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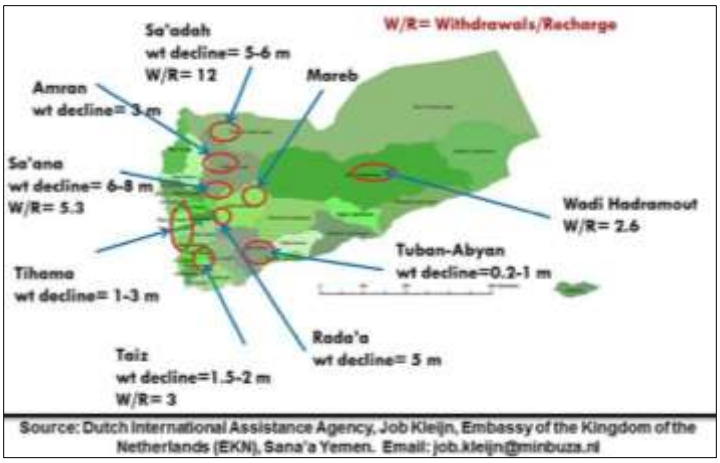
Water Resource Management in Yemen:
Grassroots Democracy and Strengthened Agriculture Value Chains as the Way Forward

"In the midst of chaos, there is also opportunity." Sun Tzu[1]

As one of the most water stressed countries in the world, Yemen faces social and economic disruption of legendary proportions. National per capita access to water, estimated at 115 cubic meters per year, is already one of the lowest in the world yet is projected to drop to 62.5 cubic meters by 2025. A 700 million cubic meter shortfall in annual renewable water resources results in the extraction of groundwater at a rate that far exceeds natural recharge.[2] Recent studies predict the depletion of multiple aquifers including the Sana'a basin by 2040.[3] The loss of ground water for Sana'a, the country's capital, and its two million residents could provoke a population out-migration not seen in Yemen since the collapse of the Ma'rib dam in 575 AD.[4]

