Program update: October 2003 to March 2008

IWMI International Water Management Institute

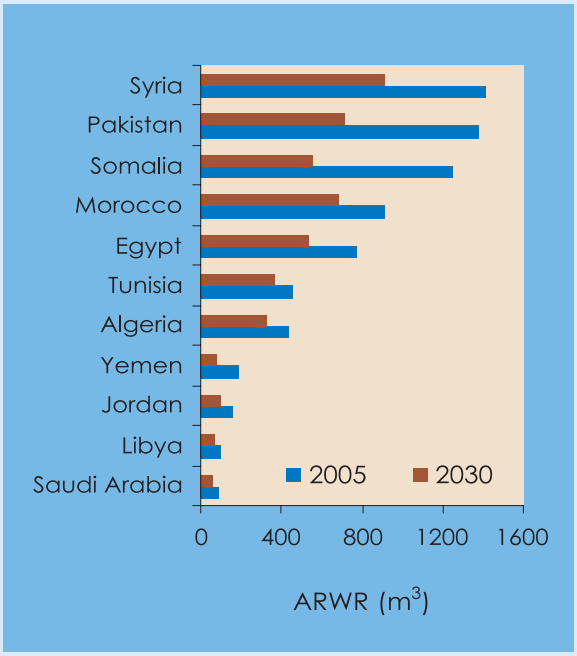
ICARDA

ICARDA-IWMI Joint Program

Marginal-quality Water Resources and Salt-affected Soils

Background

The natural global water cycle yields an annual renewable water supply of about 7000 m^3 per capita, suggesting perhaps that there is enough freshwater available every year to fulfill the world's current needs. However, in certain regions and countries the annual renewable supply of water is less than 500 m^3 per capita. In addition, the availability of water varies greatly over time in these areas, with periodic extreme water shortages. What this contrast illustrates is that freshwater resources and population densities are unevenly distributed worldwide. Considering the current demographic trends and future growth projections, as much as 60% of the global population may suffer water scarcity by 2025.



Annual renewable water resources (ARWR) per capita in some countries of West Asia and North Africa, in years 2005 and 2030 (projected)

In addition to water scarcity, water quality deterioration is expected to intensify in resource-poor countries in the dry areas, due to human activity and the increasing possibility of extreme events as a result of climate change. Saline water intrusion is projected to intensify due to sea level rise in coastal zones as well as salt-induced soil degradation and water quality deterioration in arid and semi-arid regions due to mismanaged irrigation practices. Households and industries will generate increasing volumes of wastewater as more people move to the cities. In addition, increased frequency of severe rainstorms will increase the amount of chemicals that run off from farms as well as urban areas. These predictions suggest the availability of greater volumes of marginal-quality water in the future, for possible multidimensional uses such as crop production, agroforestry, and aquaculture.

There are two broad categories of marginal-quality water: wastewater generated by the domestic, commercial, and industrial sectors; and saline water from agricultural drainage systems, surface runoff, or pumped from overexploited aquifers. Millions of small-scale farmers around the world irrigate with marginal-quality water, often because they have no alternative.

Wastewater generated by domestic and industrial activities contains a variety of constituents at levels higher than those usually found in freshwater, including salts, metals, metalloids, residual drugs, organic compounds, endocrine disrupter compounds, active residues of personal care products, and pathogens. Irrigation with

Wastewater is used to grow a variety of crops and vegetables

Wastewater irrigation in peri-urban Cairo, Egypt

Salt-induced land degradation is a major impediment to sustainable crop production in arid and semi-arid regions

untreated, partly treated, and/or diluted wastewater creates multidimensional impacts, including environmental and health risks. The impacts are particularly complex when untreated domestic and industrial wastewaters are found in the same irrigation system. Most farmers and some government agencies in many developing countries are not fully aware of these impacts — but the consequences could be severe, unless wastewater is carefully managed.

