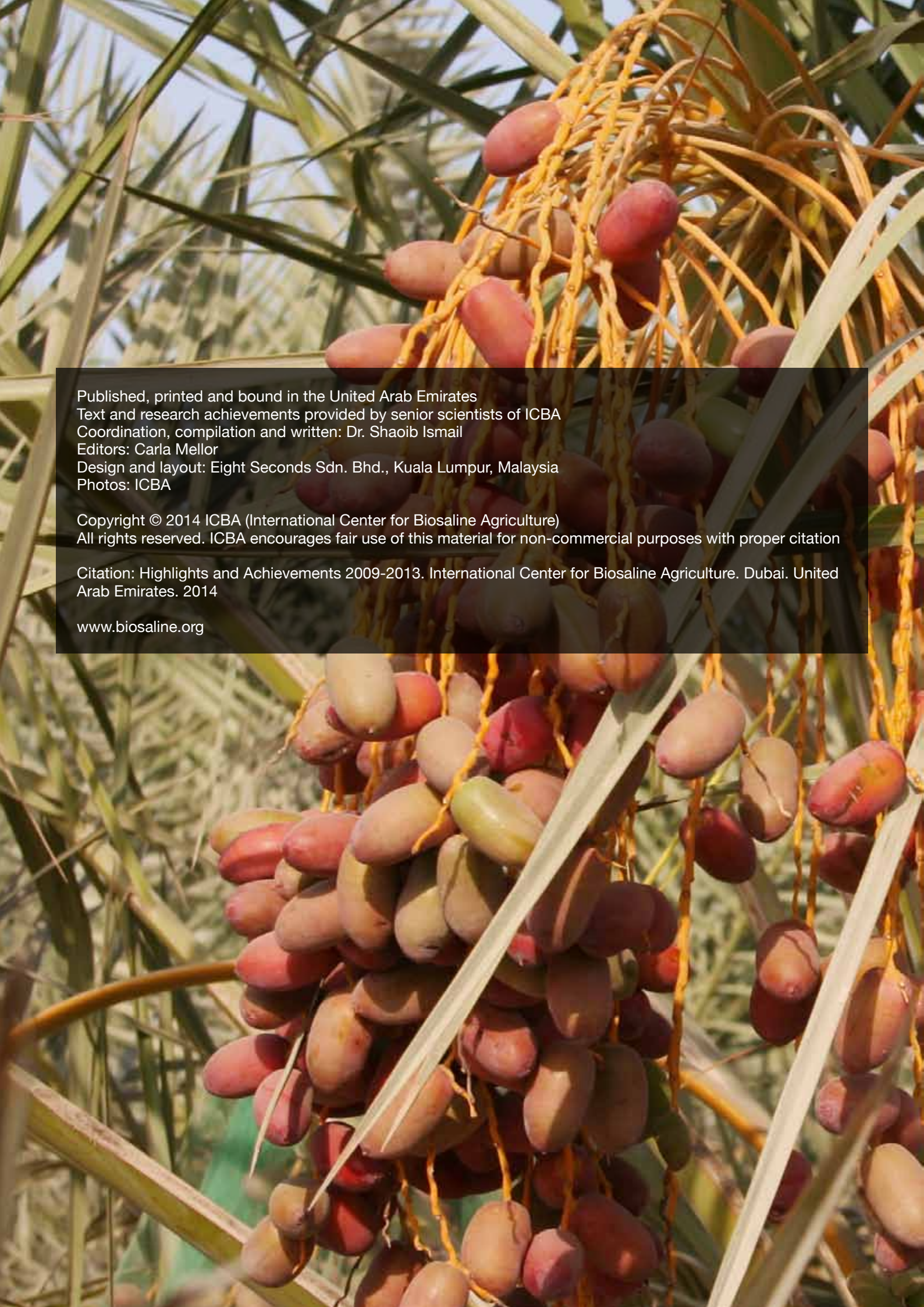
ICBA Programs Highlights and Achievements

2009-2013

تزرع للغد

ICBA

AGRICULTURE FOR TOMORROW



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Executive Summary

ICBA – The International Center for Biosaline Agriculture is a non-profit, autonomous international agricultural research center with headquarters in Dubai, UAE. ICBA conducts research and development programs that aim to improve agricultural productivity and sustainability in marginal environments. ICBA's multi-pronged approach to strengthening the agricultural sector through expanding food production through improved and better access to technology, improved germplasm, policies, strategies and programs, is critical to achieve greater water, environment, income and food security. During its second strategic phase (2007-2011), ICBA moved from its initial focus on salinity management to increased emphasis on water management issues related to agriculture, including marginal water quality. In 2013, the Center developed a new strategic direction addressing the closely linked challenges of income, water, nutrition, and food security. The new Strategy 2013-2023 takes innovation as a core principle and has identified five innovations that form the core research agenda: assessment of natural resources; climate change adaptation; crop productivity and diversification; aquaculture and bio-energy, and policy analysis.

This report is a summary of ICBA's achievements for the period 2009-2013. The highlights and achievements during this period have been summarized under the following thematic areas:

Thematic Area of Research	Highlights
Climate change downscaling and adaptation to climate change	Development of a modeling and remote sensing hub through the MAWRED (Modeling and Monitoring Agriculture and Water REsources Development) program to develop new data and insight on water resources and agricultural water use, at both regional- and country-scale for the Middle East North Africa (MENA) region. Diversification of crop and livestock production to adapt to climate change in the MENA region through improvement of forage yield under saline conditions (focus on pearl millet and sorghum). Evaluation of the efficiency of soil micro-organisms (rhizobia and mychorrhiza) to improve establishment and growth of plants.
Alternative crops for marginalized environments	ICBA's research has found several salt- and heat-tolerant alternative crops such as quinoa, mustard, sesbania, safflower and triticale with good adaptation for marginal environments. Identification of alternative forages such as livestock feed with sea water; optimizing management practices for halophytic forages, agroforestry systems for improving farm income and productivity, production of dates and its quality under saline water irrigation, bio-energy crops on saline wastelands; potential of producing *Salicornia* as biofuel with sea water.
Innovation in irrigation technologies for water conversation and improving water efficiency	Technologies that could improve on-farm water efficiency e.g. a moisture and salinity sensor system (SCADA), the first AFG system and small scale irrigation in sub-Saharan Africa. Safe use of treated waste water for forage and fruit production and to artificially recharge aquifers.
Soil mapping for land use planning	Management of the Soil Survey of Abu Dhabi Emirate and Northern Emirate utilizing GIS, satellite image processing and the Abu Dhabi Soil Information System (ADSIS) to produce state-of-the-art soil information. Proposal to undertake national soil mapping to ensure that land use in Mauritania is sustainable through the provision of soil related information for decision makers, and to promote the knowledge of soils in Mauritania.

During the last five years, ICBA has been involved in preparing **strategies and vision documents** for countries, regional and international stakeholders. These include the following:

- United Arab Emirates Water Conservation Strategy
- A strategy for Sustainable Agriculture in the United Arab Emirates
- Ensuring safe disposal of brine from reverse osmosis desalination plants
- Standards for brine disposal in the United Arab Emirates
- Capturing, re-cycling and re-using water
- Legal and regulatory framework of Abu Dhabi Emirate water law
- Reclaimed Wastewater Strategy for Abu Dhabi Emirate
- Water Master Plan for Abu Dhabi Emirate
- Establishment of Abu Dhabi Water Council
- A national salinity strategy for Oman
- A water vision for the Organization of Islamic Cooperation
- Contribution to the World Bank study on Adaptation to a Changing Climate in the Arab countries

ICBA provides a number of **services and consultancies** to its stakeholders. The Central Analytical Laboratory (CAL) has provided soil, water and plant analytical services to ICBA in-house projects and to external clients including Environment Agency - Abu Dhabi, Masdar Institute, GRM International, University of Sharjah, UAE University Al Ain, GreenGood Eco-Tech. During the last five years CAL has analyzed over 5000 soil, water and plant samples.

The ICBA soil museum is a unique collection of soil and rock samples from the UAE and provides information to youth, university students, researchers, professionals, land use planners and policy makers dealing with agriculture, desertification, environmental protection, ecological restoration and biological diversity conservation.

ICBA provided field survey services to Environment Agency - Abu Dhabi in the selection of a potential site to establish the Abu Dhabi gene bank and botanical garden.

