# URBAN WATER: Re-Introduction of Sustainable Water Cycles through Urban Agriculture

GUNDULA PROKSCH
University of Washington

> "Almost three quarter of our Earth's surface is covered by water, but only about 2.5 percent of all the water on earth is fresh, and two- thirds of that is locked in glaciers and ice caps. The renewable freshwater supply on land--that is made available year after year by the solar- powered hydrologic cycle in the form of precipitation--totals a mere 0.008 percent of all the water on earth."[1]

Water is quickly turning into the most valuable commodity on the planet. Turbulences on the international agricultural commodities market in August 2010 have drawn international attention to the resource 'water'. Heat waves, disastrous droughts and desertification as a result of climate change lead to extreme losses of crop yield, most recently in Russia. Despite these catastrophes, global water problems have not yet penetrated into general consciousness.[2] For too long water has been seen as an inexhaustible resource with unlimited renewable capacity, but in fact it is a finite resource.[3] The extinction rates of other non-renewable resources such as oil, coal, gas and minerals are carefully monitored, but accessible fresh water resources are increasingly threatened by pollution, climate change and highly unsustainable water use patterns[4] caused by human activities. The moment freshwater is used beyond the rate at which it can be naturally replenished the hydrological cycle is endangered.[5]

This sensible equilibrium is already out of balance in many regions, which support growing populations, urbanization and intensive agriculture. Since the middle of the 20th century, global water consumption has tripled. In the next 20 years, it is expected to rise an additional 50 percent.[6] Growing water demand cannot be met by opening up new resources; only a more sustainable approach to water supply and management will satisfy this demand.

This study responds to the imbalance between the pressures on cities to supply their inhabitants with fresh water in contrast to the industrial agriculture's wasteful water use. Especially in regions of extreme water scarcity, cities and agriculture compete for the same very limited resources. For example, not only do the cities of Los Angeles and Las Vegas depend on the water of the Columbia River, but also crop irrigation in the deserts of Arizona, California and Mexico's Mexicali Valley.[7] Expanding the water supply for one user means taking away from another.[8] This investigation highlights approaches that contribute to both the (re)-creation of more sustainable water cycles and more water efficient agricultural practices.

## ENVIRONMENTAL BENEFITS OF URBAN AGRICULTURE

Emerging strategy in urban agriculture work as a form of green infrastructure creating more ecological water flows. In the context of managing stormwater and urban water, these strategies utilize natural processes to slow, treat and absorb runoff and wastewater, returning the purified water back to the natural water cycle. Therefore the positive input of these agriculture projects is two-fold: they support low impact urban water management and demonstrate water efficient, sustainable agricultural methods, which can be adapted by industrial agriculture. With both contributions, these projects are poised to improve the current challenging water situation of cities. They stand also as positive precedents for more extensive, indispensable change to approach water security holistically and preserve the health of our environment sustainably.

Scholars and activists have written extensively about the precarious global water situation, especially the competing, growing demands of cities and wasteful practices of industrial agriculture.[9] More sustainable approaches to agriculture, particularly in form of urban agriculture projects, have also been documented in many North American cities, such as Philadelphia, New York, Milwaukee, Portland, Seattle and Vancouver, BC. Most projects and publications reinforce the social and economic benefits; however, relatively little has been written about the environmental benefits. The main ecological benefits documented are the revitalization of brownfield sites, improved air quality, reduced heat island effect, reduced energy demand connected to decreased food miles, and an improved biodiversity.[10] Positive impacts of these practices on the water cycle have not been adequately acknowledged, although the environmental value of the underlying green infrastructure systems, such as green roofs[11], low impact water management[12] and biological water treatment has been widely recognized. This paper focuses on the environmental benefits of urban agriculture, especially in relation to sustainable water management and water efficiency as well as their potential impact on the larger water cycle. The intention is to connect the currently disjointed strands of research.

## URBAN WATER CHALLENGES

Urban areas are places of high water consumption; the concentration of human settlements and industrial processes place severe strain on existing water resources. Municipal authorities are responsible for providing urban residents with adequate water supply and acceptable water quality.[13] To support their water needs, most cities import water by either pumping it from underground sources (aquifers and wells) or transporting it long distance from surface sources (reservoirs, lakes, or rivers). During the transport and handling, dilapidated infrastructure causes a loss of up to 50 percent of the potable water by seeping into the ground, not only in newly industrialized countries, but also in the metropolitan areas of the western world.[14] Other threats to the water resources and water security of cities include unsustainable overpumping of groundwater and aquifers as well as the pollution and contamination of these water sources. Inevitably, groundwater around major cities, near industrial developments, beneath industrial farms or as a result of leaking landfills, already contains contaminants.[15]

Urbanization causes large areas of ground to be covered with buildings and relatively impermeable materials, which collect precipitation on roofs and other surfaces.[16] Instead of harvesting rainwater as an additional fresh water source, many municipalities prohibit such practices due to health, land use, and building code regulations or the undemocratic ownership of water rights.[17] To make matters worse, sealed surfaces in urban areas disallow infiltration of water into the ground and evaporation over time, which increases the amount of runoff. Runoff water captures pollution, carries it into the water bodies in and around the city, and contaminates freshwater sources and saltwater bodies. In cities with combined sewer systems, harmful overflow events even add sewage to the contamination. With the natural, self-regulating water cycle largely disturbed, most cities have developed complex urban water management systems involving hard infrastructure for urban drainage, prevention of flooding, as well as wastewater treatment and sludge handling. These processes are often energy and cost intensive and the infrastructure requires expensive maintenance. Only recently have communities started to expand their efforts to integrate green infrastructure to move toward more sustainable low impact water management.