With increasing use of saline water for agriculture, salinity and sodicity will also increase. Soil, irrigation, and crop management practices will need to be modified to cope with these increases. More than 20% of the world's irrigated land is already salt-affected; with a significant part belonging to poor smallholder farmers, who rely on that land to satisfy their food and feed needs. With population growth and increased demand for food, feed, fiber, and energy, larger areas of salt-affected soils will need to be cropped in the future. These soils are a valuable resource that cannot be neglected, especially in areas where significant investments have already been made in irrigation infrastructure.

Addressing the following questions (with all the associated challenges and opportunities) will help guide investment and management decisions on land and water use in agriculture.

- What is the extent of marginal-quality water resources and salt-affected soils and what are the environmental, health, and socioeconomic implications of their use in agriculture?

- How best can we use marginal-quality water resources and salt-affected soils to improve food security and environmental quality in the near to medium term?

Considering these aspects, ICARDA and IWMI developed a joint program to address the assessment as well as economically and environmentally sustainable management of marginal-quality water resources and salt-affected soils. The program was initiated in October 2003 with the joint recruitment of a Marginal-Water Management Scientist*. Activities of the program range from global to region-specific projects and other initiatives.

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Joint Projects and Research Activities

Salinity Bright Spot Project in Central Asia (2005-2008)

Socioeconomic development in Central Asia has historically been dependent on water and land resources. A significant proportion of the population is dependent on irrigated agriculture. In 1960, the area of irrigated land in the Aral Sea Basin — Amu-Darya and Syr-Darya Basins — in Central Asia was 5.2 million hectares. Further development of irrigation led to the conversion of virgin lands into agricultural lands, resulting in significant increases in employment opportunities and income generation. With approximately 9.5 million hectares under irrigation, Central Asia is currently one of most heavily irrigated regions in the world.

The positive effects of irrigation development are not without negative environmental implications. Excessive irrigation, caused by either lack of information on actual crop water requirements or a recognized need to apply leaching water, has resulted in rising groundwater levels and accumulation of a variety of undesirable salts. Inadequate drainage has compounded the situation. Currently, nearly half of the irrigated land in Central Asia has salt-affected and waterlogged soils. Salt-induced land degradation and water quality deterioration are major impediments to optimal utilization of crop production systems.

Considering the challenges of land degradation and water quality deterioration in Central Asia, IWMI, ICARDA, and the International Center for Biosaline Agriculture (ICBA) are working together to develop community-based interventions to reverse resource degradation in a sustainable manner, while maintaining or enhancing food security and income generation. Funded by the Asian Development Bank, the project is implemented in partnership with the farming communities and researchers from three Central Asian countries (Uzbekistan, Turkmenistan, and Kazakhstan).

Evaluation of certain tree species in regulating groundwater level as an alternative option in areas where drainage systems are non-existent, non-functional because of poor maintenance, or expensive to install and operate

Project activities include identifying innovative local farming practices that enhance productivity on salt-affected

Extent of salt-affected and waterlogged soils (million hectares) under irrigated agriculture in Amu-Darya and Syr-Darya River Basins, 1990 to 2000

Soil degradation type	Amu-Darya Basin		Syr-Darya Basin	
	1990	2000	1990	2000
Waterlogged soils	1.29	1.57 (22)*	0.55	0.90 (64)
Salt-affected soils	1.16	1.82 (57)	0.34	0.61 (79)
Sum of both soils	2.45	3.39 (38)	0.89	1.51 (70)

* Figures in parentheses indicate percentage increase in salt-affected or waterlogged area in 2000, compared to 1990

Patchy germination and growth of cotton on a high-magnesium soil in Kazakhstan

Improved germination and growth of cotton on a high-magnesium soil through the application of phosphogypsum in Kazakhstan

lands, selecting salt-tolerant crop and forage species, and developing a range of technologies for the efficient use of salt-affected soil and saline water resources. The project-led interventions have resulted in measurable increases in the productivity of high-magnesium soils through the application of phosphogypsum. This intervention has already been out-scaled over 100 hectares in Kazakhstan. Project partners are working with policy makers to scale out this technology to a much larger area.