During 2009-2013 ICBA organized 30 **capacity building and training** course, with 602 trainees receiving formal training and a further 230 participating in other capacity building events such as farmer field days. In addition, an international conference in 2010 on “Soil Classification and Reclamation of Degraded Lands in Arid Environment” was held in Abu Dhabi (ICSC2010). The ICSC2010 was attended by over 250 scientists from over 35 countries.

The importance of ICBA’s scientific research findings on date palms was recognized during the prestigious Khalifa Date Palm **Awards**. ICBA was one of the eight winners chosen out of 131 regional and international participants with its research on the Potential of Arbuscular Mycorrhizal Technology for Date Palms which was awarded second place in the first category of Distinguished Research and Studies.

ICBA was engaged in many local, regional and international projects during the years 2009-2013. **Partnership Agreements** include 25 Project Agreements (PA) and 33 Memorandum of Understanding (MoU) and Memorandum of Agreement (MoA).

ICBA has cultivated a range of **partners** over the past five years. ICBA has worked with 15 different donor agencies over this time. In addition, it collaborated with 58 agencies, including different Ministries, national centers of different countries regional organizations, CGIAR centers and International R&D organizations.

During the years 2009-2013, ICBA’s scientists contributed to 165 **publications** including peer reviewed journals, conference proceedings, books chapters and other publications.

Climate change downscaling and adaptation to climate change

The problem of lack of freshwater is exacerbated by climate change, whether it is dry areas becoming drier or other changing weather patterns such as temperature, humidity, and wind; all of which directly affect crop water use. Adapting to long-term climate change requires many different policy and technology approaches including climate change modeling and adaptation to climate change through diversification of crop and livestock production and improving natural resource management.

A knowledge hub for agricultural water use and management

ICBA has initiated new research dimension in addressing climate change and adaptation issues by establishing a modeling and remote sensing hub (Modeling and Monitoring Agriculture and Water Resources Development-MAWRED), to develop new data and insight on water resources and agricultural water use, at both the regional- and country-scale, for MENA decision-makers. In coordination with NASA's Goddard Space Flight Center (GSFC), and with funding from USAID, the program has developed regional and country-scale monitoring and modeling of groundwater, soil moisture and surface resources, as well as land cover and irrigation water use. This program harnesses cutting edge space-based earth observations and land surface modeling to bring new insight to water and agriculture resource assessment in the region.

Up-to-date information on water use in different sectors and the likely effects of changes in climate on water resources and agriculture are essential in managing water for sustainable development. To provide governments with comprehensive information ICBA and partners are collecting and processing data and new information from geographic information systems (GIS), remote sensing and modeling to model future scenarios and perform risk analyses. Governments can use the scenarios and analyses to assess opportunities and constraints imposed by regional climate conditions on sustainable development and food security.

In the MENA region, irrigation is a very important variable in the water cycle because of low annual rainfall. Simulating the irrigation process is therefore a key component that is included in the MENA modeling work, but does not currently exist in NASA's Land Information Systems (LIS) software. Work has begun to adapt an existing irrigation model for use in LIS; it includes simulating the practices used in the region (when, how and how much we irrigate). The team has developed a combined irrigation intensity map for the entire MENA region so as to locate the areas of irrigation.

Crop modeling received a new focus in 2013. ICBA has led the development of estimates of crop yield under certain climatic, management and plant physiological conditions. When combined with other data from climate, crop maps and water availability, the crop modeling informs decision-makers on local production yields under wide-ranging conditions. This work directly supports food security planning as well as strategic climate change adaptation ideas.

A modified crop type map of the Tunisian footprint has been produced using images from the new Landsat mission, Landsat LDCM. Data collected from the field in addition to local knowledge have been used at training sites to distinguish between the different main crop types. Seven main classes were studied: forests, olive trees, oat, cereals, orchards, citrus trees, and vineyards. Work also progressed to further develop crop modeling for cereals in Tunisia.

Similar efforts to develop models of irrigation and crops are underway in Iraq, and in mid-2013 ICBA hosted a mission from Iraq's Ministry of Water Resources. The meeting discussed the future of the program and highlighted the areas in mapping and modeling of water/agriculture and climate change that Iraq most needs.

Diversifying crop and livestock production to adapt to climate change in Middle East and North Africa

Another effort made by ICBA in dealing with climate change is diversifying crop and livestock production to adapt to climate change in the MENA. The aim is to improve forage yield in harsh environments where the salinity of irrigation water is constantly increasing. Crop options provide less expensive, more sustainable solutions for enhancing the crop-livestock productivity of salinity-affected lands. The project is funded by IFAD, AFSED and ICBA and undertaken in collaboration with the national agricultural research systems (NARS) of Jordan, Oman, Egypt, Palestine, Syria, Tunisia and United Arab Emirates. The partnership is equipping farmers with the knowledge and skills to become more efficient in farmer-based seed production technologies and delivery systems for wide-scale cultivar adoption and efficient forage production. Focus has been on pearl millet and sorghum which are considered two main fodder crops in the MENA region that have the potential role to fill the gaps in farm productivity and in a crop livestock system.

Other salt-tolerant crops evaluated have been barley, buffel grass, canola, triticale, mustard, sesbania, quinoa and guar. The project has worked with progressive farmers to enhance their capacity in efficient on-farm seed production and delivery systems of selected stress-tolerant forages, also to help them benefit from more efficient packages of forage production and use.

Many farmers in marginal environments have difficulties finding varieties adapted to their particular farming conditions and getting hold of seed. To address this issues and widen the range of crops available to farmers, ICBA and partners tested several varieties of pearl millet and sorghum under different management practices on 50 field stations and 80 farms in six

Pearl millet and sorghum trials

countries - Jordan, Egypt, Oman, Syria, Tunisia and Yemen in West Asia and North Africa (WANA). Trials involved 400 farmers across 40 marginal environments. The project outputs included: assessment of salinity and drought tolerance in a set of 377 varieties from 22 crops and selection of 32 high performing varieties among 6 species; production of c.a. 10 tons of grain from 148 farms to meet seed requirements; adjustment of the key crop management system components in the irrigation agro-systems using saline and waste water, and 15 capacity building events for farmers and extension services. Farm incomes from pearl millet plots under best management practices were 43–62% higher than from traditional management and for sorghum, 33–48% more. Farmers have also been trained to produce seed as farmer-managed seed production is low-cost and has long-term benefits. To meet demand from farmers for seed, pure seed of the most widely adapted pearl millet and sorghum were supplied to the NARS for multiplying. NARS have organized 21 field days, training courses and workshops involving more than 670 farmers. To provide governments with comprehensive information, ICBA and partners are collecting and processing data and new information from geographic information systems (GIS), remote sensing and modeling to model future scenarios and perform risk analyses.

Improving natural rangelands management in Uzbekistan

In Uzbekistan work has been started in improving natural rangelands vulnerable to climate change. The foothill rangelands near the Papanaya settlement, Nurata district, have areas with high biodiversity, are threatened by desertification spreading from the Kyzylkum desert. Without adaptation measures these natural habitats will be lost due to land degradation exacerbated by climate change. ICBA's collaboration with NARS and international centers (ICRISAT and ICARDA) aims to mitigate the spread of the desert into the areas with high biodiversity by establishing forage production on degraded lands.

In many parts of Uzbekistan arable lands are in serious decline due to mono-cropping of cotton and wheat. Use of intensive surface irrigation is causing soil erosion, loss of organic matter, salinization and water logging, all of which greatly reduce the sustainability of agriculture and undermine the long-term security and income of poor rural communities.

Promising research is underway to increase the agro-biodiversity on low productive lands with uncertain levels of water and increasing soil salinity. The strategy has been to identify salt-loving (halophytic) plant varieties and salt-tolerant dual-purpose crops such as sorghum and pearl millet; these could replace traditional crops (e.g. cotton, wheat, corn, rice) or augment them where land is marginal. ICBA, together with partners, are assessing the best way to integrate these non-conventional varieties as food crops or livestock feed in local farming production systems.

The teams have screened more than 52 improved lines of pearl millet through on-station and farmer-participatory trials under different field management practices. They have identified a number of salt/drought tolerant varieties productive for food, grain and forage production. When grown near watering points in the vicinity of livestock herds of around 2,000 animals on a 10-hectare area, these cultivars can double their daily ration from 2.0 to 4.0 kg per animal during the severe winter months. The trials also identified promising dual-purpose varieties that produce grain for human food and feed for poultry or livestock. In addition, the varieties tested proved better than the local varieties and have also been used for local breeding programs to produce high yielding new varieties which are now produced commercially.