## WATER WASTE IN INDUSTRIAL AGRICULTURE

The omnipresent challenges to meet the urban water needs and water management demands of cities obscure the impact of the largest contributor to increased global water consumption; not the domestic or industrial sectors, but a wasteful model of agriculture has turned food-growing into an industrial process. The scale of farming production has grown to be gigantic and destructive to the environment, in favor of supplying commercial food and generating an unsustainable food industry. One of the most destructive factors is the agriculture's demand for intensive irrigation. Today farming accounts for 70 percent of the worldwide water use with the largest portion taken by irrigation.[18] Furthermore, the irrigation technologies used are often inefficient; up to 60 percent of water could be saved with the use of up to date, appropriate and properly managed equipment.[19]

Even more challenging is the fact that 15-35 percent of irrigation withdrawals are unsustainable.[20] Groundwater overpumping and aquifer depletion are now occurring in many of the world's most important crop- producing regions, including the western United States, where water tables are dropping 3 feet a year. This drop is a signal that groundwater use has exceeded its limits and also that a portion of the world's food supply is produced through unsustainable water use.[21] One estimate suggests that up to 10 percent of the world's grain is being produced by water that will not be renewed.[22]

The United States is one of the most dramatic examples of water waste in agriculture. In the western states, irrigation accounts for 90 percent of total water consumption. Irrigated land increased from four million acres in 1890 to nearly 60 million in 1997, of which 50 million are in the arid states.[23] At the same time, most of the fastest growing cities in the United States, like, Houston, Dallas-Forth Worth, Austin, San Antonio, Phoenix, Salt Lake City, and San Diego,[24] are located in the same arid states, which increases the pressure on the water resources and the competition between cities and farms.[25]

## RECOGNIZING THE TRUE COST OF WATER

Unfortunately, large subsidies for agricultural water use keep water prices artificially low and continue to discourage investments in more efficient methods.[26] They convey the false message that water is abundant and can be wasted, even as rivers are drying up and aquifers are being depleted. Farmers in California pay about 1.4 percent of the price that the state's urban residents pay for water;[27] therefore they have little incentive to use water efficiently.[28] Although poverty alleviation and other social goals may justify some degree of irrigation subsidy, especially for poor farmers, the levels of subsidization that exists today is an invitation to waste water.[29] Recognizing the true cost of water is essential. Realistic water pricing would create incentives to both promote efficiency and reuse, by encouraging growers and manufactures to implement water conservation measures and to allocate water more productively.[30]

## SUSTAINABLE USE OF WATER IN AGRICULTURE

Emerging practices in urban and peri-urban agriculture demonstrate the re-integration of more sustainable water use into locally adapted farming. At the same time, these methods and projects re-establish natural water cycles. Often developed and tested for small-scale operations, these framing methods have the potential to be adapted to and to transform the practices of large-scale agriculture. The primary strategies fall into three groups: the selection of crops based on their water efficiency, use of appropriate types of irrigation systems and use of alternative water resources available in cities.

The starting point for more sustainable water use in agriculture is the selection of crops based on their water efficiency and adaptation to the local climate. Studies have shown that if no other factors are limiting plant growth, total production is proportional to the amount of water a plant transpires. Larger or deeper root systems that allow plants to take in more moisture can thus increase yield. Cultivating varieties with shorter growing seasons can also help to reduce the overall water use.[31]

The largest reduction of water use can be achieved through the selection of more efficient irrigation system suitable for the specific crop, climate and soil condition. The basic aim is to optimize the timing and amount of moisture in the root zone to allow the crop to use moisture productively.[32] Therefore irrigation that operates near or below ground level, like drip and trickle systems, are considered the most efficient.

The best holistic strategies in this context are the development of closed water systems and the use of alternative water sources. Several urban agriculture projects have developed closed loop systems; these systems circulate water through different stages of plant irrigation, purification, aquaponics and self- fertilization, which makes them self-sustaining and reduces their overall water needs.[33] Specifically in areas that depend on irrigation, urban agriculture promotes rainwater harvesting and the treatment and reuse of urban wastewater. These resources of cities are currently often un-mined or under-utilized. The reuse of wastewater does not only guarantee a fairly reliable supply independent of seasonal and climatic variations; it also