Researchers and farmers work together to develop community-based interventions for the productive use of salt-affected soil and water resources in Central Asia

Sustainable Water Use for Securing Food Production in the Mediterranean Region (2008-2012)

Multiple abiotic stresses and deteriorating water quality have major impacts on agricultural productivity in dry areas of the Mediterranean region. Abiotic stresses, such as drought and salinity, and marginal-quality waters are becoming even more pronounced with changing climate (drier conditions, higher temperatures) and desertification. There is a need to select, introduce, and test cereals, grain legumes and new crops and cultivars with improved abiotic stress tolerance. Similarly, it is imperative to assess the environmental impact of using marginal-quality water resources in agriculture, and to develop environmentally feasible interventions aiming at the efficient use of these resources.

ICARDA and IWMI have joined hands on a multi-partner project proposal on climate-proof crops and safe use of marginal-quality water resources in dry areas of the Mediterranean region. The project proposal has been approved by the European Commission Seventh Framework Programme on research and technological development. The expected outcomes of the project include: improved

productivity and sustainable use of water and land for agriculture, more diverse farming systems, stronger economic development in Mediterranean countries, and accelerated adoption of improved agricultural technologies to meet future constraints imposed by the changing climate.

Participants of the project proposal development workshop (7-8 February 2007, Marrakech, Morocco) where all the partner institutions discussed different elements of the FP7-KBBE-2007-1 proposal

The joint work of ICARDA and IWMI in the project will address environmental impact assessment by evaluating the effects of using marginal-quality water (saline water and wastewater) on salt balance, nutrient availability status, metal ion concentration in irrigated soils, water quality, and crop yield and quality. In addition, selected genotypes of grain legumes (chickpea, lentil, and faba bean) will be tested for tolerance to two abiotic stresses, salinity and drought.

Led by the University of Copenhagen, Denmark, the 4-year project will be initiated in July 2008. Other partners include: Universidade Nova de Lisboa, Portugal; Institute for Agricultural and Forest Mediterranean Systems, Napoli, Italy; Centre for Ecology and Hydrology, Wallingford, UK; Centre for Environment and Development for the Arab Region and Europe, Cairo, Egypt; Institut Agronomique et Veterinaire Hassan II, Rabat, Morocco; Cukurova University, Adana, Turkey; and Institute of Agriculture, University of Western Australia, Crawley, Australia.

Crop-Livestock Systems in Salt-affected Areas of West and Central Asia (2007-2008)

Salt-induced soil degradation is prevalent in arid and semi-arid regions. The extent of the problem has increased steadily over the last few decades in several river basins in South and Central Asia, with substantial economic losses and environmental implications. For example, the annual economic losses due to salinization are estimated to be US$ 230 million in the Indus Basin in Pakistan; US$ 210 million in the Syrian part of the Euphrates Basin; and US$ 2 billion in the Aral Sea Basin in Central Asia. Crop-livestock production systems are an integral part of livelihoods for poor rural communities in salt-affected areas of these basins; but high-quality livestock feed is in short supply due to lack of high-quality grazing lands, and lack of efforts in exploiting marginal-quality soil and water resources to narrow the gap between feed supply and demand.

There is a need to develop biophysical interventions and promote institutional and policy options for sustainable and integrated use of salt-affected soil and saline water resources for feed and forage crops in order to improve food security, alleviate poverty and enhance ecosystem health in smallholder crop-livestock systems in South and Central Asia. This can be achieved by improving the productivity of the crop-livestock systems per unit of saline water and/or salt-affected soil resources, fortifying feed, enhancing the adoption of innovative strategies, and income generation for resource-poor farmers while reversing salt-induced soil degradation and water quality deterioration and enhancing environmental goods and services.