Improving nitrogen and farm productivity through salt-tolerant rhizobia

Inoculums of the soil bacteria rhizobia are an easy and inexpensive way to enhance soil nitrogen and agricultural productivity. But the tolerance of rhizobia to environmental stress varies and also its symbiotic effect related to the host plants. The naturally occurring soil rhizobia in root nodules of cowpea and Sesbania in the United Arab Emirates are, however, adapted to salinity and heat. ICBA scientists used sequencing technologies to isolate *Sinorhizobium meliloti* and *S. kostiense*, and three other species reported for the first time in the Arabian Peninsula, *S. terangae* and *S. arboris*. As these particular rhizobia are tolerant to high salinity and temperatures they can be very valuable as inoculums to improve the productivity of leguminous crops grown in other regions with similar conditions. The work on agroforestry systems with *Acacia ampliceps* and its association with two salt-tolerant forage species, *Sporobolus arabicus* and *Paspalum vaginatum*, have shown that native salt tolerant rhizobia are well adapted to heat and salinity abiotic stresses and are able to fix atmospheric nitrogen and sustain productivity of the two grasses.

Management of salt-affected soils and water for sustainable agriculture

Management of salt-affected soils and water for sustainable agriculture was the desired outcome of a partnership with the Sultan Qaboos University, which concluded in 2009. The three-year project was implemented by a number of organizations in salt-affected farms at the Ministry of Agriculture Agricultural Research Station in Rumais and in private farms in Oman. The extent and intensity of salinity was assessed by using remotely sensed satellite images, ground truthing and the preparation of GIS (geographic information system) maps. Solutions included agronomic (e.g. sowing methods), nutritional (including microbial nitrogen mineralization in saline conditions), engineering and water management (e.g. irrigation), and biological (identification of salt-tolerant crops and fruit trees for various salt-affected regions in Oman). The effects of feeding salt-tolerant forage crops to sheep were also assessed.

ICBA along with SQU in Oman completed (2009-2012) feasibility of managed aquifer recharge (MAR) using excess treated wastewater. The broader objective of this study was to conduct a socio-economic and technical feasibility of MAR schemes in Oman especially in the Muscat areas. The feasibility included:

1. Monitoring to ensure that the treated wastewater produced at the different plants including the Oman Wastewater Services Company's (OWSC) sewage treatment plants (STPs) meets quality constraints of recharge water.
2. Evaluation of the hydrogeology in the vicinity of OWSC's STPs and determine their aquifer potential.
3. Evaluation of recharge techniques available and identify suitable methods for recharge and recovery.

Quinoa yield trial

Crops for marginalized environments

Agricultural food production needs to increase between 50 and 70 % by 2050 to match the projected population growth. Because new agricultural land will be scarce, increasing food production will require increased productivity. However, abiotic stresses such as water scarcity, temperature extremes and salinity, and increasing marginality of production systems are emerging as the major constraints to enhance productivity at the farm level, resulting in food and nutrition security challenges too many arid and semi-arid regions. In the major agricultural areas, uncontrolled extraction has depleted the groundwater reserves. It has also caused seawater intrusion in places where the water table was below sea level. Moreover, in several countries, priority for scarce freshwater resources is going to the growing urban areas leaving agriculture to use low-quality brackish and salty water with adverse effects on agricultural productivity as most of the commonly cultivated crops are salt-sensitive. In this scenario, diversification of production systems based on salt-tolerant alternative crops is seen as an important strategy to sustain agricultural productivity and economic growth at the farm level. ICBA has a strong body of work conducted between 2009 and 2012 to find sustainable solutions for agricultural production in marginal environments, especially those characterized by deterioration in the quality of the soils and water resources.

Alternative crops for marginal environments
ICBA's research has found several salt- and heat-tolerant alternative crops such as quinoa, mustard, sesbania, safflower and triticale with good adaptation for marginal environments. These alternative crops, in addition to their tolerance to salinity and heat-stress, require less water to grow and have a wide range of uses such as food, feed and industrial, which make them promising candidates for the diversification of production systems and economic use of marginal quality soil and water resources.

Quinoa: Quinoa is a facultative halophyte and can grow successfully in poor soils (including pure sand) and in environments with annual rainfall as little as 200 mm. In recent years, quinoa has been receiving worldwide attention as a multi-purpose agro-industrial crop that can thrive in extreme soil and climatic conditions. Studies conducted by ICBA have indeed showed quinoa's potential as an alternative crop for marginal environments characterized with poor soils and low quality irrigation water. Thus grain yields of up to 533 g/m^2 were obtained at the ICBA Research Station Dubai (ECiw 2-3 dS/m), and up to 970 g/m^2 in on-farm trials in salt-affected areas (ECiw 15-18 dS/m) in the Western region of Abu Dhabi.

The prospect for a wider scale-adoption and production however requires further testing under a range of constrained biophysical environments (e.g. salinity, water scarcity and nutrient-poor soils) and development and evaluation of production technologies for optimal yields under local growing conditions. ICBA, in partnership with the UAE's Ministry of Environment and Water (MOEW), Abu Dhabi Farmer's Service Center (ADFSC) and the Peruvian organizations Institute of research and scientific cooperation and technological Arabic - Latin American and the Caribbean (ICCTALA), Instituto Nacional de Innovacion Agraria (INIA) and Universidad National Agraria La Molina (UNALM), has started evaluating the performance of several quinoa varieties. Testing their productivity on a range of soils using different qualities of irrigation water is ongoing in order to identify high-yielding salt- and heat-tolerant quinoa lines/varieties.

The prospects for quinoa are promising. With further testing there is a prospect for a wide-scale adoption and production in the region. ICBA has initiated work with partners to improve food security and nutrition security through a substantial increase of quinoa production. ICBA and its partners are together evaluating the potential of quinoa as an alternative food and feed crop for salt-affected areas, focusing on selected countries of the Middle East most affected by salinity and water scarcity and where agriculture and the agri-food sector contribute significantly to the national GDP.

Sesbania: Sesbania has shown to have excellent potential as an alternative legume to replace alfalfa in the forage production systems, and cutting management was shown to significantly improve the biomass yields. Thus, with low-salinity water for irrigation (2 dS/m) and 3-cuts per year, a mean dry matter yield of 44.6 t/ha was obtained, which was 40% more compared to the uncut treatments. In a study of the effect of salinity, increase in irrigation water salinity from 5 to 10 dS/m has led to 39% decrease in plant height and 68% reduction in the dry weight. At 15 dS/m water salinity, plant height decreased by another 23% and dry weight by 53%.

Mustard: Mustard is cultivated for its tender green leaves and seeds which are a source of edible oil and also used as a condiment. In field trials at ICBA, the seed yields of five mustard accessions (previously selected for superior performance from a set of 100 accessions) ranged between 1025 kg/ha to 1510 kg/ha with an overall average of 1330 kg/ha. In a separate study at ICBA, no significant differences were found in biomass yields between fresh and low-salinity water (5 dS/m), though further increase in salinity to 10 dS/m and 15 dS/m reduced yields by 33% and 50%, respectively.

Safflower: Safflower is a multi-purpose oilseed crop with great potential for development as a forage crop. Evaluation of 52 genotypes in field plot trials over two seasons using irrigation water salinities corresponding to electrical conductivities of 10 and 15 dS/m showed that salinity reduced biological and grain yields and the flower number by 50, 75 and 25%, respectively. The results from this study showed that safflower is moderately salt-tolerant and cultivation on salt-affected land can prove beneficial to farmers.

Triticale: The use of Triticale (x *Triticosecale*), which is a hybrid of wheat and rye is increasing as a feed

crop for cattle, swine and poultry and it can be used as an alternative for corn and soybean. Forage yield and quality of triticale is comparable to barley and oat. Thirty seven accessions selected from a larger group of 150 accessions, when evaluated for biological (BY) and grain yield (GY) under field conditions at three salinity levels, dry matter yield varied between 5.6 to 10.9 t/ha and grain yield between 2.2 to 5.6 t/ha. Accession PI 429166 ranked the highest for dry matter yield as well as for grain production. Accessions showed clear variation for dry matter and grain yield that can be exploited for further genetic improvement. The accessions can be grown for dry matter, grain or as dual purpose end uses.