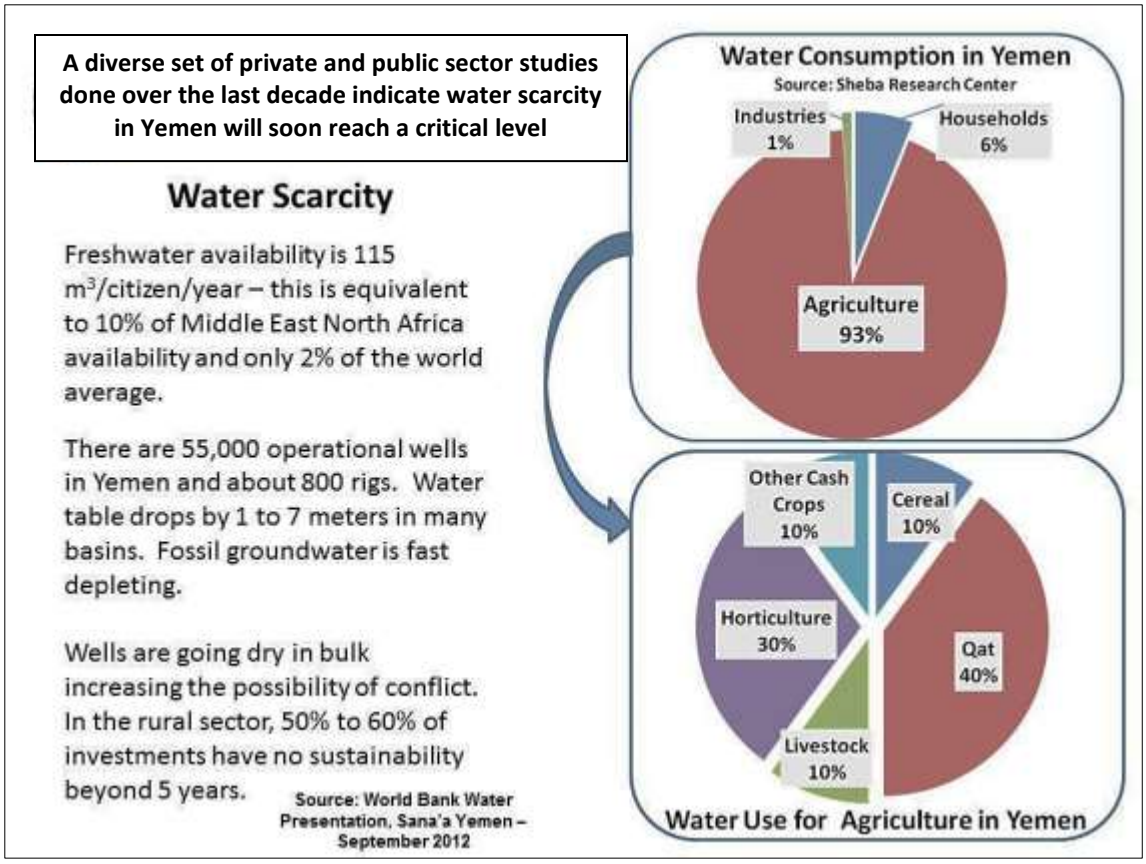


Source: Dutch International Assistance Agency, Job Kleijn, Embassy of the Kingdom of the Netherlands (EKN), Sana'a Yemen. Email: job.kleijn@minbuza.nl

This situation arises out of a classic "tragedy of the commons" issue[5] in which Yemeni citizens have drilled wells and pumped groundwater without regard to sustainability or future impact. As indicated in the illustration at left, withdrawal of water from aquifers far exceeds recharge. While common ownership and management of water resources is a challenge in any country, in Yemen, it is a matter of survival.

[1] The ancient philosophy of Sun Tzu (The Art of War) focuses on potential – on the power of perception translating into reality where weakness is made into strength and many parts into a resilient whole.
[2] Cam McGrath . "YEMEN: Qat Cultivation Draining Water Reserves." (Sana'a - Thursday, May 28, 2009 Inter Press Service. See http://www.globalissues.org/news/2009/05/28/1643
[3] Alazzany, Murad, and Robert Sharp. "Yemen's Water Crisis Demands Concerted Action." Yemen Times. 24 June 2014. Web. 13 Dec. 2014. See http://www.yementimes.com/en/1792/health/4018/Yemen's-water-crisis-demands-concerted-action.html.
[4] The Geology of Yemen: An Annotated Bibliography of Yemen's Geology, Geography and Earth Science. By R. Lee Hadden. Army Geospatial Center January 2012. See http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA559006.
[5] Garrett Hardin's "Tragedy of the Commons" article in the December 13, 1968 edition of Science Magazine provides an understanding of what a social good (like access to water) means and how that common asset can be managed for the benefit of the general public. Hardin explained that individual and absolute freedom to use a common asset results in a negative outcome. Preventing a negative outcome requires action to exclude or limit access to the common good. This excludability, which is the key to sustainability, can be achieved either through private or public ownership along with the potential to create cultural and reciprocity mechanisms that would encourage good stewardship. See http://www.sciencemag.org/content/162/3859/1243.full.

With ninety percent of Yemen's water resources dedicated to agriculture production, the solution to the country's long term water issues will depend on finding ways to communally and more effectively manage those resources. The current chaotic situation adds to the complexity of the problems faced in Yemen and makes the hope of a long term solution ever more difficult to achieve. The final solution will rest with the Yemeni people and a return to a 5,000 year old tradition of local management of renewable water resources.



Water management in Yemen has failed; private ownership, public control, and/or culture and reciprocity mechanisms have been ineffective. Private ownership means digging a well and pumping until the aquifer drops too low and then drilling a deeper well leading to a complete depletion of accessible groundwater. Public control requires a government that has a monopoly on violence, not the case in Yemen, to enforce existing water access and regulation laws. Finally, cultural and reciprocity mechanisms have worked to a degree but depend on the use of tribal violence which generates larger social problems and usually does not control water extraction over a large enough area to prevent depletion of key aquifers.

