SII – Sustainability Innovation Inventory

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Networked Hydration Systems (for Farms and Urban Green Spaces)

Image from: http://www.popsci.com/files/image cache/article_image_small/files/articles/sey.jpg)

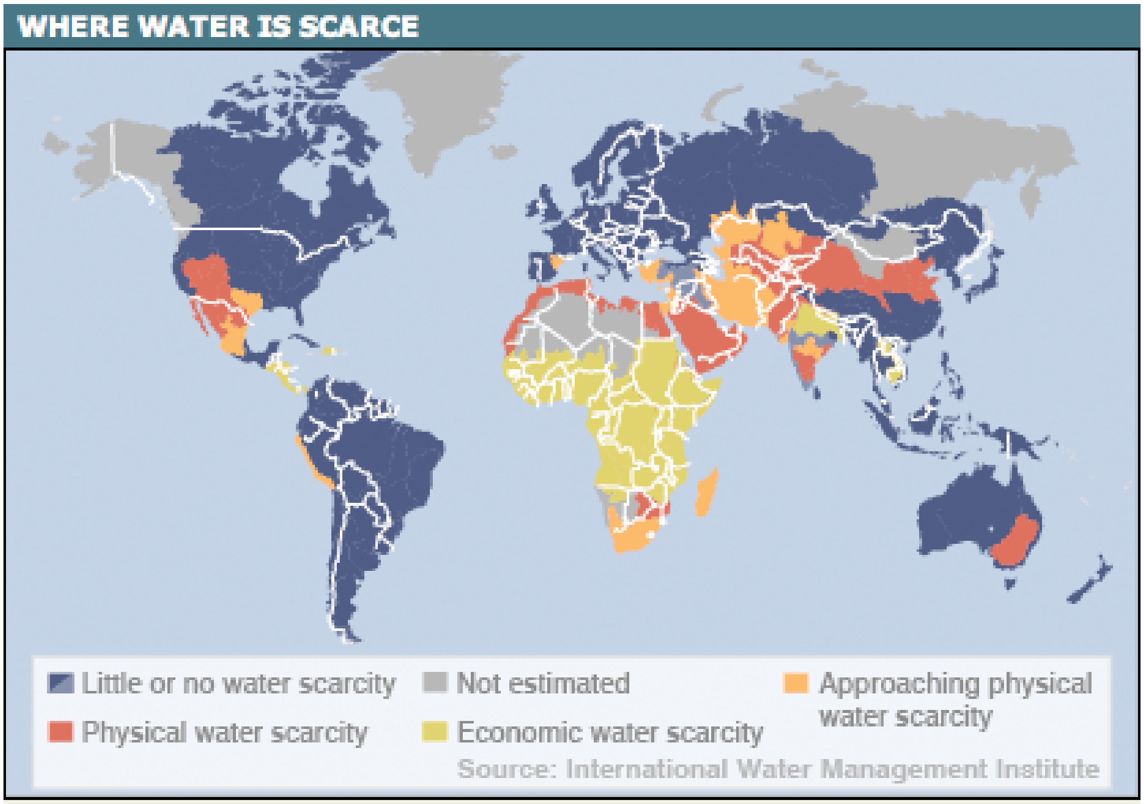
Executive Summary

Research projects supported by the governments of Australia and the United States have been investigating ways to monitor and respond to the water needs of plants remotely and/or automatically. These wireless sensor networks connect hundreds of wireless nodes, which send data collected from moisture, temperature and evaporation sensors on plants to a central server via WiFi or radio transmitters. The central server can then analyze the data, send alerts to farmers or park managers via cell-phone or the Internet, and communicate commands to irrigation pumps when the plants require watering. This technology has positive implications for water conservation, energy reduction, and work efficiency (since irrigation can be managed remotely) and can be applied to city green spaces and residential areas as well as farmland.

Pilot tests of these monitoring networks indicate savings of 1-2 days of watering per week for some plants and millions of dollars of savings per year in water and energy costs.

How is Remote Monitoring of Plants' Water Needs a Sustainability Technology?