Salt-tolerant native grasses as forages

With the increasing pressure on all types of water resources in the UAE, there is need to replace the water thirsty forage/fodder species such as rhodes grass and alfalfa with more water-efficient species. ICBA has studied the response to salinity of two native grasses, *Lasiurus scindicus* (Dhai) and an introduced African variety of *Cenchrus ciliaris*. Both these grasses showed better adaptability, growth and biomass under saline conditions than other introduced forages. The quality of forge was also found to be better (less fiber and more protein). In recent harvests, the average dry biomass varied between 8-10 t/h for *C. ciliaris* and 5-7 t/ha for *L. scindicus* over the three salinity treatments (5-15 dS/m), showing a gradual reduction over previous years indicating that these grasses need to be rooted and re-planted after every 2-3 years.

Livestock feed with seawater

NyPa grass (*Distichlis spicata* var. *Yensen 4a*) has the potential as forage and landscaping grass in the coastal regions, where sea water can be used for irrigation. Over the last four years, ICBA and NyPa International have tested NyPa grass in the arid conditions of the UAE. Maximum biomass yields of about 24 t/ha was obtained from three harvests with irrigation water salinity of 25 dS/m and ET_0 x 1.5, showing that NyPa grass irrigated with seawater can be grown to feed livestock in coastal areas.

Halophytes production - optimizing management practices

ICBA has been investigating the benefits of growing halophytic grasses (*Sporobolus virginicus* and *Distichlis spicata*) and shrubs (*Atriplex* spp.) for feed production in highly salt-affected areas. Valued as a high-protein animal feed, Atriplex is one of the most salt tolerant crops, which can withstand harsh growing conditions such as marginal quality irrigation water and poor quality soils. In long-term trials conducted over seven years at ICBA, *A. lentiformis* and *A. nummularia* performed well at higher salinities and maintained higher yield. *A. lentiformis* proved its hardiness and re-growth potential with the highest survival rate of 83 to 88% compared to the survival rates of *A. nummularia* (26-34%) and *A. halimus* (15-23%). *A. lentiformis* also produced the highest green biomass which ranged between 10.3 to 26.8 t/ha, followed by *A. nummularia* (8.3 to 20.4 t/ha) and *A. halimus* (2.9 to 12.6 t/ha).

Agroforestry trials at ICBA

Sporobolus virginicus and *Distichlis spicata* are two highly salt-tolerant grasses each planted at ICBA on an area of 6000 sq.m for research and demonstration using split-split plot technique with three replications. Three treatments viz: salinity (10, 20, 30 dS/m), irrigation level (ET_0, 1.5ET and 2ET) and fertilizer rate (0, 50, 100 and 150 Kg/ha of NPK and urea) were applied. $ET_{1.5}$ and application of 40:20:20 of NPK/ha were found to be the most optimum levels of inputs for the highest and sustainable production over the years. In both the grasses, dry matter yield increased with increased irrigation level and increased fertility but decreased at the highest nutrient level. In recent harvest, averaged over all treatments, dry matter yield of *S. virginicus* varied between 21.6 to 30.8 t/ha/year across various salinity levels while that of *D. spicata* ranged between18.8 to 28.4 t/ha/year. The dry matter yield of both *D. spicata* and *S. virginicus* increased with increasing salinity level and the yield was highest in summer harvests.

Agroforestry systems for boosting farm income and productivity

Integrating trees and shrubs with other farm enterprises can generate additional income as well as increasing the system's productivity. ICBA has been studying *Acacia ampliceps*, which is one of the most successful plant species tried in many partner countries - from Central Asia to North Africa. The plant fixes atmospheric nitrogen, provides forage/fodder for animals, fares well with other companion species, as well as a potential source for bio-energy. ICBA's research over the past six years has demonstrated the compatibility between *A. ampliceps* and two salt-tolerant grasses, *Sporobolus arabicus* and *Paspalum vaginatum*, in response to different salinity and fertilizers treatments. Studies showed that *Acacia ampliceps* can fix nitrogen under different salinity levels (10-30 dS/m), thus supporting the nutrient requirements for the two grasses studied. Based on average values over the project duration, the unfertilized plots showed a 7-13% reduction in biomass yields between for *S. arabicus*, but insignificant difference for *P. vaginatum*. The average yield of these grasses varied from 22-28 tons dry matter/ha/yr. In addition, the foliage from the trees harvested at 2 m from the ground surface additionally provided ~ 10 tons dry matter/ha/yr. Attempts were made to check the nodulation status in *A. ampliceps* trees under different salinity levels and the results showed nodulation even at 30 dS/m with the bacteria showing the characteristic feature of gram negative *Rhizobium*. The fixation of nitrogen by the *Acacia* trees helps in increasing the soil nitrogen through the root system and supporting the forages.

Salt-tolerant date palm varieties

ICBA in collaboration with the Ministry of Environment and Water (MOEW) has long-term research in date palms with the goal to identify high-yielding, salt-tolerant date palm varieties and improve crop management techniques to maintain optimal functioning of the agro-production system and survival of the plants under stressed environments. Date palm canopy attributes and yield parameters were recorded for

Castor evaluation at ICBA

10 local and 8 exotic varieties from Saudi Arabia. There were significant variety, salinity and variety x salinity effects for all parameters. The study showed that local varieties, Shahla and Lulu, can be recommended for intermediate and highly saline water of irrigation, respectively. In contrast, varieties such as Nabatet Sultan, Um Al Hamam and Ajwa-Tul-Madinah seemed to be less adapted to saline conditions, also showing high inter-year variation in yield. Varieties Farad, Barhi and Shahlah were suitable for landscaping purposes and showed good growth even at high water salinity levels.

ICBA's research is the first long-term investigation that demonstrated clearly the significant growth responses of date palms to mycorrhizal inoculation under nursery conditions. The research demonstrated that AM-fungi can enhance the growth of date palms (*Phoenix dactylifera* L.) under low nutrient and saline conditions - that AM-inoculated date palms grow better than non-inoculated palms. Since date palms possess a coarse and limited root system and are often grown in saline and nutrient poor soils, the research clearly showed that AM-technology will enable sustainable date palm production in marginal conditions.

Salt-tolerant Rhizobia for improving legume productivity

Leguminous plants through their symbiotic relationship with certain soil bacteria, collectively known as rhizobia, help to fix atmospheric nitrogen. Naturally occurring soil rhizobia were isolated from the root nodules of cowpea and Sesbania plants growing at ICBA research station. These were identified as *Sinorhizobium meliloti*, *S. kostiense, S. terangae, S. arboris* by sequencing of the PCR amplified 16S rDNA – the last three species being reported for the first time from the Arabian Peninsula. In vitro studies at a range of temperatures (20-50°C), salinities (0-100 dS/m), pH (2-12) and heavy metal (Zn, Mg, Cu, Pb and Fe) revealed that the native rhizobia had higher levels of tolerance to stress conditions than the reference strain (TAL 169). A study of the ability of the two *S. kostiense* and *S. terangae* to nodulate cowpea seedlings under saline conditions showed that both the strains are effective in forming nodules even at high salinity (12 dS/m). The tolerance to environmental stresses, especially high salinity and temperature make these rhizobia highly valuable inoculums to improve productivity of the leguminous crops cultivated in marginal/salt-affected soils.

Salicornia evaluation

Bioenergy crops on saline land

Studies have shown that castor and mustard can be successfully cultivated as bioenergy feedstock crops with significant economic benefit using reclaimed wastewater, when public acceptance for growing food and feed crops is still a major issue. Use of reclaimed wastewater to grow bioenergy crops not only avoids competition with traditional crops with respect to the usage of fresh water but also allows productive use of this resource which is otherwise wasted by dumping into the sea. In studies conducted at ICBA, both castor and mustard were found to tolerate up to 5 dS/m of irrigation water salinity with no adverse impact on seed yields. Thus, while the mean seed yield of 11 castor hybrids was in the range of 2,180 kg/ha, the mean seed yields of 5 mustard accessions was about 1,330 kg/ha, both being very similar to the yields obtained from traditional growing areas.

The research team of ICBA and partners has surveyed 50 farms affected by the conditions in the high vulnerable zone of the Aral Sea Basin in Central Asian countries. The project has also conducted field surveys to collect seed of some native salt-tolerant halophytes. Four halophytes (*Atriplex nitens, Climacoptera lanata, Salsola sclerantha, Kochia scoparia*) were planted in pure stands and intercropped with salt-tolerant crops (sorghum, pearl millet, artichoke and licorice) using artesian water for irrigation. The team examined the feasibility of using biomass from these demonstration plots as livestock feed or as a renewable energy resource.