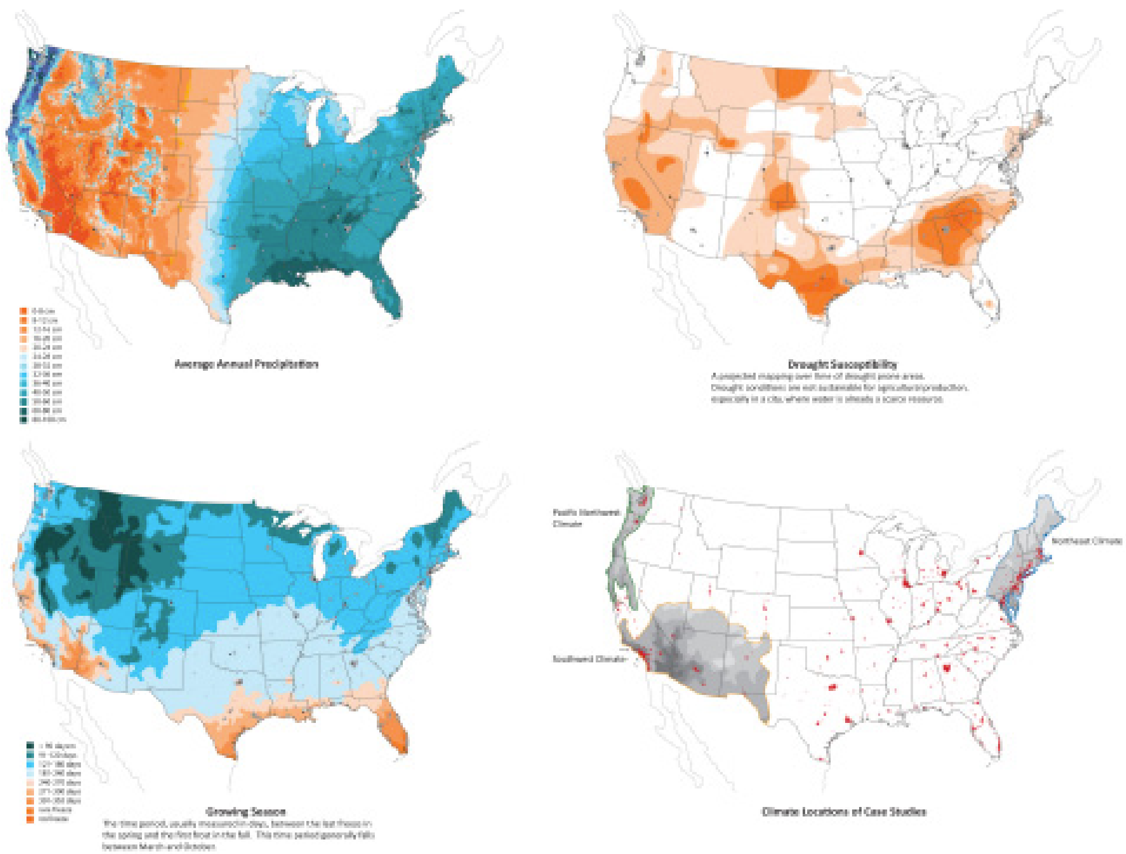


Figure 1: Climate Zones and Water Challenges

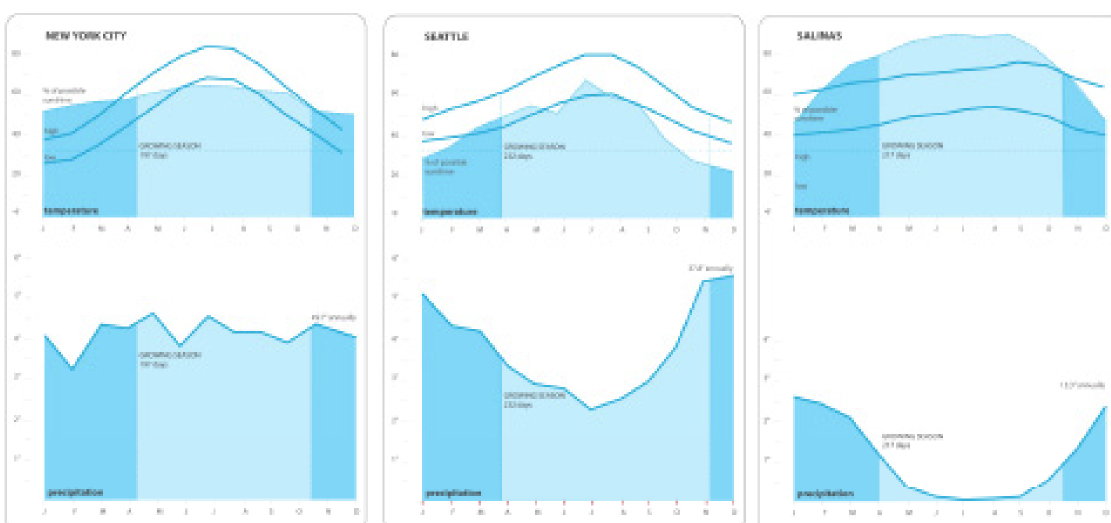


Figure 2: Comparison of Climate Conditions

grants additional environmental benefits. Wastewater contains nitrogen and phosphorus, which can pollute ecosystems when released to lakes and rivers but are nutrients when applied to plant propagation.