Participants of the project proposal development workshop (24-26 May 2007, Tashkent, Uzbekistan) where all the partner institutions discussed different elements of the SLP-CGIAR proposal

In partnership with national research institutions from three countries of West and Central Asia (Pakistan, Uzbekistan, and Syria), ICARDA and IWMI are working together to synthesize and analyze the existing information on crop-livestock interactions in salt-affected areas of the Indus, Euphrates, and Aral Sea Basins. Other major partners are the International Centre for Underutilised Crops; University of California, Riverside, USA; and Justus Liebig University, Giessen, Germany. Based on a workshop involving all the partner institutions and extensive discussions, a project proposal is being developed using a seed grant provided by the CGIAR Systemwide Livestock Programme (SLP).

Production, Use, and Implications of Wastewater Irrigation in Syria (2004-2005)

In Syria, about 69,000 hectares are irrigated with treated, partly treated, or untreated wastewater. The area under wastewater irrigation is small (less than 5% of the county's irrigated area), but economically important. In partnership with Syrian national institutions, ICARDA and IWMI aim to maximize the safe use of wastewater and minimize threats to the environment and human health. During 2005 nearly one-third of Syria's wastewater was treated before being used for irrigation or discharged into rivers or the sea. The construction of wastewater treatment plants completed in 2007 and 2008 will increase the amount of treated wastewater by 10%.

The joint study assessed the production, treatment, and use of wastewater in Aleppo region. Aleppo, the second largest city in Syria (population 2.4 million), is located within the Euphrates-Aleppo Basin in the northeastern part of the country. For centuries, the city's water requirements were met from the small Qweik River, which originates in Turkey. Continuous extraction of water within the Turkish part of the river has rendered the the Syrian part almost dry. The flow rate of the river before entering Aleppo is less than 1 m^3 per second. Formerly a source of freshwater, the Qweik River is now a carrier of wastewater generated from Aleppo.

Once a source of freshwater, the Qweik River carries wastewater generated by urban and peri-urban areas of Aleppo

Farmers with lands near the river practice wastewater irrigation as and when needed. The study found three main reasons why farmers prefer wastewater irrigation. The most important reason (given by 57% of farmers) was the year-round availability

of wastewater. The second most important reason (26% of farmers) was the high nutrient content of wastewater, which reduces or even eliminates the need for expensive chemical fertilizers. The third reason (17%) was that pumping wastewater costs less than pumping groundwater.

Wastewater irrigation in Aleppo region, Syria

The Syrian Standardization Commission Code of Practice (2003) prohibits wastewater irrigation of vegetables that are eaten raw. Wheat is the major crop, occupying more than half of the wastewater irrigated area. A comparative benefit-cost survey in the Aleppo region showed that the return on wheat irrigated with wastewater is double the return on wheat irrigated with groundwater. For each US dollar invested in wheat irrigated with wastewater the return is US$ 5.31. Wheat irrigated with groundwater returns US$ 2.34 for each dollar invested. Wheat irrigated with wastewater gives higher yields because of the wastewater's high nutrient content. Farmers also save on the costs of fertilizer (US$ 95 per ha) and pumping.

The study found a critical shortage of Syrian staff trained to monitor and analyze solid and liquid wastes. Few staff have the technical skills to operate, maintain, and monitor industrial wastewater treatment plants. Staff in government institutions need help in installing and running new treatment plants and in applying options for use of treated wastewater. Building skills is particularly important because responsibilities for treatment, disposal, and reuse of wastewater span institutional boundaries. Along with capacity building, research leading to new technologies for using wastewater could help maximize the benefits to communities and minimize adverse environmental impacts.

Water Productivity Project in Karkheh River Basin in Iran (2004-2008)

The Karkheh River is an important water resource in Iran, for both dryland and irrigated agriculture. Water availability in the Karkheh River Basin is limited and becoming scarcer as population and demand increase. Irrigation management is inadequate, cropping systems are sub-optimal, and policies and institutions are weak. The basin reflects in many aspects the problems of water management in other basins in the region, such as the Euphrates and Amu-Darya River Basins, which are characterized by widespread salinization of land and water resources.