Human population growth and increased industrialization are putting major demands on the Earth's water resources. Recent studies of global water distribution and usage show that many parts of the world are already experiencing water shortages, and overall human water consumption is expected to exceed the natural capacity of the Earth's hydrocycle by 2025 (see Figures 1 and 2). Moreover, demand for water is increasingly the cause of inter-state and international conflict (BBC, 2006; UCB News Center, 2007). With these growing constraints on the global water supply, better water management is needed as soon as possible (BBC, 2006; NICTA, 2007).



- **Physical water scarcity:** More than 75% of river flows are allocated to agriculture, industries or domestic purposes (accounting for recycling of return flows). This definition of scarcity - relating water availability to water demand - implies that dry areas are not necessarily water-scarce, eg Mauritania.
- **Approaching physical water scarcity:** More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.
- **Economic water scarcity:** Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists. These areas could benefit by development of additional blue and green water, but human and financial capacity are limiting.
- **Little or no water scarcity:** Abundant water resources relative to use. Less than 25% of water from rivers is withdrawn for human purposes.

Figure 1: Global Water Scarcity Map
(Map from BBC News: http://news.bbc.co.uk/2/hi/science/nature/5269296.stm)

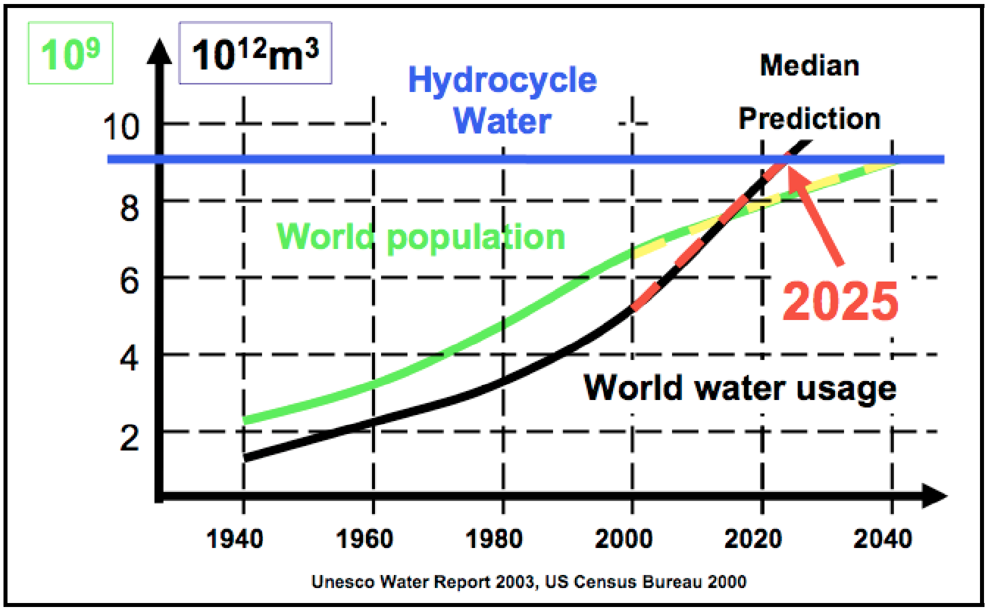


Figure 2: World Water Usage Predictions *(NICTA)*

According to Australia's National Information and Communications Technology Centre (NICTA), standard irrigation methods used around the world have not changed significantly in centuries, if not millennia, and they tend to be very wasteful. By some measures, water efficiency in human applications is below 50% (NICTA, 2007). While many solutions to water management involve expensive new infrastructure or extensive retrofits, wireless water sensor networks can be applied quickly and inexpensively, using existing off-the-shelf sensors and communications technology.

On a global level, improving the efficiency of water use in farming promises to drastically improve water shortages, as agriculture accounts for about 70% of the world's water use (see Figure 3).

