seaweed are popular products.[92]

In commercial systems, high-value plants with short growth cycles are often chosen to maximize profit potential. Culinary herbs, such as basil, cilantro, chives, parsley and mint all do well in aquaponic and hydroponic systems and command a good market price. Lettuces also grow rapidly, can tolerate higher levels of pH needed by fish and also are more space efficient, since most of what is harvested (the entire lettuce head) is edible.[93] The wide range of plants that can be grown by recirculating farms makes the systems able to meet much of local market demands.

Economics

Recirculating farming makes sense economically as well as and ecologically. High efficiency year-round food production, ways to turn 'waste' into additional revenue streams and the ability to site the farms close to markets all mean recirculating farms are a wise investment in our future. As with all business, however, the profitability of any specific farm relies on a number of factors, including the design, location, products grown, market demand, competition and more. Still, recirculating farms are uniquely poised to meet the ever-increasing need for sustainably produced food both in rural and urban areas. Commercial entities and non-profit organizations alike are finding success by bringing these farms into their communities.

At the Baltimore Urban Recirculating Mariculture System, a project of the University of Maryland Biotechnology Institute, Dr. Yonathan Zohar and his team are proving that land-based recirculating aquaculture farms can raise fish more efficiently than other forms of aquaculture and make a profit by producing high-value, marine finfish species close to market. Focusing on Mediterranean gilthead seabream – which can sell for around $10 per pound -- they have designed a system that can be scaled up in urban environments, using existing municipal water infrastructure and maximizing the re-use of water.[94] Dr. Zohar chose to raise a species that was not caught nearby to avoid completion with local fishermen, giving his product an additional edge in the marketplace and avoiding conflict with those making a living from fishing. Furthermore, the farm demonstrates that marine

species can be raised successfully in urban centers, drastically reducing the costs of transporting seafood to markets far from salt water.[95]

Freshwater aquaculture .

Rural areas can also benefit from recirculating farming. In Ohio, former chicken farms are becoming fish farms. In 1983, Fresh Water Farms in Urbana, OH became one of the first recirculating farms in the state. Producing 100,000 pounds of fish annually, including rainbow trout and freshwater prawns, it continues to be the largest, but has been joined by 150 other licensed farms, as well as nearly 50 in the experimental stage.[96] Fresh Water Farms sells its rainbow trout at a retail price of $8.99/lb, and a variety of other products to local residents and nearby markets.[97] Dr. Steven Smith, President of Freshwater Farms, also helped to transform many other hog, cattle and chicken farms into fish farms.[98]

Recirculating farm technology addresses one of the big challenges to profitability of traditional fish farming – expensive fish feed. Although fish are highly efficient at converting their feed into fuel for them to grow, fish feed still makes up 40 to 60 percent of total operating costs for fish farmers. In open-water and flow through systems, 65 to 70 percent of that feed is lost as unusable fish waste.[99] In a closed loop system however, solid waste and excess nutrients become the basis of other valuable products – fertilizer to grow plants (either in the same aquaponic system or for soil-based plants elsewhere) or even repurposed for renewable energy – like converting fish waste to methane gas that can be used to power a generator to run lights at a farm. Additionally, many recirculating farms create their own food – for example by raising herbivorous fish (those that eat plants) to feed carnivorous fish (those that eat other fish or worms, insects, etc.) on site at the farm.

Combining the technology of fish farming and hydroponics in aquaponics also cuts down on major costs associated with each system separately. Hydroponics requires the purchase of nutrients to add to water and stand-alone recirculating aquaculture requires filtration systems to return clean water to the fish tanks. In aquaponics, nutrient rich water from the fish is combined with nitrifying bacteria to create a perfect food for the plants. As discussed above, the plants in turn filter the water for the fish, reducing the need for additional filters. By combining the two systems, farmers can both increase and diversify their production.[100] One analysis done by Auburn University looked at the economic feasibility of aquaponics for struggling traditional catfish farmers in Alabama and found that an aquaponic model combining tilapia and tomato production would be a viable business and provide an entrance to a new market.[101]

There Grows the Neighborhood mural at Sweetwater Organics – an aquaponic farm in Milwaukee, Wisconsin.

Indoor recirculating farms can help to meet the demand for fresh produce and fish, year-round. Because indoor farms are not constrained by the weather, farmers can time their harvests to meet out-of-season demand and switch crops during times of high supply or competition from other agriculture, providing opportunities for better prices. They may also increase revenues through organic certification. Currently, the demand for organic products at the retail level is outpacing the supply.[102] Hydroponic and aquaponic farms could help fill this gap.