Over-irrigation is a major cause of soil salinization in the Lower Karkheh River Basin

An important component of the project is community-based management of salt-affected land and saline water resources to improve crop productivity and farmers' income. Interventions include the evaluation of salt-tolerant crop varieties, and agricultural use of saline water and soil resources in the Lower Karkheh Basin. Funds are provided by the CGIAR Challenge Program on Water and Food.

Researchers at one of the study sites in the Lower Karkheh River Basin

Other Projects and Activities

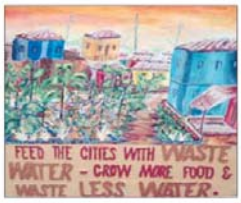
Other IWMI and ICARDA activities where technical input has been provided under this joint program include

- Use of Wastewater as a Source of Supplemental Irrigation to Improve the Productivity of Rainfed Wheat in Algeria: Algeria-ICARDA project, funded by the International Development Research Centre (IDRC)
- Soil and Water Project in Central Asia: ICARDA project in all Central Asian countries and Azerbaijan, funded by the Asian Development Bank
- Water Benchmark Project in West Asia and North Africa: ICARDA Project co-financed by International Fund for Agricultural Development (IFAD), Arab Fund for Economic and Social Development (AFESD), and OPEC Fund for International Development (OFID)
- Soil Degradation and Water Quality Deterioration in Central Asia: joint IWMI-ICARDA initiative supported by both centers
- Extent, Characterization, and Implications of Salt-affected Land Resources in Iran: IWMI initiative supported by IWMI-Iran.

Participation in Global Initiatives

Comprehensive Assessment of Water Management in Agriculture

The Comprehensive Assessment of Water Management in Agriculture critically evaluates the benefits, costs, and impacts of the past 50 years of water development, the water management challenges communities are facing today, and solutions people have developed. The results will enable better investment and management decisions in water and agriculture in the near future and over the next 50 years. The assessment is produced by a broad partnership of practitioners, researchers and policy makers.



Feed the cities
Artist: Titilope Shittu, Nigeria

11 Agricultural use of marginal-quality water—opportunities and challenges

Coordinating lead author: Manzoor Qadir

Lead authors: Dennis Wichelns, Liqa Raschid-Sally, Paramjit Singh Minhas, Pay Drechsel, Akiça Bahri, and Peter McCornick

Contributing authors: Blanca Jimenez, Juan Antonio Sagardoy, Samia El-Guindy, Safwat Abdel-Dayem, Jeroen H. J. Ensink, Jacob W. Kijne, J. D. Oster, Wim van der Hoek, Sasha Koo-Oshima, Fatma Attia, Lekan Oyebande, and Robert Abaidoo

Overview

Millions of small-scale farmers around the world irrigate with marginal-quality water, often because they have no alternative. There are two major types of marginal-quality water: wastewater from urban and peri-urban areas, and saline and sodic agricultural drainage water and groundwater. Around cities in developing countries, farmers use wastewater from residential, commercial, and industrial sources, sometimes diluted but often without treatment. Sometimes farmers in deltaic areas and tailend sections of large-scale irrigation schemes irrigate with a blend of canal water, saline drainage water, and wastewater. Still others irrigate with saline or sodic groundwater, either exclusively or in conjunction with higher quality surface water. Many of those farmers cannot control the volume or quality of water they receive.

Wastewater often contains a variety of pollutants: salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds, and active residues of personal care products. Any of these components can harm human health and the environment. Farmers can suffer harmful health effects from contact with wastewater, while consumers are at risk from eating fruits and vegetables irrigated with wastewater. Application of wastewater has to be carefully managed for effective use.