The research team also assessed potential biogas production out of biomass from seven wild halophytes species. *Karelinia caspia* was flagged as the most promising of the seven for biogas production in desert areas of Central Asia, with possible sources of biomass coming from harvesting plants from the wild or plantings on abandoned saline arid lands.

One potentially profitable crop that can be grown with seawater is *Salicornia*, also known as sea asparagus. Seeds of *Salicornia* can be used to produce biofuel. Masdar Institute (MI), along with other companies Boeing, Etihad Airways and UOP Honeywell, are looking at the potential of growing *Salicornia* and native halophytes with sea water for use as biofuel feedstock. In 2012, ICBA and MI studied the growth of *Salicornia* irrigated with seawater under the United Arab Emirates

(UAE) conditions and the results were encouraging. ICBA and MI have evaluated several genotypes of *S. bigelovii* and native UAE halophytes for their oil potential. The encouraging results have led to further collaboration in 2013 to evaluate various *S. bigelovii* genotypes at different seawater salinities for green biomass and seed production. Similar work to look at short duration genotypes that can grow with seawater was undertaken in collaboration with King Abdullah University of Science and Technology in Saudi Arabia. Preliminary results are very encouraging in demonstrating the potential of growing Salicornia in the coastal areas in GCC countries with seawater irrigation. The challenge is to select the desired traits of growth and seed production for developing better varieties that are suitable for high temperatures prevailing in the region.

In addition to the United Arab Emirates, other countries like Saudi Arabia and Oman are keen to test and introduce Salicornia on a production scale.

BIOSAFOR Project - Renewable energy production from in saline wastelands

ICBA's partnership with Bangladesh Agricultural Research Institute (BARI); Central Soil Salinity Research Institute (CSSRI) in India; Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA) in Spain, and University of Agriculture, Faisalabad (UoF) in Pakistan has facilitated the production of renewable energy, biomaterials and fodder in saline wastelands through biosaline agroforestry. The project was funded by the European Union for 4 years and had seven different work packages (WP) from experimental trials to case studies, leading to global characterization of saline/sodic wastelands. ICBA led WP1 and WP2 and has a significant role in other WP's. In addition, it acted as Regional Coordinator for activities in Bangladesh, India and Pakistan.

As part of the project, 60 new salt-tolerant germplasm accessions obtained from CSIRO, Australia and other sources were screened. The plants were grown under variable salinity (ECw: 10-50 dS/m) for a year and different growth and biomass characteristics were measured. Data on shoot and total dry biomass were used to establish responses curve against the soil salinity. Piece-wise and sigmoidal regression equations were used to compute the threshold salinity levels and slopes from the curves.

For WP2, extensive studies on biomass and its components were carried out on *Eucalyptus camaldulensis, Prosopis juliflora* and *Tamarix articulata* in two different locations in India and Pakistan. The sites represented the typical salinity/sodicity situation of marginal lands. Replicated trees were chopped and leaf, stem and wood weight were determined. The biomass data were used to establish different regression equations based on plant height, crown volume and other growth parameters to predict wood and green biomass at other salinity conditions. ICBA has also assisted in saline land characterization in partner countries that would lead to identification of marginal/waste lands where bioenergy trees can be grown with minimum management and cost. In addition, ICBA participated in different coordinating activities given its role as the Regional Coordinating Unit for South East Asia. These results linked with other work packages were used in identifying areas globally that have potential for growing salt tolerant trees for bioenergy. Using climate, land and water data obtained from climatological, remote sensing and GIS, economic models were developed for rehabilitating saline wastelands for bioenergy production.

Perennial grasses grown with saline water of 15-18 dS/m in Madinat Zayed

Diversifying agriculture on marginal land in Central Asia
ICBA has collaborated with local institutions in the Central Asian countries of Uzbekistan, Turkmenistan and Tajikistan to improve the livelihoods of rural communities in saline desert environments. Sorghum, pearl millet and alfalfa varieties introduced from ICBA, when screened at salinity levels of 3190-8100 mg/l, produced significantly higher biomass than the local varieties. The trials identified promising dual-purpose varieties that produced grain for food or to feed to poultry, as well as forage for livestock. In Uzbekistan, as a result of breeding the highly productive, open pollinated population "HHVBC tall" with local varieties, followed by several years of field testing conducted at Uzbek Corn Station in collaboration with ICRISAT, resulted in a new, promising, dual-purpose variety of pearl millet named "Hashaki 1" (released in 2011). It has shown good re-growth after two cuttings, while relative growth rates, biomass (fresh and dry) and grain production of the newly released variety exceeded the local varieties by more than 200%. "Hashaki 1" silage has proved itself the equal of maize silage when cut at 8-12 weeks. This new variety has performed well in dryland saline environments and has promise for planting widely to boost grain and forage production – either as the main crop in early spring, or as the second crop following the wheat harvest or as part of a rice rotation system.

Productive use of saline lands in Iraq
In parts of central and southern Iraq, soil salinity is so high that salt-tolerant crop varieties are the only answer to sustain agricultural production. Collaborative work by ICBA, the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Water Management Institute (IWMI) and funded by ACIAR (2010-2011) looked strategically at mitigation and adaptive measures to combat salinization in the central part of Iraq. ICBA focused on crop improvement and production system management at the farm-level and as well supplied germplasm of salt-tolerant plants. The trial focused on, the impact of salinity and boron content of irrigation water on the growth of winter cereals (wheat and barley) in Deir-Azzor in Syria as part of the Mirror Trial in Iraq and on the need to improve production in wheat and barley cropping systems in marginal soils. In another activity summer forages (sorghum and pearl millet – ICBA – supplied salt-tolerant varieties and two local varieties), sesbania, guar and cowpea at Al-Dujaila (Wasit) were evaluated at the salinity range of 10-20 dS/m.

Results showed that salt-tolerant varieties of wheat and barley can make agriculture productive across a wide range of salt-affected lands. On moderately saline land, wheat produced 3–5 t/ha of grain and summer forage crops produced 5–12 t/ha of dry biomass. On more saline land, barley produced 0.8–1.3 t/ha of grain and salt-tolerant grasses produced 7–12 t/ha of dry biomass. In addition, in high salinity areas, the prospects for non-conventional forages were well established and the salt-tolerant genetic material of many non-conventional types of forage were provided by ICBA to the national partners in Iraq. The multi-partner research project helped to address one of the biggest threats to food security in Iraq, as well as providing policy makers with the information to develop long-term plans for managing salinity.

ICBA gene bank – repository of germplasm of salt-tolerant crops
ICBA's gene bank serves as the source of genetic diversity for researchers around the world working to improve productivity of salt-affected farmlands. Between 2009 and 2013, over 3,090 germplasm accessions including barley, maize, cowpea and amaranthus were acquired from various sources. With these additions, the number of accessions held in the gene bank has reached 12,567, representing 62 genera and 226 species. During the same period the gene bank has also distributed over 360 samples of salt-tolerant germplasm of various crops to nine countries for research and development. The gene bank is unique in holding salt- and drought-tolerant genetic materials in the region.

Model farm approach for technology transfer and rehabilitation of abandoned farms
ICBA and the in Abu Dhabi Farmers' Services Centre (ADFSC) have tested salt-tolerant annual and perennial grasses as substitutes for Rhodes grass on three degraded farms at Madinat Zayed, Mezaira'a, and Ghayathi in the Western Region, Abu Dhabi. Recognizing that on-farm trials with farmers' participation will speed up the selection and introduction of new crops to diversify the production systems, the ICBA/ADFSC team developed these farms as model farms representing the different salinity levels (ranging from between 15 and 18 dS/m) and the harsh biophysical environments. The farms were selected after a survey and soil and water analyses by ICBA. The farm at Madinat Zayed has been planted with four salt-tolerant perennial grasses: *Distichlis spicata, Sporobolus virginicus, S. arabicus* and *Paspalum vaginatum*. In Mezaira'a and Ghayathi, in addition to the grasses, *Acacia ampliceps* and five species of Atriplex namely, *A. canescens*, *A. halimus*, *A. amnicola*, *A. nummularia* and *A. lentiformis*, were also planted. While the grasses were first established in the field at ICBA and strips of 50 cm^2 were removed and transported to the farms in the Western Region for splitting and transplantation, *A. ampliceps* seedlings were raised by sowing seeds and *Atriplex* spp. were established through rooted stem cuttings, both in plastic bags. The farm in Ghayathi has been equipped with a fully automated irrigation system and salinity sensors to monitor field salinity in real time. Soil salinity in these farms was regularly monitored through sampling at the root zone and analyses at ICBA's Central Analytical Laboratory.