Recirculating farms are being built by both commercial businesses and charitable organizations. Growing Power, a non-profit founded by Will Allen with "Community Food System" operates sites in Milwaukee, WI and Chicago, IL. By integrating a number of systems, including aquaponics, the organization's Milwaukee site generates about $5 per square foot of produce annually, translating to $200,000 per acre.[103] Also in Milwaukee is Sweet Water Organics - a pioneering for-profit social enterprise raising fish and plants in what was once an abandoned factory site. It raises yellow perch, blue gill and tilapia, producing about 80,000 fish annually, as well as a variety of lettuces, sprouts, basil, wheatgrass, oyster mushrooms and Swiss chard.[104] These farms are proving that recirculating farming can produce both fresh food and enough profit to grow their projects in an environmentally and economically sustainable way.


Wheat grass growing indoors at Sweetwater Organics – an aquaponic farm in Milwaukee, Wisconsin.

Recirculating farms are also in use as a means to revitalize neighborhoods and contribute healthy fresh affordable food where it is otherwise scarce or inaccessible for various reasons. For example in New Orleans, LA in areas recognized as food deserts, communities both on the West Bank of the city and out East are building aquaponic farms, that turn empty or overgrown lots into edible green spaces. These beautify the surroundings as well as provide healthy fruits, vegetable, herbs and fish to the neighborhood, and sometimes beyond. In addition to supplying fresh food to their own community, the Mary Queen of Vietnam Community Development Corporation sells their food commercially for profit. Even when the primary focus is on increasing local food security by consistently supplying affordable healthy fresh food in underserved areas, recirculating farms can provide economic benefits to their farmers.

Although research and development in the fields of recirculating aquaculture, hydroponics and aquaponics has been ongoing for well over 30 years in the U.S., the current food system crisis sparked a flurry of activity and interest in recirculating farms recently as a way toward a healthier, more sustainable food culture. Farmers, entrepreneurs and researchers alike are continually improving on areas like fish feed and energy efficiency and developing new business models to incorporate both social and economic considerations. Below are just a few examples of innovations taking place in this rapidly expanding industry.

Hydroponic plant walls.

Fish feed is a necessary input for any aquaculture system. A major constraint in the sustainability of farming carnivorous marine species is the removal of forage fish from the wild to produce feed for farmed fish.[105] A number of advances were made in recent years to decrease the amount of wild fish used in the diet of farmed fish. Protein replacements, such as worms, algae, black soldier fly larvae and soy have been tested. Each new feed development must be closely reviewed for potential problems, so as not to simply swap one concern for another. For example, an increased demand for soy as aquaculture feed requires the use of agricultural land, which could otherwise be used to grow food to feed people directly. Industrial scale soy farming has also led to soil erosion and devastation of forest ecosystems in Latin American countries.[106] Further, soy is not a natural food item for fish and as such is not likely to be the best replacement for wild fish. Feed developments such as worms, algae and black soldier fly larvae, whose production may even be integrated as a component of recirculating farm operations, are more sustainable options.[107] Raising herbivorous or omnivorous fish, which naturally can eat a variety of foods, such as tilapia, also enables farmers to choose the most sustainable feed.

Enhanced recirculating aquaculture systems are being developed. These use worms and microalgae to filter water. Intergrated-multitrophic aquaculture introduces bivalves such as oysters or mussels which further filter wastes from the system and produce an additional product for sale. Harpswell Oceanic Center, Inc. in Maine hopes to pioneer this new technology to demonstrate its effectiveness and to provide an alternative to offshore marine aquaculture.[108]

Advances are cropping up in energy use at recirculating farms as well. At the University of Massachusetts, researchers are working on a "Building Integrated Aquaculture" (BIAq) design that maximizes energy efficiency using a solar water-heating system, strategically locating air-ducts and combining heat pumps, exchangers and refrigeration packets to manage humidity. Their goal is to help small businesses save money by ensuring that their location

is ideally suited to fish farming.[109] And in the City of Keene, New Hampshire a project is underway to capture methane from a capped landfill and turn it into power that will heat a greenhouse for an aquaponics operation as well as deliver power to the energy grid. The recirculating farm will also eventually produce algae for use as biofuel.[110]

Recirculating farms are inspiring innovative new business models too, using food production to meet both social and economic goals. Many new and existing operations combine an element of knowledge sharing in their operations, offering everything from farm tours to formal training on establishing an aquaponics operation, to promote self-sufficiency and sustainable food production nationally. Community Supported Agriculture Aquaponics in California, Friendly Aquaponics in Hawaii, Green Acre Aquaponics in Florida and Growing

Where In The World Are Recirculating Farms?