In contrast to wastewater, saline and sodic water contains salts that can impair plant growth but rarely contains metals or pathogens. However, it can lead to soil salinization and waterlogging, which impair productivity on millions of hectares of agricultural land. Irrigating successfully with saline or sodic water requires careful management to prevent near-term reductions in crop yield and long-term reductions in productivity.

The Comprehensive Assessment synthesis book *Water for Food, Water for Life* was published in 2007. An important chapter in the book, entitled Agricultural Use of Marginal-quality Water — Opportunities and Challenges, discusses issues relating to categorization, implications, response options, and policy and institutional aspects of marginal-quality water resources. The chapter was written by a team of 19 authors (Coordinating Lead Author: Manzoor Qadir).

International Assessment of Agricultural Science and Technology for Development (IAASTD)

Within the framework of a global assessment and five sub-global assessments, the IAASTD addresses the fundamental questions of reducing hunger and poverty; improving rural livelihoods; and facilitating equitable, environmentally, socially and economically sustainable development through the generation of, access to, and use of agricultural knowledge, science and technology. One of the sub-global assessments covers the Central and West Asia and North Africa (CWANA) region. Chapter 2 of the IAASTD-CWANA assessment Historical and Current Perspectives of Agricultural Knowledge, Science and Technology was developed by a team of 15 authors (Lead Author: Manzoor Qadir).

Capacity Building

Bridging Workshop Series

First Workshop: Sustainable Management of Marginal-quality Water Resources in Water Scarce Countries

IWMI and ICARDA have launched a "Bridging Workshop Series" to bridge the knowledge gap between advanced research institutions and young professionals from national agricultural research institutions in developing countries. These workshops will guide the young researchers towards the state-of-the-art in multi-disciplinary and cutting-edge research, applying an open-space and open-mind environment where participants are mentored by experienced scientists, and encouraged to interact and ask all those questions they could never ask in a conventional workshop. This initiative will involve lead international scientists and young scientists in the exchange of information and experience relating to different aspects of marginal-quality water resources. Each workshop is expected to culminate in the development of workshop proceedings and joint initiatives for future collaboration in research and capacity development.

Participants of the first Bridging Workshop (11-15 November 2007, Aleppo, Syria)

With a focus on the safe use of wastewater in agriculture, the first Bridging Workshop was organized during 11-15 November 2007 at ICARDA's headquarters in Aleppo, Syria. The opening session outlined the particular character of the Bridging Workshops. This was followed by three further sessions:

- Stimulating presentations by lead scientists/resource persons on predefined topics, highlighting the challenges and opportunities, followed by about one hour of discussions.
- Country presentations by young researchers actively involved in research relating to the stimulating presentations
- Final session on summarizing research challenges and gaps as identified in the previous sessions

The stimulating presentation sessions covered the following topics: .

- The reversed water chain approach: optimizing agricultural use of urban wastewater
- Low-cost decentralized water treatment and the way forward
- Moving towards a more holistic approach to research on wastewater and greywater use: Where are we at?
- What can be done in cases where wastewater treatment does not work?
- Linking sanitation and agricultural sectors for more effective resource recovery through multi-stakeholder platforms and learning alliances
- Social, economic and livelihood impacts of wastewater use in agriculture
- WHO guidelines, the basis for their revision, and future perspectives

The workshop was funded by the International Development Research Centre, Canada, and Wageningen University, the Netherlands. Over 25 scientists and technologists from 13 countries participated. Four young researchers won awards for best papers presented at the workshop. The next Bridging Workshop will be held during the final quarter of 2009.