## CASE STUDIES

The following case studies in New York City, NY, Seattle, WA and Salinas, CA show how urban and peri-urban agriculture projects re- introduce sustainable use of water into the local food production and, through their practices, contribute to the low impact water management of their respective cities. All three case studies follow the same core idea of using urban water as resource. Depending on the local water challenges, the projects utilize different, currently under developed water sources.

The three case studies have been selected from zones in the United States with different levels of water scarcity, the Northeast, the Pacific Northwest and the West/Southwest (in order of increased water pressure). The zones of different water challenges have been identified depending on their climatic condition and natural water availability in respect to growing seasons and agricultural production. (Figure 1) With a decreasing amount of water naturally available, the measures these projects utilize range from stormwater retention to rainwater harvesting and wastewater reclamation.

## NEW YORK, NY: ROOFTOP FARMING

The Northeast, with cities like New York, Boston, Philadelphia and Providence, is characterized by a temperate climate and ample rainfall all year. (Figure 2) Currently, a sustainable storm and wastewater manage- ment necessary to protect their estuaries and water bodies is one of the largest water challenges to these coastal cities and large urban agglomerations.

A number of rooftop farms have been constructed and started operation over the past three years in New York City. The largest and most ambitious farm project presently is Brooklyn Grange with a 40,000-square-foot growing area. (Figure 3) Located atop the Standard Motor Products Building in Long Island City, the farm sowed its first crop in mid-May of 2010 and plans to grow vegetables nine months of the year. With an estimated 5.5 tons of organic food production per year, the farm creates a new system of providing the local community with access to fresh, seasonal produce. Brooklyn Grange plans to expand quickly in the next few years, covering multiple acres of New York City's unused rooftops with vegetables. Besides environmental benefits, such as stormwater retention, carbon seques- tration, air-quality improvement, and reduction of the urban heat island effect,[34] this business also generates community benefits by allowing urban dwelling customers to know their farmer and the origin of their food.[35]

New York City relies on a combined sewer system, which collects storm water with wastewater and sends them both on to the same treatment plant. Each day, New York City's fourteen wastewater treatment plants handle and process 1.3 billion of gallons of water, and during dry conditions, the system functions well. During heavy rain conditions, the system risks backing up a mix of storm water and raw sewage if the additional runoff is significant enough to double the water flow into the plant. To avoid excess flow backing into homes and streets, all additional flow above the level that the plant can handle is diverted to a combined sewer overflow (CSO) outfall, and the outfall then discharges the untreated water into the harbor. Over 700 CSO outfalls dot the harbor, and are estimated to be used 50 percent of the time rainfall occurs, leading to an estimated 40 billion gallons of untreated waste pouring into the city's waterways.[36] In an effort to reduce the water pollution of the harbor in the future, three underground reservoirs to hold the excess water during rainfall are currently under construction.

Building more extensive infrastructure, like these holding tanks, is a high cost and energy solution, which will need to be upgraded or expanded in the future with urban growth, unless we shift our paradigm for water management. A more sustainable, less infrastructure dependent approach would involve reducing the runoff at its source, by utilizing green infrastructure. Conventional stormwater management techniques, including storage reservoirs, ponds, and constructed wetlands are surface area intensive technologies and difficult to implement in dense urban areas. Green roofs, as for example in the form of rooftop farms, are ideal because they make use of existing roof space and prevent runoff before it leaves the lot.[39] Existing research shows that runoff can be as low as 15 percent for an intensive

Figure 3a: New York City: Eagle Street Farm[37]