A key aspect of water conservation lies in finding ways to improve irrigation efficiency and farmer income by conserving water while creating greater value. Agriculture uses over 90 percent of all water resources yet the country has very low irrigation efficiency compounded by equally low agriculture productivity.[6]

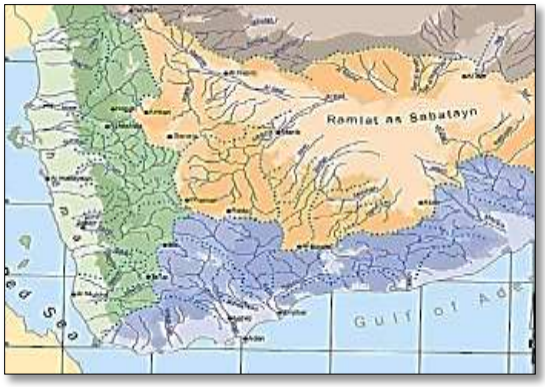
[6] "The Water Crisis in Yemen" Ward, Christopher. Chapter 6 – Water and Agriculture. I.B. Tauris, New York, NY 2015

History of Water Management

For over three thousand years, Yemen has produced and exported high value agriculture products. In Roman times, the chief exports were frankincense and myrrh traded by city states along desert trade routes. Irrigation was practiced as early as the late third millennium BC and in some areas (e.g., Marib) evidence of intensive irrigated agriculture has been found dating from at least 2000 BC. Four city states along the fringe of the desert used water management to produce crops of frankincense and myrrh which was in strong demand for embalming and temple incense in Mesopotamia and the Mediterranean.[7]

Traditional water management in Yemen over its history has depended in large degree to its ability to manage runoff from seasonal rains through elaborate terraces and other water harvesting structures. The efficient management of springs and ground water through shallow wells allowed agriculture to spread beyond the base of wadi runoff areas and resulted in high value production systems of frankincense, myrrh, indigo and coffee. Careful management of very scarce water resources allowed Yemen to survive and thrive over the millennium.

Map of Ancient City States of Yemen - Jona Lendering, http://www.livius.org/pictures/a/maps/map-of-ancient-yemen/



Water Catchment Boundaries - "Water Resources of Yemen" Jac Van der Gunn, 1995

Saba, home of the Queen of Sheba, was the largest and most powerful state established in antiquity. Its capital, Ma'rib, one of the largest cities in Arabia with 4.5 km of defensive walls and an enclosed area of 90 square km, controlled caravan trade as well as produced and exported frankincense. In order to provide water for agriculture production, the Sabeans built the Ma'rib dam to divert seasonal floods from Wadi Adhana onto their fields. According to Pliny the Elder, this hydrological management system allowed them to support frankincense tree groves the entire length of the wadi. The common trait of each of the major city states of Felix Arabia was their proximity to the runoff from wadis that provided annual floods that could be captured to sustain agriculture.[8] The failure of the Ma'rib dam, which had survived 1,200 years and was mentioned in the Holy Qur'an, marked the symbolic decline of Yemen.[9]

[7] Frankincense probably reached the Mediterranean in the 9th century with the advent of camel transport becoming available in South Arabia. By the time of Pliny, the Roman historian, in the first century AD, 1,500 tons of frankincense and 500 tons of myrrh were exported each year to the Roman Empires.

[8] Ward, Christopher, "The Water Crisis in Yemen: Managing Extreme Scarcity in the Middle East" I.B. Tauris, New York, NY 2015

[9] Dresch, Paul, "Tribes, Government and History in Yemen (London: Oxford University Press, 1993)

Traditional Management Systems

The archeological record indicates that irrigation apparently developed in South Arabia out of the necessity to mitigate climate change over 5,000 years ago. Numerous sites indicate a wide variety of traditional water management systems.

Spate Irrigation (Flood Irrigation) – Earth-built systems and temporary dikes (ogma) were built to direct water flow often in succession so that as runoff descended the wadi it could be captured by a series of farmers. Rules were developed to govern the diversion of water and governance systems developed as these systems became more complicated. Water management, in many ways, drove the formation of early civil institutions.

Tanks and Cisterns – Structures exist throughout Yemen in areas adept for capturing rainfall and runoff which allow for water storage. At Aden the 17 Tawila tanks date from the Himyaritic period (100 BC to 500 AD) and were used to provide water for city. Similar cistern systems can be found in many communities in Yemen; they are used for domestic water supply or for livestock. Many are covered and have steps to allow easy access to water.