Recirculating farms are gaining in popularity worldwide. Following are just a few examples from around the globe:

Berlin, Germany: The world's largest roof-top aquaponics operation is set to open in Berlin in 2013 atop a former malt-factory. Tanks once used for soaking malt will be transformed into fish tanks and housed in a 4800 square yard greenhouse. The operation will grow perch and a variety of produce.[111]

London, England: In London, an old storefront is now an urban food-hub called FARM:Shop. An aquaponics system produces vegetables and fish served up at the on-site café. The storefront demonstrates the viability of urban farming and provides a unique events venue. [112]

Midrand, South Africa: Charlton Park Tilapia is growing red-breasted tilapia without commercial feed. Fish are fed entirely by plants and algae, including lettuces, duckweed and grass cuttings, which are grown on site. Fish and produce are sold to local restaurants and the community. There is a growing interest in aquaponics in South Africa, evidenced by the sold-out training courses held on his farm. [113]

Navidad, Chile: Researchers in Chile are developing the ideal system for raising fish and produce using aquaponics for arid regions of the country. The current aquaculture industry in Chile is highly concentrated in open-water, net-pen salmon farming. Aquaponics offers an alternative to diversify the economy and create new opportunities throughout the country.[114]

Perth, Australia: Aquaponics has taken off in Australia. Backyard Aquaponics, based in Perth on Australia's west coast sells about 300 backyard systems each year.[115]

San Juan del Sur, Nicaragua: At the sustainable living community, Finca las Nubes in Nicaragua, an aquaponic system with about 800 tilapia and 2000 plants ensures that fresh produce and fish are always on hand. [116]

Tohoku, Japan: A company called Japan Aquaponics is on a mission to help rebuild communities devastated by the 2011 earthquake in Japan and subsequent meltdown of the Fukushima nuclear plant which left soil in its surrounding area too contaminated for farming. Through partnering with schools, the company will provide demonstration systems and teach children the basics of aquaponics. It is also planning the establishment of community-led projects to promote economic growth.[117]

Westmorland, Jamaica: In Jamaica, students at the Belmont Academy are learning how they can use aquaponics to produce local, healthy food in their communities and to help promote economic development.[118]

Aquaponics system at Sweetwater Organics – an aquaponic farm in Milwaukee, Wisconsin.

Power in Wisconsin, to name just a few, are all examples of farms that open up their doors to those eager to learn.

Aquaponics is also being used to meet various social needs of communities. In Louisiana, the Mary Queen of Vietnam Community Development Corporation is exploring aquaponics as a way to improve the opportunities of community members whose traditional livelihood - fishing - was altered from both Hurricane Katrina and the BP Horizon oil spill.[119] And at Hawai`i State Hospital on O`ahu, aquaponics is being used as part of an occupational work therapy program. Patients learn valuable skills and the weekly harvests of produce are served in the cafeteria.[120] The application for recirculating farms is limited only by the imagination.

Conclusion

Recirculating farms hold the promise of making safe, affordable and sustainably produced food widely available in every community. Water, space and energy efficient, their unique design opens up new possibilities for growing food close to where it will be consumed, increasing local control over food production and reducing environmental impacts. And most excitingly, this ability to grow food in previously unthinkable spaces is capturing the imagination of a new generation of entrepreneurial farmers, many who are interested in producing value for their communities far beyond their profit margins and are a dynamic part of a healthy food culture.

Consumers, farmers and policymakers alike all have a role to play in supporting the development of recirculating farms. Consumers can demand sustainably produced foods and seek out businesses that carry products from recirculating farms or even start a farm in their own backyard or community. Farmers can work together to share ideas and innovations, to pool resources and to more deeply integrate themselves into a regional food hub. And policymakers can help incentivize the growth of the recirculating farming industry by supporting research and development and shifting subsidies from industrial agriculture and aquaculture to recirculating farms. Working together, we can make a real change.

Aquaponic farm behind a strip mall in Winter Park, Florida – Sahib's Aquaponic Produce.

Endnotes

1. While some methods of hydroponics and aquaponics systems discharge water, this report focuses solely on hydroponic and aquaponics systems that recirculate their water. Similarly, references to the benefits of recirculating aquaculture deal solely with land-based systems, as opposed to those in open water, such as in oceans and lakes.
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