Determination of the fresh and dry biomass yields of the four grasses after one year of growth and establishment showed differences in productivity across locations. The yields of all the grasses were higher in Ghayathi, as the quality of the irrigation water was relatively better than in Madinat Zayed

Harvesting of the perennial forage grasses

and Mezaira'a. Averaged over the locations and the number of harvests, the fresh biomass yields of the four perennial grasses ranged between 25.6 t/ha and 52.4 t/ha, with an overall mean of 43.2 t/ha per harvest. *Paspalum vaginatum* produced the highest biomass yields, followed by *D. spicata, S. virginicus* and *S. arabicus*. Considering three harvests per year, the total biomass yields are expected to be in the range of 75-100 t/ha, which correspond to 30-40 t/ha of dry matter depending on the species.

The three model farms were also planted with winter annuals that included barley, pearl millet, sorghum, mustard and quinoa. Buffel grass which is perennial was also planted in the three farms. Determination of the biomass yields about 120 days after planting showed that mustard produced the highest yield, followed by quinoa, barley, pearl millet and sorghum. In terms of genotypes, the mean yields were highest for 58/1A in barley, ICMS 7704 in pearl millet, ATC 90783 in mustard and Ames 13761 in quinoa. In Ghayathi, in spite of the high salinity of irrigation water (ECw 14-18 dS/m), the seed yield in quinoa was found to be very high, with an average of 7.5 tons/ha over the genotypes.

Using the flow meter data from Madinat Zayed, the forage yield data for a harvest was estimated to illustrate the yield per m^3 of water applied which was found to be about 6 kg/m^3 for *Paspalum and Distichlis*. When compared to the water use efficiency of Rhodes grass which has a maximum of 3.97 kg/m^3 with low salinity water (2 dS/m), the yield currently obtained per m^3 of highly saline water (18 dS/m) is 66% more, illustrating the potential of the new grasses. In terms of water saving, it meant saving 44% of water to produce the same amount of forage as Rhodes grass.

A Farmer's Day was organized in June 2012, when the first harvests of these grasses were made for farmers, FSC managers and extension staff. The event demonstrated the harvest and bailing procedures in the field. In addition, two training courses were conducted for the extension staff of Abu Dhabi and Al Ain regions.

Water sensor usage at ICBA research farm

Innovation in irrigation technologies for water conservation and improving water efficiency

Optimizing irrigation through water productivity (crop per drop)

Work to optimize irrigation usage through water productivity research (crop per drop) using sensor technology to monitor near-continuous soil water content and movement in the soil started in 2011. Soil water content was monitored at depths of 10, 30 and 50 cm every 10 minutes in a control plot as part. In this innovative research the Decagon® 10HS soil water sensors were used with a logger that communicates over the GSM mobile phone network to send data to a server from where it can be retrieved over the internet as required. In addition, weather data were used to estimate daily and hourly reference crop evapo-transpiration. In efforts to use the sensor technologies, water productivity in small grain cereals (pearl millet, sorghum, barley and triticale) was evaluated under three salinity levels in the irrigation water and under four different irrigation amounts. The sensors provided valuable information on soil water content, its use by the crop, and its movement within and below the root zone. Research was also initiated on the use of a sensor that measures the electrical conductivity and temperature of the soil in addition to soil water content (Decagon® 5TE).

DuPont pervaporation irrigation technology in which the growing medium is humidified by water vapor movement through a polymer was also trialed at ICBA. In this technology, the subsurface polymer pipes desalinate saline water before it is used by crops. Small-scale green house experiments were completed.

ICBA promotes the fundamental tenet that good irrigation management is knowledge of crop water requirements, which are driven largely by weather considerations. The Center supports a weather station to collect continuous data on critical factors such as temperature, humidity, wind speed and solar radiation. These data are processed into an equivalent depth of water required from irrigation in order to meet crop water requirements at various time scales – hourly, daily, weekly etc. as appropriate.

The usefulness of weather data for improved irrigation management relies on it being readily available when required. ICBA regularly collects daily weather data for use by ICBA research projects. In 2013, ICBA installed another weather station on a farm in Ghayathi, in the Western Region of Abu Dhabi, as part of a project with the Abu Dhabi Farmer Services Center to further elaborate this technology on farmers' fields.

Moisture and salinity sensors for managing irrigation – SCADA system

Under arid and saline conditions, good irrigation management means supplying the right amount of water at the right time. The sensors to measure soil water content and salinity near-continuously and in

near-real time is a powerful tool for improving irrigation management. Advances in instrumentation and communication can now provide agricultural producers with the information they need, and also enables automatic monitoring and feedback control of irrigation. ICBA has established a system based on supervisory control and data acquisition (SCADA) to demonstrate the technical feasibility of using real time measurements of soil moisture and salinity to manage irrigation in sandy soils. The sensors provide information on soil water content, conductivity, and temperature, crop-water use, and the movement of water within and below the root zone. Control systems that combine up-to-date weather information and data from moisture and salinity sensors can improve irrigation management and conserve water.

An excellent example of how weather data are used at ICBA for research purposes can be seen in its incorporation into irrigation management regimes in the SCADA automated irrigation platform. Here the daily estimates of potential evapo-transpiration (evaporation of water from soil and plant) are used to determine the irrigation duration required, and then to automatically turn the irrigation on and off while simultaneously recording factors such as water flow rate, pressure, and salinity.

Another example is a project initiated in 2013 and scheduled for implementation early in 2014 in partnership with Environment Agency Abu Dhabi and scientists in New Zealand to measure the actual flow of water through date palms (transpiration) as a function of hourly evapo-transpiration. This will enable operators to determine the amount of water required by this major UAE crop compared with the amount actually applied, helping them to develop improved irrigation guidelines. So far, the actual daily and hourly measured water use by date palms at ICBA (using sap flow measurement technology) correlates very well with the daily and hourly evapo-transpiration, showing considerable potential to reduce irrigation water usage. As well, the contribution of daily weather data could lead to 50% water savings.

Evaluation of the first AFG treated salt water for crop and forage production

The project started with the objective to evaluate the effect of AFG-unit treated water on crop production in comparison with untreated water from the same water source. The preliminary experiments show that treated water is showing relatively better performance over the feed water (i.e. groundwater) especially on plant growth and mortality rate. In case of seed weight, the treated water showed a slightly better result over the groundwater treatment, although the groundwater treatment performed better for both the number of seeds and yield parameters. The treated water, however, did not show a better performance over both mixed and low salinity waters on any tested parameters.

Use of treated waste water (TWW) for forage production

In recognition of the value of treated waste water as a resource for irrigation, ICBA started a project on the safe use of treated wastewater (TWW). In the last decade several countries have expanded production of TWW in order to recycle it for agricultural use. In this project Jordan, Oman and Tunisia have participated in a three-year study on the sustainable use of TWW. It is predicted that TWW production in the countries under

study would double by 2025, and consequently the use of this resource could be increased with the implementation of production systems on marginal agricultural lands. The research focuses on the effects of TWW on plant productivity, the limitations of TWW utilization for irrigating agricultural fields, an assessment of the environmental impact and the evaluation of methods to safely use TWW in agriculture in order to save fresh water resources and enhance the productivity of resource-limited farmers in the region.

The researchers undertook screening/evaluation of a range of crops over the three partner countries and sought to establish the optimum application of TWW. A series of 81 on-farm trials totaling 60 ha was set up to determine the socio-economic returns of TWW reuse in irrigation compared to the existing methods. In Jordan, evaluation of TWW use in tree production led to the study of two farms of olive trees and the biofuel plant, *Jatropha*. Forage trials in Jordan and Oman returned good results for yield and quality. In addition, the non-conventional crops such as *Medicago*, *Jatropha* and *Jojopa* that were tested with either saline or TWW irrigation, produced fodder that did not differ from conventional fodder for animal digestibility, fertility and health. In Tunisia, extensive work on fruit trees, especially olive, citrus and pomegranate orchards, and applied irrigation using TWW in three representative locations on experiment stations and in on- farm trials. The yield and quality of orchards in Tunisia did not significantly decrease when irrigated using TWW.