Springs – Where available, springs provided more reliable flows of water. Rights to the water were part of land ownership although systems were put in place to divide access to water among communities so as to avoid violence. An example of this type of shared access was noted in Wadi Dahr with upper and lower communities receiving 15 days each.[10]

Rainwater Harvesting – Runoff was a key source of water in the high plains and elaborate rights were developed to assign specific slopes to downstream areas. The proportion was determined by the area but the ratio of slope to bottom land could run as high as 20 to 1. Infringement on runoff could cause violence – care had to be taken to avoid a violation of the downstream community rights or else face the consequences.

Terraces – Yemen is renowned for its terrace structures, some of which were built more than 4,000 years ago. Archaeological exploration in the Khawlan area near Dhamar, south of Sana'a, indicate that terraces were constructed as early as the third millennium BC for barley, wheat, legumes and chickpeas production. Terrace construction flourished during Himyaritic period.

Dams – Small dams and retention structures have been built since ancient times in Yemen. Evidence of 100 small dams dating from the Himyaritic period were found near Dhamar. Two types of dams were built (1) high dams to impound seasonal floods and (2) low dams (wiers) built across valley floors to retain water and encourage filtration.

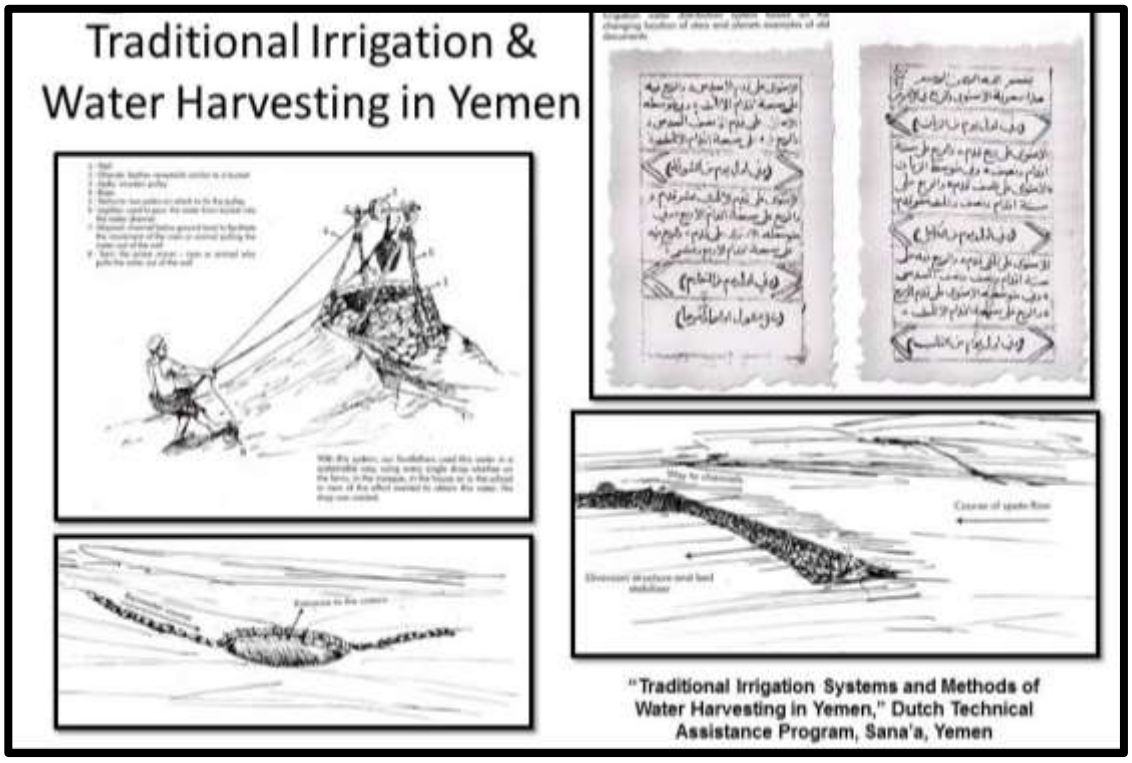
Groundwater – Wells, which until the 1970s were hand dug, are the principal means of extracting groundwater. Introduction of tube wells constructed using modern drilling rigs changed the nature of groundwater extraction making it unsustainable.