Post-doctoral Fellow

Dr Ahmed El-Hawary: Drainage Research Institute (DRI), Delta Barrage, Cairo, Egypt; funded by the Mediterranean Network on Wastewater Reclamation and Reuse (MED-REUNET)

Research Topic: Simulating the effects of different practices of irrigation using marginal-quality water (1 October 2004 to 30 November 2004)

Ph.D. Students

Tulkun Yuldashev: Central Asian Research Institute for Irrigation (SANIIRI), Tashkent, Uzbekistan; funded by SANIIRI and Salinity Bright Spot Project in Central Asia

Research Topic: Tree plantations as a biological ameliorant for the degraded lands in Hungry steppe in Uzbekistan (2005 to present)

Amir Hussain: Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan; funded by the University of Agriculture, Faisalabad, Pakistan and ICARDA

Research Topic: Accumulation and partitioning of cadmium, zinc and copper by cereal and legume crops under city effluent irrigation (2006 to present)

M.S. Student

Tichatonga Gonah: Wageningen University, the Netherlands; funded by Wageningen University

Research Topic: The use of marginal-quality water in agriculture and its impact on the environment: Opportunities for improving its use in the Jabbul area in Syria (2006-2007)

Individual Non-degree Training

Saif Ullah: Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan; funded by ICARDA

Research Topic: Management of marginal-quality water resources (10-24 November 2007)

Training Courses Organized

Training Workshop and Expert Consultation on the Evaluation of Technologies Addressing Salt-prone Land and Water Resources in Central Asia (9-12 April 2006, Tashkent, Uzbekistan); ICARDA-IWMI Joint Course funded by the Salinity Bright Spot Project in Central Asia

Training Course on the Procedures and Tools for Salinity Related Data Processing and Statistical Analysis (26-30 March 2007, Tashkent, Uzbekistan); ICARDA-IWMI-ICBA Joint Course funded by the Salinity Bright Spot Project in Central Asia

Participation in other training courses:

- Training Course on Water Management for Improved Water Use Efficiency in the Dry Areas (co-sponsored by the Japanese International Cooperation Agency and ICARDA), organized annually in May-June for researchers from developing countries

- Training Course on Biosaline Agriculture: Principles and Applications (sponsored by the International Center for Biosaline Agriculture), organized for researchers from Central Asia and the Caucasus (2-10 September 2004, Tashkent, Uzbekistan)

Publications and Presentations

Peer Reviewed Publications

Journal Articles

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Ghafoor, A., M. Qadir, M. Sadiq, G. Murtaza, and M.S. Brar. 2004. Lead, copper, zinc and iron concentrations in soils and vegetables irrigated with city effluent on urban agricultural lands. Journal of the Indian Society of Soil Science 52:114-117.

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Ryan, J., S. Masri, and M. Qadir. 2006. Nutrient monitoring of sewage water irrigation: Impacts for soil quality and crop nutrition. Communications in Soil Science and Plant Analysis 37: 2513-2521. *ISI Journal*

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Vyshpolsky, F., M. Qadir, A. Karimov, K. Mukhamedjanov, U. Bekbaev, R. Paroda, A. Aw-Hassan and F. Karajeh. 2008. Enhancing the productivity of high-magnesium soil and water resources through the application of phosphogypsum in Central Asia. Land Degradation & Development 19: 45-56. *ISI Journal*

Qureshi, A.S., P.G. McCornick, M. Qadir, and Z. Aslam. 2008. Managing salinity and waterlogging in the Indus Basin of Pakistan. Agricultural Water Management 95: 1-10. *ISI Journal*

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Qadir, M., A.S. Qureshi, and S.A.M. Cheraghi. 2008. Extent and characterization of salt-affected soils in Iran and strategies for their amelioration and management. Land Degradation & Development (in press) *ISI Journal*

Karimov, A., M. Qadir, A. Noble, F. Vyshpolsky, and K. Anzelm. 2008. The development of magnesium-dominant soils under irrigated agriculture in southern Kazakhstan. Pedosphere (accepted for publication) *ISI Journal*

Qadir, M., A. Tubeileh, J. Akhtar, A. Larbi, P.S. Minhas, and M.A. Khan. 2008. Productivity enhancement of salt-affected environments through crop diversification. Land Degradation & Development (in press) *ISI Journal*

Book and Book Chapters

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