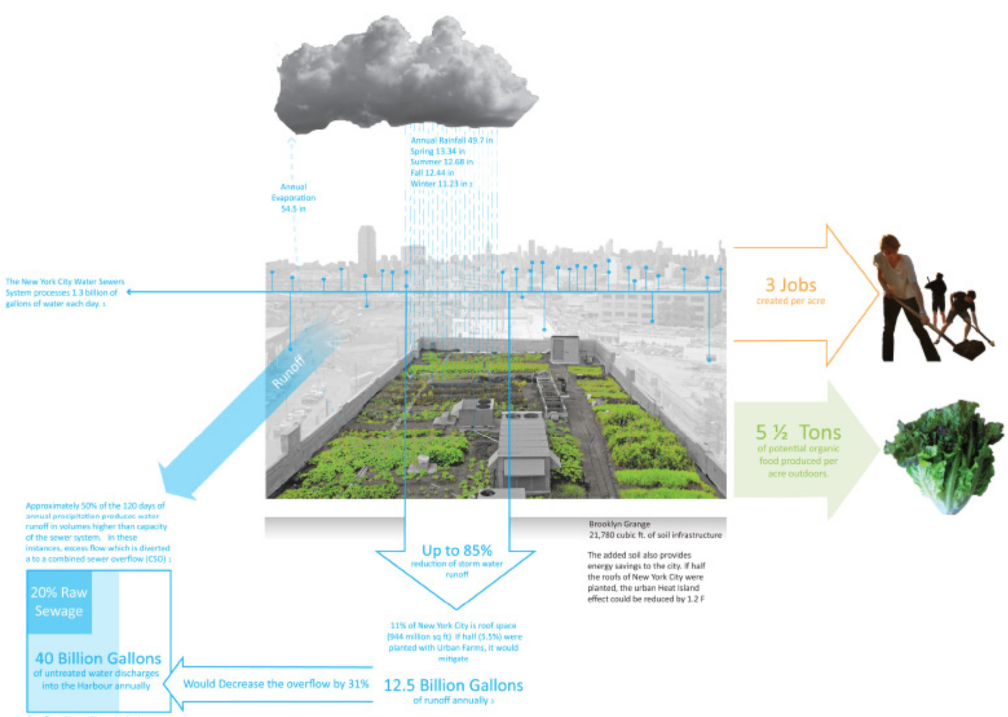


Figure 3b: New York City: Brooklyn Grange Diagram[38]

green roof.[40]

Figure 4a: Seattle: Eco Laboratory[43]

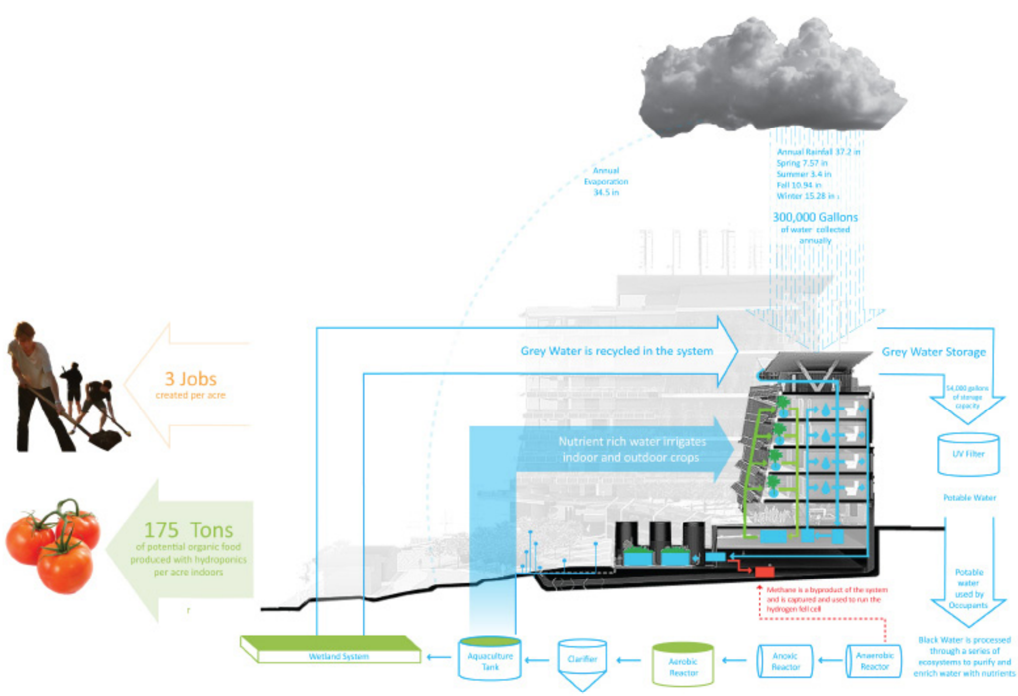


Figure 4b: Seattle: Vertical Farming Diagram[44]

Estimation shows that if half of New York City's roofs would be covered with rooftop farms, 12.5 billion gallons of runoff could be mitigated each year, thereby reducing the frequency of harmful overflow events. In terms of figures, the volume of untreated water currently discharged in the harbor every year during storm events could be reduced by one third. Additionally, an extended implementation of low impact water management strategies, such as other means of runoff reduction and water retention, would make a significant impact on improving of the health of New York City's estuaries, marine life and water cycle.

## SEATTLE, WA: ECO LABORATORY

The weather pattern in the Pacific Northwest is characterized by wet winters and three dry summer months that coincide with the growing season. (Figure 2) Cities such as Seattle and Portland have taken active measures for rainwater harvesting to conserve water resources by generating an ecologically sustainable water supply and to provide additional stormwater management. Policy and planning measures are moving forward to lift barriers to water collection. On October 12, 2009, the Department of Ecology within the State of Washington issued an Interpretive Policy Statement, which clarified that water rights are not required for rooftop rainwater harvesting. The Eco-Laboratory,[41] an award- winning building proposal by Weber Thompson, is a self-sustaining ecological system inter- connected to Seattle's downtown fabric. (Figure 4) Located adjacent to a site, which has been utilized as a community garden for the past thirty years, the Eco-Laboratory expands upon the agricultural amenity: blending building functions into the productive landscape and grafting sustainable food production inside the building. The building programmatically combines agricultural functions with a multilayered approach to residential units, a training facility, a public sustainability educational center and a neighborhood market. The social programs reach out to the surrounding community, educating residents on the concept of urban agriculture, food preparation, farmers' market operations and Eco-Laboratory's specific systems and maintenance, while also providing substantial amount of food to the local homeless population.