Tunnels (Qanat) – Tunnel systems for conveying water from underground springs were used as early as the fifth century BC. These systems known as "qanats" were typically hand dug and extended for long distances. An ancient system in Sana'a tapped the springs located in the Hadda area to the south and above the city. Water was channeled to the "Old City" for domestic use the grey water used for domestic gardens.

[10] Muncy, Martha, "Domestic Government: Kinship, Community and Polity in North Yemen" (London: I.B. Tauris, 1995).

Way Forward

What is the way forward for a country facing these types of water constraints? Yemen's answer lies in her history and her future.



Addressing the tragedy of the commons issue in Yemen should focus on reviving and revitalizing these traditional water management systems. This is critical not only in terms of long-term access to water, but also impacts agriculture development and the incomes of smallholder farmers.

A recent study indicates that the value of agriculture production is directly correlated to maintenance of terraces; the more valuable the crop being grown, the more likely the terraces will be maintained.[11] With sixty percent of the population employed in agriculture, finding ways to promote sustainable water use in these production systems will increase the chance for a more secure Yemen.

Traditionally, mechanisms were in place to capture rainwater, allocate it effectively for agriculture and domestic use, and ensure equity and fairness within watershed areas.[12] These areas were usually controlled by a dominant clan or tribal group and reciprocity rules ensured social order. Within these social structures "water user groups," to various degrees of sophistication, were formed to maintain and manage water resources.

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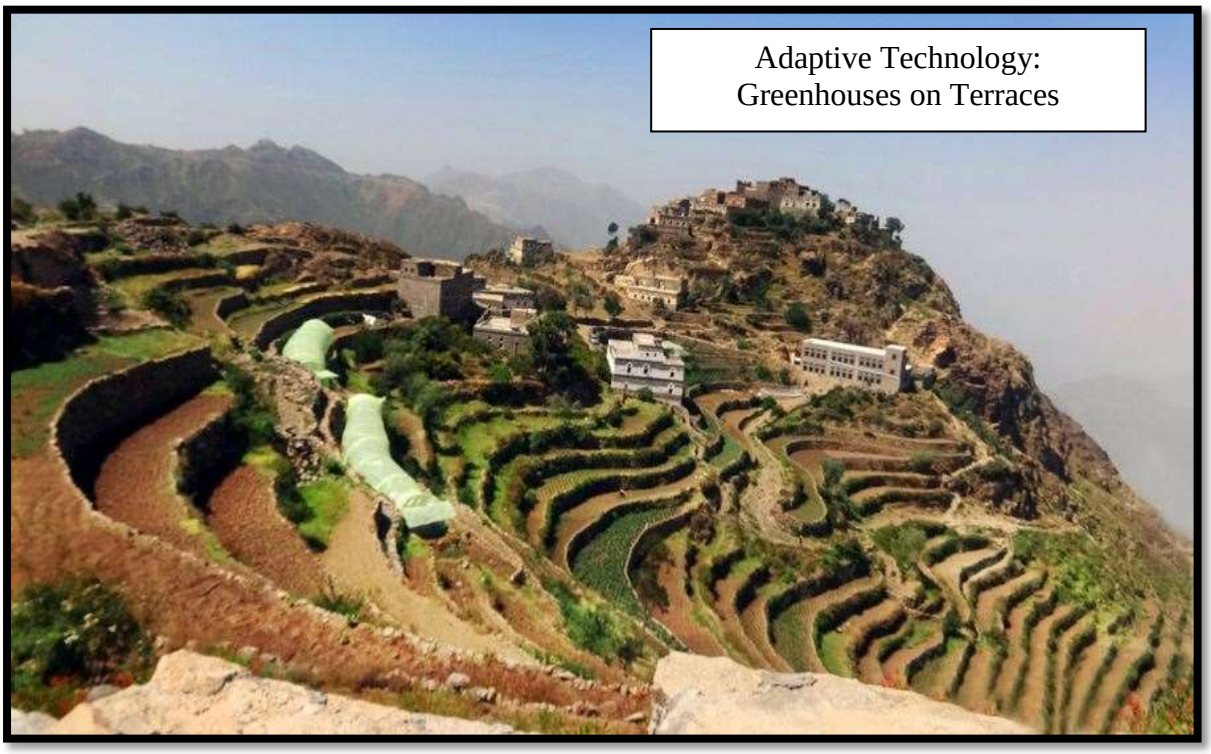
[11] O. Ghanem, A. Jazem, K. Djili. "Causes of Agricultural Terraces Degradation in Al-kimmah Watershed (Yemen)." Australian Journal of Basic and Applied Sciences, 5(12): 136-144, 2011
ISSN 1991-8178.