Experiments using TWW to artificially recharge the overexploited ground water table were successful and also led to a slight decrease in salinity. Another nine trials were implemented in experiment stations to analyze soils, water (irrigation, drainage and ground waters) and harvested plants (forages and fruits) for mineral composition (heavy metals and nitrates), parasites and bacteria composition. Results show that in sandy and silty-clay soils there can be significant soil contamination from both fecal indicators and heavy metals at 0–60 cm depth. There was no reported fruit contamination with fecal bacteria, despite the fact that *Escherichia coli* concentration in TWW at times was above the World Health Organization limit. Further work will include more analyses on a wider sample size to ensure that TWW doesn't affect human health. Other analyses are projected to gain more knowledge about the effect on fodders and to produce a guideline about forage processing techniques to decrease potential threats. These guidelines will be shared between the partner countries in an effort to establish unified Arab guidelines. As an additional knowledge exchange activity ICBA is looking to share the knowledge gained from this project at an international conference in 2014 and to extend capacity building activities

Determination of crop water requirements using weighing lysimeter

Improved irrigation planning and irrigation scheduling require precise assessment of all components of the water balance equation. Weighing lysimeters are one of the available technologies to assess the components and is one of the best means for measuring crop water use. The current irrigation practices in the UAE are based on extensive water use rather than water demand management. In order to improve the water use efficiency, ICBA applied its technical expertise to contribute to improved irrigation planning and irrigation scheduling through precise assessment of all components of the water balance equation, thus

ensuring that the goal of irrigation – to supply the correct amount of water required and no more – is achieved. Barley, sorghum, and pear millet were the crop used in the weighing lysimeter to extend findings to ICBA's research program into the crop water use of difference crops/forages and developing crop efficient values.

Improving water storage through Managed Aquifer Recharge systems
Managed Aquifer Recharge (MAR) is practiced widely all over the world to store water in aquifers during periods of water surpluses and withdraw during deficits. ICBA partnered with Sultan Qaboos University in the "Managed Aquifer Recharge" project in the Muscat area of Oman. In this project ICBA field tested recycled water reuse in growing wheat and provided backstopping in groundwater flow modeling for evaluating recharge scenarios. ICBA conducted field experiments to compare two potential irrigation methods (i.e. drip and furrow) with three wheat varieties. The ultimate goal was to increase irrigation efficiency and water productivity with treated wastewater from MAR schemes.

Towards productive irrigated agriculture in Sub-Saharan Africa
In sub-Saharan Africa, irrigated agriculture needs to become more productive and market-oriented in order to create jobs and stem migration from rural areas. ICBA started, in 2012, to improve integrated crop and seed production systems through an inter-disciplinary approach to improve the performance of irrigated farming systems in Burkina Faso, Gambia, Mali, Mauritania, Niger, Nigeria and Senegal that considers water, soils, irrigation, crop varieties, seed production, commercialization, diversification, socio-economics, markets and value chains. The multiple benefits for the sub-Saharan countries generated from such an approach include improved sustainable agricultural production, improved water management for seed production for commercialization and diversification. To date partners have made inventories of irrigation technologies, surveyed cropping patterns and collected data on water resources. Some countries have moved on to testing and demonstrating irrigation technologies, evaluating crops, cropping patterns and crop production.

Soil Mapping for Land Use Planning

Soil survey of Abu Dhabi Emirate
ICBA, on behalf of the Environment Agency-Abu Dhabi (EAD) managed the Soil Survey of Abu Dhabi Emirate project that was completed in 2009. The project was done in two phases, phase 1 - an extensive soil survey of the emirate; phase 2 - an intensive survey of 400,000ha identified as having potential for irrigated agriculture expansion. During this project, soil as well as many thematic maps (irrigated agriculture suitability, land degradation, soil salinity, hard pan depth, water table depth, rangelands suitability, current land use etc) were published. To ensure that the information created in the soil survey was readily available to users, the Abu Dhabi Online Information System (ADSIS) was developed to access the soil database. In addition a number of UAE nationals were trained on different aspects of soil survey activities.

Soil survey of Northern Emirates
In recognition of the Soil Survey of Abu Dhabi Emirate, and on behalf of EAD, ICBA took the lead and prepared project scope and terms of reference for the Northern Emirate Soil Survey project. The purpose of the project was to have digital soil information to aid in broad land use planning and agricultural expansion in the Northern Emirates. The survey utilized Geographic Information Systems, satellite image processing and the Abu Dhabi Soil Information System (ADSIS) to produce state-of-the-art soil information. ICBA provided technical back-stopping as member of the Technical Committee. Soil and thematic maps were prepared and ADSIS updated to United Arab Emirates Soil Information System (UAESIS). The system displays all the maps produced during the survey, with the powerful functionality of allowing a user to view particular locations of interest and extract data related to all the map units and observation sites described during the survey. If registered as an advanced user, it is possible for a user to tailor the criteria for thematic maps based on the soil map properties or that of individual observation sites.

National soil mapping of the Islamic Republic of Mauritania
National development essentially requires scientifically-based soil information. Soil data is used in master planning, environmental monitoring, environmental impact assessment, soil conservation, farming, sustainability assessment, land degradation assessment and meeting multiple new demands. In countries where extensive fertile soils and ample high quality water supplies exist, little efforts are required for efficient agricultural production, however Mauritania lacks an abundance of these resources, making the need to map the soils. Acknowledging this need, the Government of Mauritania approached ICBA to prepare a proposal to undertake national soil mapping to ensure that land use in Mauritania is sustainable through the provision of soil related information for decision makers, and to promote the knowledge of soils in Mauritania. ICBA scientists visited Mauritania and met with potential partners and shared the benefits of soil mapping in national development, ICBA experience in the subject matter. In 2013, ICBA prepared a concept note and shared with the Mauritanian government for review and to set a way forward.

Soil mapping of ICBA experimental station
The soil mapping of ICBA research station was undertaken to provide information classified using the USDA Soil Taxonomy and thus enhance the validity of applied research at ICBA transferable to arid and semi-arid Islamic regions covered by ICBA's mandate.

QuickBird Remote Sensing Imagery (40 cm resolution) was used to aid in grid survey (50mx50m) to investigate 325 sites. Three soil taxa are identified, that is:

1. Typic Torripsamments, mixed, hyperthermic.
2. Typic Torripsamments, carbonatic, hyperthermic.
3. Typic Haplocalcids, sandy, carbonatic hyperthermic.

The project was completed in 2010.

Preparation of Strategies

ICBA has been steadily increasing its role in the policy and governance arena of the agriculture and water sector in the United Arab Emirates. Policy documents such as the United Arab Emirates Water Conservation Strategy, the Recycled Water Strategic Plan for Abu Dhabi Emirate and Sustainable Irrigation Development within the UAE add to the body of knowledge about the UAE. The latest strategies include the forthcoming UAE agricultural strategy and the Kuwait Investment Strategy for Food Security. The policy instruments and research findings are also highly relevant to other water-scarce countries in the region. Outside the UAE ICBA prepared the Oman Salinity Strategy and as a follow-up there is a national plan for its implementation.

United Arab Emirates Water Conservation Strategy
The United Arab Emirates Water Conservation Strategy identified basic initiatives to manage water resources sustainably in order to conserve water resources from exploitation and pollution. The focus on water conservation was a significant step in the water development process because previous plans had focused primarily on meeting unregulated and unconstrained demand for water. Based on an integrated approach that anticipates meeting future water demand from a mix of investment in new water infrastructure and efficiency improvements of existing water supplies (natural resources, desalination and reclaimed water), the Strategy identified the key questions, assumptions and areas of risk to future water development. The strategy will inform national policies, rules and regulation designed to improve the sustainable management of the nation's precious water resources and enhance their contribution to the economic growth of the country.

A strategy for sustainable agriculture in the United Arab Emirates
The United Arab Emirates has limited renewable fresh water resources and limited land suitable for agriculture. Groundwater resources are dwindling and the quality is deteriorating. In the past the UAE produced a variety of agricultural produce, mainly fruit, dates, vegetables and animal feed. However, few farms are now productive because land has become salinized and water has been over-exploited.

In 2012, ICBA and the Ministry of Environment and Water began developing a national strategic plan for improving plant and animal production in the UAE. The plan considers water productivity, water efficient crops and best management practices, and provides a framework for developing the agricultural sector while sustainably using natural resources. Work has been completed on assessing land, water, agricultural systems and production, and a socio-economic survey of crop, livestock and crop-livestock systems, and abandoned farms.