Ecological interconnected systems recycle collected water through a closed loop system promoting cyclical use and reuse. Rainwater is collected, purified though a UV filter, initially used as potable water in the building, and recaptured and recycled through grey water fixtures. The resulting black water is then treated through a series of the wastewater treatment systems to purify the water for agricultural use. This nutrient rich water is utilized for growing crops outdoors and within interior hydroponic growing systems. Water is also treated further through wetlands and purified through a UV filter to once again become potable water. Additional resources are also given careful design consideration. Methane, a byproduct of the wastewater treatment system, is captured and used within the hydrogen fuel cell to generate heat and electricity for the building.

## SALINAS, CA: SEA MIST FARMS

Large areas of the West and Southwest fall into an arid climate zone with little available water altogether. The urban agglomerations of Los Angeles, Salt Lake City, Las Vegas, Phoenix and San Diego are part of this region. (Figure 2) Their southern latitude, however, allows an extended growing season, in some parts even all year around that can only be realized with (massive) irrigation. Notwithstanding, California is a highly productive agricultural region, supplying half of fresh fruits and vegetables consumed by Americans[42] as well as 15 percent of the nation's total agricultural export.[45] In recent years California has faced significant water supply challenges due to climate change and growing population. In 2009, California received only 80 percent of its average precipitation and 60 percent of its average snowpack leading to a total statewide runoff estimated to being reduced to around 70 percent of normal.[46] Over the next 20 years, water-use projections suggest demand for municipal and environmental uses to increase to 4.3 million acre-feet annually. As a positive step, policy measures will be put in place, which will reduce the agricultural irrigation demand to 2.3 million acre-feet per year. However the disparity of 2 million acre-feet remains, and municipalities are in search for alternative water resources, with water reclamation and recycling being the most sustainable option.

Located along the Central Coast of California, the Salina Valley faces water issues resulting from a slowly declining water table. (Figure 5) Primarily, the Salinas River replenishes the valley's aquifers and constitutes 49 percent of the annual supply. The remaining aquifer recharge supply is composed of 13 percent subsurface flows entering the valley, 9 percent precipitation infiltration, and 29 percent re- infiltration of pumped extraction. The annual municipal and agricultural overpumping of water exceeds the calculated aquifer recharge supply by 7 percent. This deficit results in a declining water table and depleting aquifer and is offset by seawater infiltration. Ocean water infiltrates the freshwater aquifers through the mouth of the Salinas River and threatens the water supply. Seawater contamination is both a water-quality concern (excessive salinity is damaging to crops) and a water-scarcity issue (as it effectively makes these supplies unusable). Sea-level rise caused by climate change threatens to increase the number of aquifers subject to this intrusion.[47]

In order to slow or prevent seawater intrusion, some municipalities inject recycled water into these aquifers. In the Salinas Valley, however, the Monterey County Water Recycling Projects (MCWRP) have utilized recycled water as a source of irrigation thereby reducing the need for groundwater pumping. Each day, serving a population of 250,000 people, the projects process 21 million gallons of wastewater[49] and deliver the recycled water to the surrounding farms for crop irrigation. As part of the MCWRP, the Castroville Seawater Intrusion Project (CSIP) funnels recycled water through 45 miles of water pipeline to deliver to surrounding farms for crop irrigation. Roughly two-thirds of all water produced by CSIP every year, is used by Sea Mist Farms, an artichoke farm that yields 5.25 tons of potential food production per acre. Recycled water comprises two-thirds of the farm's total water use. Well water is used only in instances where water demand exceeds the supply of recycled water. Active measures are being instigated to further water efficiency in the area. Throughout the year the demand for recycled water fluctuates, whereas urban sewage is collected at a steady pace. In the winter demand is decreased due to increase of precipitation and decrease in growing crops, while during the summer the demand increases. As a consequence, the MCWRA is also planning a groundwater replenishment project, similar to Orange County,