[12] Guttmann-Bond, Erika. "Sustainability out of the past: How Archaeology Can Save the Planet." World Archaeology Vol. 42(3): 355–366 Archaeology and Contemporary Society. 2010. See http://studystream.org/upload/data/783/Sustainability%20out%20of%20the%20past.pdf.

The long-term solution to Yemen's water problems will be found in helping water user groups return to the rich heritage of traditional water management. By combining these water systems with high value crops and new technology (e.g., drip irrigation, solar power pumps for water transport, greenhouse production, etc.), Yemen can create value and increase the incomes of smallholder farmers. Increased incomes can mean sustainable water use through these traditional systems.

In order to respond to higher value markets, Yemeni farmers will have to find ways to improve both agriculture productivity and irrigation efficiency. Both these areas are also critical objectives in any water strategy for Yemen. Bringing farmers together to focus on high value crops could be a sustainable, market-driven water conservation strategy that builds its strength from a grass roots level up. Through the use of rainwater harvesting, high efficiency drip irrigation systems and solar power pumping to move water and create pressurized systems for drip technology, a significant savings could be realized in water use for agriculture.

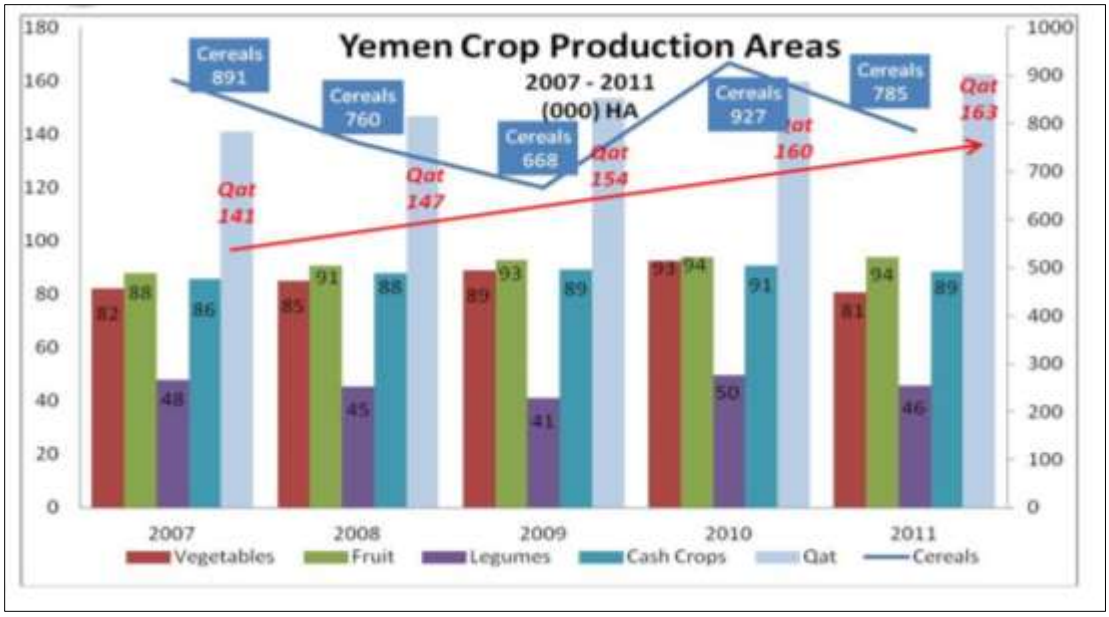
Following through on this strategic approach, USAID Yemen is promoting key value chains aimed at working with Yemeni farmers through a "cluster working group" mechanism to manage water collection and use in combination with specialty coffee, horticulture, livestock and honey production under the Competitive Systems for High Value Crops (CASH) project. This project is based on dramatic results obtained in a predecessor program where, for example, greenhouse horticulture production systems using drip irrigation and solar pumping allowed farmers to achieve six metric tons of cucumber production on 374 m^2 of land with only 32.5 liters of water per kg of cucumber instead of the normal 500 plus liters.[13]