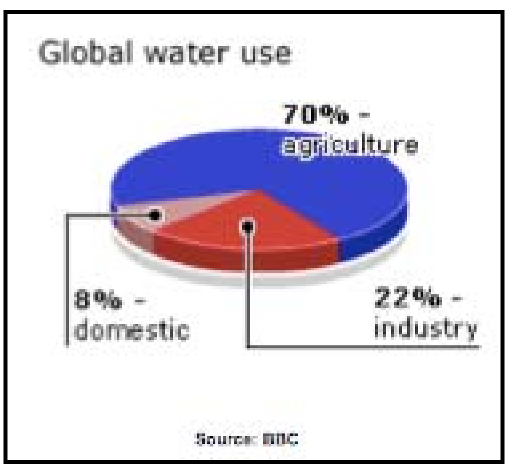


Figure 3: Distribution of Global Water Use *(NICTA)*

However, researchers are designing water sensor networks for a variety of different kinds of plants, including plants commonly found in urban green spaces (UCB News Center, 2007). In the future, this technology could allow urban parks to be monitored and watered remotely from a central office, saving the city water, employee time, and money. It could also help cities maintain difficult-to-reach green spaces, such as green roofs, storm water reclamation projects, and other landscape projects designed to take advantage of plants' natural capabilities but not intended for public use.

Current Technology

Plant monitoring networks use widely dispersed individual sensors, communication nodes, and central servers to collect and analyze information about plants across a large area (see Figure 4). All parts of the network have WiFi or radio transmitters for sending and receiving information. Depending on different system requirements and user preferences, up-to-date information on plant conditions can be accessed from a central control center, over the Internet, or via mobile phone. This system allows users to monitor plant health remotely and send back commands to irrigate different sections of a field or type of plant independently.

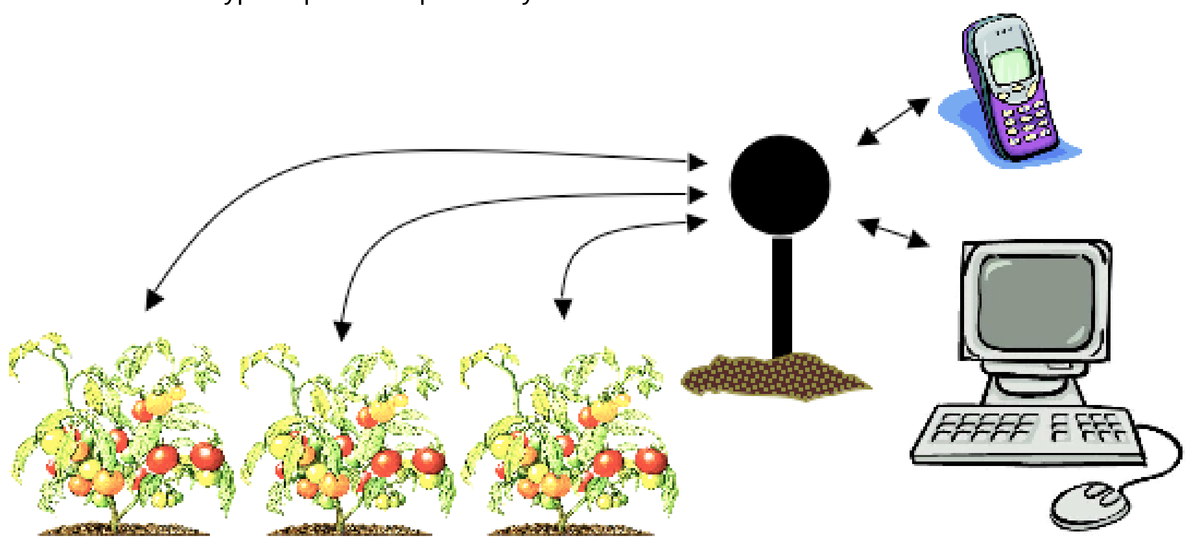


Figure 4: A Basic Plant Monitoring Network Schematic. *Sensors on or near plants send information to a local node, which sends aggregate information and alerts to a central server, which regulates irrigation as needed for different plant varieties and field sections.*