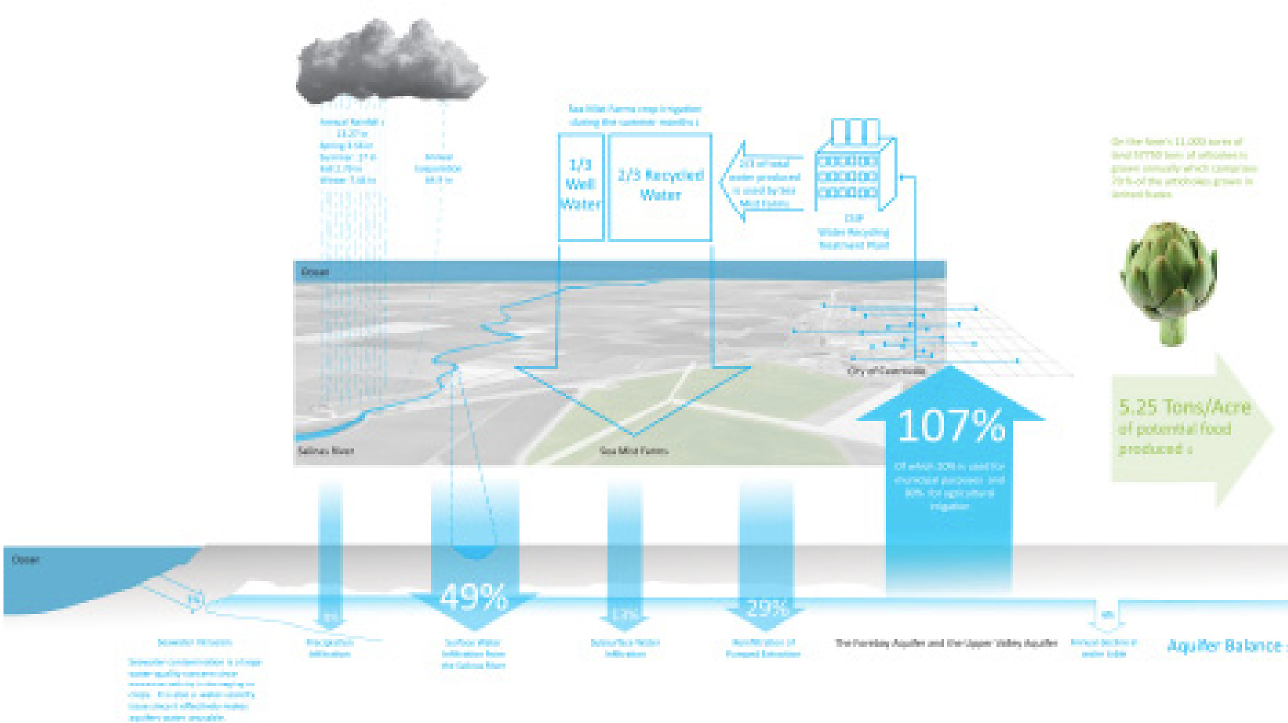


Figure 5: Salinas: Farming with Recycled Water Diagram[48]

that would inject secondarily treated wastewater into the aquifer during the winter season.

The peri-urban farms in the Salinas Valley are good examples for the use of urban water on an expanded scale. Urban wastewater is valuable commodity and necessary asset, which supports their intensive production in a more sustainable way and helps to conserve the precious groundwater resource. They also demonstrate that sustainable water management systems can take hold in large- scale agricultural operations, especially if market and governmental forces make the use of alternative water sources unavoidable.

## CONCLUSION

Through their two-fold agenda of supporting low impact urban water management and demonstrating water efficient, sustainable agricultural methods, these case studies share the powerful ability to reconnect the urban environment to its natural water cycle and turn food production again into a sustainable operation. The supply of the basic human needs of drinking water and food should not be connected with environmentally destructive processes. With many water reserves already overlapping, urban and agricultural water management are interconnected and have to be looked at in context of a global, interdependent water cycle.

The plentiful social and economic benefits of urban agriculture, like local food production, education, job training and employment creation and contribution to social equity and justice, are important and have been discussed elsewhere. The foci of this investigation are the environmental benefits of these projects, especially their contribution to more sustainable urban water approaches, which are often underestimated. Individually, these case studies may only make a small contribution to the improvement of the urban water situation, but if they become the new paradigm for water management in cities, they would have an immense impact. The Sea Mist Farms underscore the impetus for these sustainable operations to grow in order to have also an impact on large scale, industrial agriculture. Besides their primary "tasks" of stormwater mitigation, conservation of water resources, and reclamation of wastewater, respectively, the projects initiate an interconnected series of positive environmental effects and benefits for the water cycle. These benefits include the improvement and protection of water quality, urban water bodies and estuaries, wildlife, reduced exploitation of water sources, reduced pollution of ecosystems, reduced use of (chemical) fertilizers, and the restoration of impaired groundwater sources and aquifers, to name a few. Their main message to the allied fields of architecture and planning is to stop managing and engineering water out of our urban environments, and instead work creatively with this resource to design places and mechanisms through which the powerful self-regulating natural water cycle can re- establish itself.