[13] Community Livelihoods Project – Agriculture Program. Dr. Mohammad Ilyas presentation May 2014, Sana'a, Yemen. This compares with traditional practice of open field planting and flood irrigation in which a kg of cucumber production requires 517 liters of water. There is also a higher use of pesticide in open field planting.

If the CASH project, and similar initiatives can demonstrate a doubling of the current estimated irrigation efficiency in Yemen of 25 percent[14] to 50 percent (which is within reason if the solar power, greenhouse production and drip irrigation are used) then we could see a reduction in the current Yemen national water deficit of over 10 percent.[15] As these systems are expanded over time, the amount of water conservation could become significant.

Groundwater irrigation accounts for two-thirds of the value of crop production – with over 50,000 farm wells irrigating more than 400,000 hectares (40 percent of Yemen's cropped areas) – this is a major drain on the country's limited groundwater resources. Water use in Yemen is estimated at 2.8 billion cubic meters versus naturally available water from rainfall of 2.1 billion cubic meters – the difference of 700 million cubic meters of water is made up by groundwater pumping. This depletion of groundwater resources is according to some experts a greater threat to Yemen's long term viability than climate change.



The total irrigated area has doubled since 1970; now, more than two-fifths of agriculture land is irrigated. The cash crop area has increased from 3 per cent in 1970 to 14 percent today and production of high value fruits and vegetables has increased 20 times, from 40,000 metric tons in 1970 to 800,000 tons today. A major crop is qat which makes up roughly 30 percent of planted area but consumes some 70 percent of groundwater extracted.[16]

[14] Defining "irrigation efficiency" as the ratio between water withdrawn and water beneficially used by the plant, overall efficiency in irrigation in Yemen is according to a 2006 World Bank study to be approximately 25 - 30 percent making it one of the least efficient systems in the world. Average irrigation efficiency for developing countries is 38 percent and for the Middle East and North Africa 40 percent.

[15] Increase irrigation efficiency from approximately 30 percent to at least 60 percent on cash crops resulting in a 10 percent reduction in groundwater requirements. 700 million cubic meters of groundwater is extracted to make up the shortfall in water needs in Yemen. Assuming 10 percent is for domestic use (70,000 cubic meters) and 70 percent is for qat (490,000 cubic meters) – that would leave 140,000 cubic meters for production of cash crops. A 50% increase in irrigation efficiency would decrease the overall amount of groundwater extraction by 10 percent.

[16] Mcleod, H. and Vidal, J.. 2010. Yemen threatens to chew itself to death over thirst for narcotic qat plant. Guardian

Recommendations

1. Under an agriculture value chain strengthening program, promote high value crops that can economically justify more efficient irrigation systems and have the potential of competing with qat;

2. Develop and demonstrate water saving technologies (greenhouse production, drip irrigation, solar power for pumping and pressure) – support financing mechanisms and market solutions to the constraints on adoption of water efficient technology;

3. Establish or work with existing farmer/water user groups to demonstrate profitability and potential of high value crops – build on work previously done under USAID and World Bank (and Other Donor) programs to support local management of water resources.

4. Continue work to strengthen forecasting capacity for climate change, groundwater availability and water scarcity issues writ large in Yemen building on the existing FewsNet activities.

The goal would be to promote cash crops that are competitive with qat by promoting more efficient irrigation systems and improve husbandry for higher productivity. Over time, there could be a move toward proven cash crops. Key to this approach will be the development of domestic and export markets that pay premium prices for the target commodities.

Pilot Program

The grass roots democratic approach represented by these groups will ensure its success and sustainability as citizens come together to address a common problem and protect a common good. Yemen can become a living example of how people, working collectively in small groups, can manage a critical resource and, in turn, create a better future. This approach is being proven in the Haraaz area among the Ismaili Community and their production of high quality Arabica coffee.

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