Different research groups have come up with varied solutions for the specific sensors involved in plant monitoring. For example, an integrated-circuit sensor only a few millimeters in length, developed at the University of Colorado at Boulder, is designed to sit on an individual plant leaf and continually measure the leaf's thickness, which provides a good indication of a plant's dehydration and stress levels (UCB News Center, 2007). Alternatively, research done by the U.S.D.A. Agricultural Research Service in Texas developed a non-contact infrared temperature sensor that measures leaf surface temperature compared to ambient temperature every 15 minutes (*Science Daily*, 2008). In a slightly more comprehensive approach, NICTA individual plant monitoring units currently in testing in Australia consist of a bundle of sensors that monitor soil moisture, leaf temperature, and evaporation activity (*New Scientist*, 2006). All sensors use wireless communications technology to relay their temperature and moisture data to a central server.

Figure 5: AgriHouse leaf thickness sensors (left) and Accent Engineering SmartCrop leaf surface temperature sensors (right): *systems of these in-field sensors monitor real-time plant conditions and communicate this data wirelessly to a central server… or a cell-phone! (Leaf sensor photo from Colorado company AgriHouse Inc., based on technology developed at University of Colorado at Boulder; SmartCrop photo from Texas company Accent Engineering, Inc., based on technology developed by the U.S.D.A. Agricultural Research Service)*

Technology and Experience Roadmap

Networked plant hydration sensors help connect water use to information technology in a way that is helpful for managing both work and natural resources. As such, this emerging technology can be productively coordinated with other environmental management initiatives.

Real-Time Water Monitoring

Resource-monitoring initiatives, such as Oberlin College's CRMS, have brought about quantifiable changes in water use in residential buildings simply by providing consumption, cost, and environmental impact information to residents. Connecting urban irrigation information to resource consumption monitoring networks could help cities educate their citizens about resource use in public spaces, and aggregate public water use data could be helpful for large-scale city design or academic sustainability projects. Similarly, personal residential water monitoring systems could help individuals choose different types of landscaping to match different climates and watering needs. Better knowledge about water needs can also help municipalities and individuals design more efficient water recycling or reclamation projects.

Green Roofing: A Promising Example of Urban Remote Plant Management

Green roofs – defined as roof material that consists of a synthetic waterproof material covered partially or completely with a layer of soil or other growing media and a combination of plant species - can help address many urban problems, including reducing the urban heat island effect, providing storm water management, reducing energy demand for heating and cooling buildings, and increasing urban green space without curtailing development. One major drawback to green roofs, however, is that they require more maintenance than traditional roofing materials. For roofs not designed as publicly accessible recreational space, green roof maintenance can be expensive and inconvenient. However, a network of green roof sensors that can communicate conditions and take watering commands remotely – perhaps as one of many managed at a central location – could make green roof technology much more manageable, cost-effective, and attractive to builders. As many of the advantages of green roof technology cannot be achieved through one or two green roof projects, but require a significant fraction of urban buildings to adopt the technology in order to achieve meaningful impact on urban processes, cities may want to consider investing in or offering subsidies for green roof hydration monitoring networks as a public policy project.

Works Cited and Sources for Additional Information:

"Invention May Allow Thirsty Crops to Signal Farmers." *University of Colorado at Boulder News Center.* 14 June 2007. Accessed on 23 July 2008. http://www.colorado.edu/news/releases/2007/244.html

"Map Details Global Water Stress." *BBC News.* 21 August 2006. Accessed on 23 July 2008. http://news.bbc.co.uk/2/hi/science/nature/5269296.stm

O'Shaughnessy, Susan. "Wireless Makes Sense in Agriculture." *The Wetting Front: Soil and Water Management Research Unit News* 9.2 (2007): 1.

"Plants Text Message Farmers When Thirsty." *ScienceDaily.* 5 May 2008. Accessed on 23 July 2008. http://www.sciencedaily.com/releases/2008/05/080502171010.htm

"Water Information Networks." *National ICT Australia.* 31 October 2007. PDF available at: http://nicta.com.au/research/projects/water_information_networks

"Watering Crops in the Wireless Age." *New Scientist.* 25 February 2006. Accessed on 23 July 2008. http://technology.newscientist.com/channel/tech/mg18925406.300-watering-crops-in-the-wireless-age.html

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