## ENDNOTES

1 Sandra Postel, "Dividing the Waters," *Technology Review* 100, n. 3 (1997): 57.
2 Udo Rettberg, "Wasser wird zum Spekulationsobjekt." http://www.zeit.de/wirtschaft/2010-08/wasser-rohstoff-investition, (accessed August 11, 2010).
3 Raquel Pinderhughes, *Alternative Urban Futures: Planning for Sustainable Development in Cities Throughout the World* (Lanham: Rowman & Littlefield, 2004), 16.
4 Living Building Challenge 2.0, 19, see: http://ilbi.org/lbc/version-2-0 (accessed August 3, 2010).
5 Godrej Dinyar, "Precious Fluid," *New Internationalist,* (Northampton, England, 2003): 12.
6 The global water consumption tripled from 1480 billion cubic kilometers (km3) in the middle of the 20th Century to 4500 billion km3 today. In the next 20 years it is expected to rise to 6500 billion km3.
7 Postel, 56.
8 Ibid., 59.
9 Sandra Postel, the director and founder of the Global Water Policy Project, has written many books and papers on water conservation issues; for example: Pillar of Sand: Can the Irrigation Miracle Last?, (New York: W.W. Norton & Co., 1999), and "Dividing the Waters." *Technology Review* 100, n. 3 (1997):54-62
10 M. Broadway, "Growing Urban Agriculture in North American Cities: The Example of Milwaukee," *Focus on Geography* 52, n. 3-4 (2009): 23.
11 J. Mentens, D. Raes, and M. Hermy, "Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century?" *Landscape and urban planning* 77, n. 3 (2006):217-26.
12 Bruce Wulkan, Steve Tilley, and Toni Droscher, *Natural approaches to stormwater management: low impact development in Puget Sound*, (Olympia, WA: Puget Sound Action Team, 2003).
13 Pinderhughes, 19.
14 Rettberg
15 Dinyar, 14.
16 Pinderhughes, 22.
17 "Living Building Challenge 2.0," 19, see: http://ilbi.org/lbc/version-2-0 (accessed August 3, 2010)
18 Dinyar, 15.
19 Postel, "Dividing," 61.
20 J. Griffiths and E. Zabey. "Water Facts and

Trends, Version 2," World Business Council for Sustainable Development, 2009.
21 Postel, 59.
22 Sandra Postel, *Pillar of Sand: Can the Irrigation Miracle Last?* (New York: W.W. Norton & Co., 1999).
23 Vandana Shiva, *Water Wars: Privatization, Pollution and Profit,* (Cambridge, MA: South End Press, 2002), 114.
24 Joel Kotkin, "The Fastest-Growing Cities In The U.S.," see: http://www.forbes.com/2010/10/11/cities-innovation-texas-great plains-indianapolis-opinions-columnists-joel-kotkin_2.html (accessed November 1, 2010).
25 Postel, "Dividing," 56.
26 Ibid., 60.
27 Agricultural use: $19 per 1,000 m3 or $19 for 264 172.052 US gallons = $.0719 per 1000 gallons, compared to Municipal use: (in San Francisco) 30.63 per 6,000 gallons = $5.105 per 1000 gallons. The cost of waster for agriculture use equals 1.4 percent of the cost of municipal water.
28 Pinderhughes, 24.
29 Postel, "Dividing," 62.
30 Ibid., 62.
31 Ibid., 61.
32 Ibid., 61.
33 See for example: Growing Power, Milwaukee, WI, http://www.growingpower.org/ (accessed November 18, 2009).
34 Erica Oberndorfer, et al. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services," *BioScience* 57, n. 10 (2007).
35 www.cityfarmer.info/2010/04/29/brooklyn-grange (accessed August 25, 2010).
36 Kate Ascher and Wendy Marech. *The Works: Anatomy of a City,* (New York: Penguin Press, 2005), 174.
37 "Goode Green, Green Roof Design + Installation," http://goodegreennyc.com/images/eagleSt1.jpg.
38 1. Kate Ascher and Wendy Marech, *The Works: Anatomy of a City*, (New York: Penguin Press, 2005); 2. "New York Climate Summary," http://nysc.eas.cornell.edu/newyork_c20.html; 3. Calcuation: (944 million sq ft/2) x 4.14 ft of rainfall/year x 85%.
39 Mentens, et al., 217-26.
40 Ibid., 220.
41 Weber Thompson, "Eco Laboratory," http://www.weberthompson.com/eco-laboratory.html. (accessed November 20, 2009).
42 Heather Cooley, Juliet Christian-Smith, and Peter H. Gleick, "Sustaining California Agriculture in an Uncertain Future," (Pacific Institute, 2009), 17.
43 Weber Thompson, Seattle, http://www.weberthompson.com/cmsimages/eco-ext_m1.jpg.
44 1. "Seattle Climate Data Summary." Western Regional Climate Center, http://www.wrcc.dri.edu/cgi- bin/clilcd.pl?wa24233; 2. "Eco Laboratory." Weber Thompson, http://www.weberthompson.com/eco-laboratory.html.
45 Ibid., 18.
46 Ibid., 22.
47 Brent M. Haddad, " Monterey County Water Recycling Project: Institutional Study," *Journal of Water Resources Planning and Management* 128, n. 4, (2002): 281.
48 Sources: 1. Haddad, " Monterey County Water Recycling Project: Institutional Study." Journal of Water Resources Planning and Management; 2. Christian-Smith, Juliet, Lucy Allen, Michael J. Cohen, Peter Schulte, Courtney Smith, and Peter H. Gleick. "California Farm Water Success Stories." Pacific Institute, 2010; 3. "Salinas Climate Summery." http://www.wrcc.dri.edu/ cgi-bin/cliMAIN.pl?ca7669; 4. Smith, Richard, Aziz Baameur, Mohammad Bari, Michael Cahn, and Deborah Giraud. "Artichoke ProductioninCalifornia."VegerableProductionSeries, (2008).
49 Monterey Regional Water Pollution, "MRWPCA Service Area."
Control Agency, http://www.mrwpca.org/about/svc_area.php. (accessed August 24, 2010).