Ensuring safe disposal of brine from reverse osmosis desalination plants
The lack of freshwater resources means an increasing use of saline groundwater for agriculture. This water is not suitable for growing cash crops, such as vegetables which are mainly grown in greenhouses. To overcome this problem, many small-scale reverse osmosis (RO) plants are used to desalinate

groundwater to produce date palm or cash crops in greenhouses or to supply drinking water to animals and poultry. The use of such technologies requires proper brine concentrate management or disposal practices; otherwise disposal practices can lead to groundwater pollution. ICBA on behalf of the United Arab Emirates Ministry of Environment and Water, completed a study to identify suitable environmentally friendly brine disposal options or alternatives. Appropriate regulations or guidelines, monitoring and capacity building are essential for better utilization of RO plants in the agricultural production system in UAE.

Standards for brine disposal in the United Arab Emirates

In the Arabian Gulf, desalinated seawater is important in meeting a significant proportion of freshwater needs. Seawater is a shared resource and must be protected from pollution, including from brine produced by desalination itself. Environmental standards for desalination plants and guidelines for monitoring discharge will help prevent pollution and minimize environmental impacts. In 2012, on behalf of the United Arab Emirates Ministry of Environment and Water, ICBA developed standards for managing and monitoring brine disposal from desalination plants. In developing the standards, ICBA reviewed existing environmental guidelines and standards in each Emirate, took into account international best practice and consulted widely with stakeholders.

Capturing, re-cycling and re-using water

In 2010 ICBA completed on behalf of Abu Dhabi Emirate and in close cooperation with the International Water Management Institute (IWMI) and water experts from The Netherlands and the UK, a comprehensive strategy to capture, recycle and re-use municipal and industrial wastewaters. During 2010 a draft comprehensive strategy for the capture, treatment and use of wastewater in agriculture, forestry and landscaping was formulated to minimize environmental impact and optimize economic value. The strategies were focused on the use of reclaimed water in landscaping such as water saving measures and integrated farming needs; field and protected agriculture production systems; and groundwater recharge especially in poor water quality and groundwater mined areas. To address governance and institutional aspects, the establishment of a body to safeguard public and environmental safety was recommended.

Legal and regulatory framework of Abu Dhabi Emirate water law

The aim of the project was to develop the legal and regulatory framework for the water sector. Water policy reforms such as a clearer determination of institutional roles, responsibilities and accountability are critical to ensure the sustainable management of water resources. The Abu Dhabi Water Master Plan identified that currently there is limited progress in regard to accountability compared with the advanced achievements in the development of water resources

and to a lesser extent progress in institutional capacity. Identification and clarification of the roles between different institutions, particularly the roles of the federal and local institutions, and consequent legislative amendment, will assist in eliminating overlap and omissions of institutional responsibilities.

Reclaimed Wastewater Strategy for Abu Dhabi Emirate
The lack of renewable resources in the Emirate of Abu Dhabi is the most challenging factor for sustainable water resources use and management. Thus, non-conventional waters are the only dependable water sources for sustainable economic development.

Among the non-conventional water sources, treated wastewater is receiving more attention as a reliable water resource. A strategy was developed to capture, recycle or reclaim, and use of municipal and industrial wastewaters that will help to set the overall direction in the sector.

Water Master Plan for Abu Dhabi Emirate
This was the first comprehensive assessment of both natural and non-conventional water in Abu Dhabi Emirate. The research involved developing new data sets on aspects of water such as the environmental and economic costs which are crucial to support decision-makers. Understanding the environmental implications was a key component of the study as the Abu Dhabi government is one of the foremost leaders in green thinking in the world.

Establishment of Abu Dhabi Water Council
Abu Dhabi Water Council (ADWC) was established to monitor and coordinate activities in the entire water sector to support strategic planning and unify the standards and practices in the Emirate. The proposed council has the responsibility to strengthen the capability in implementing integrated water resources management strategies through proper planning and integration of resources. Establishment of the ADWC minimizes duplication of work among these agencies; thus, in the long term saving resources across government.

A national salinity strategy for Oman
In Oman, the expansion of agriculture in the 1990s had a negative effect on agricultural productivity. The 'Oman Salinity Strategy', developed collaboratively by ICBA and the Omani Ministry of Agriculture and Fisheries, is a framework for preventing salinity and pollution, and for using water resources sustainably and economically. The strategy is based on a scientific assessment of salinity problems in Oman. Consultations with key ministries, government agencies, and local and international specialists ensured that recommendations are based on up-to-date information and current thinking. The strategy assesses current water resources and future demand, water use in agriculture and the impact of salinity, socio-economic issues, governance, legal and regulatory frameworks and policies, and developing capacity for managing salinity.

A water vision for the Organization of Islamic Cooperation
In 2012, two years of consultations culminated in the adoption by the 57 countries of the Organization of Islamic Cooperation (OIC) of a vision to foster collaboration and cooperation on water. The OIC Water Vision responds to the challenge of securing reliable access to water for health, livelihoods and production, and managing risks related to water associated with population growth, depletion of resources, environmental degradation and climate change.

Close collaboration with major stakeholders, mainly the ministries responsible for water and key Islamic organizations, has ensured that the vision is culturally and politically appropriate as a framework for developing water policy and management in all 57 countries. The UAE has nominated ICBA to support translating the vision into action.

Contribution to the World Bank study on Adaptation to a Changing Climate in the Arab Countries
While Arab region has been adapting to changes in rainfall and temperature for thousands of years, the speed with which the climate is now changing has, in many cases, outstripped traditional coping mechanisms. ICBA scientists contributed three chapters to the World Bank's study "Adaptation to a Changing Climate in the Arab Countries" that drew on extensive regional knowledge and expertise for a comprehensive analysis of the potential impact of climate change in Arab region.

Services and Consultancies

Central Analytical Laboratory
The Central Analytical Laboratory (CAL) is an integral part of the Research and Innovations Division of ICBA. It has provided soil, water and plant analytical services to ICBA in-house projects and to the external clients (Environment Agency - Abu Dhabi, Masdar Institute, GRM International Australia., University of Sharjah, UAE University Al Ain, GreenGood Eco-Tech etc). During the last 5 years CAL has analyzed over 5000 soil, water and plant samples. CAL is continually upgraded on demand basis and is specialized in analyzing physical, chemical, nutritional and engineering aspects of samples.

Soil Museum
The ICBA soil museum portrays the value of soils and in particular the soils of the UAE as related to national development. It is intended that the soil museum provides a unique resource to youth, university students, researchers, professionals, land use planners and policy makers dealing with agriculture, desertification, environmental protection, ecological restoration and biological diversity conservation.

The soil museum consists of various sections; a section is dedicated to equipment commonly used in soil investigations from various contexts (routine soil testing in the field and salinity testing and monitoring). Monoliths of key soils from UAE are displayed to witness their characteristics in nature.

A central display presents diversity of soil features for education - colors of UAE soils, particle size classes,

organic and inorganic soil amendments, chemical fertilizers, soil structures, precious resources of UAE coastal lands, polymorphism of gypsum crystals, dryland, and pottery to indicate soil a part of life. A unique feature of natural gypsum overgrowth on *Zygophyllum* is housed in the museum along with rocks and minerals specimens from UAE. A sand dune simulation model gives opportunity to visualize the sand movement and sand dune formation in the desert. A section is dedicated to soil library where in addition to information about the UAE soils, national soil information from Oman, Kuwait, Qatar, and Saudi Arabia can be obtained. Using computers in the museum, the UAE Soil Information System (UAESIS) can be accessed online (www.uaesis.ae) to experience soils of the UAE, their distribution, and soil and thematic maps.

Field survey services - Abu Dhabi Genebank and Botanical Garden

ICBA provided field survey services to Environment Agency - Abu Dhabi to select a potential site to establish Abu Dhabi Genebank and Botanical garden. To assess the suitability of potential sites, a criterion was established and tested on site characteristics for three suitability classes (low, medium and high). The four sites were ranked on the criteria and the information shared with Environment Agency Abu Dhabi.

Capacity building (training courses, internships, etc)

During the 2009-2013 ICBA organized and engaged with 30 capacity building initiatives, whereby 602 trainees received formal trainings in training sessions and a further 230 participated in other capacity building events such as farmer field days.

1. Soil survey and sustainable use of land resources in Abu Dhabi Emirate (1-5 Feb 2009) ICBA Headquarters
2. Agricultural management under water and soil saline conditions (17-18 Jun) ICBA Headquarters
3. Biosaline agriculture technologies in the arid and semi-rid regions (25-29 Oct 2009) KISR, Kuwait
4. Biosaline agriculture technologies for arid and semi-arid regions with reference to Africa (BADEA) 23 May to 03 Jun 2010, ICBA Headquarters
5. Biosaline agriculture technologies and its role in the mitigation of climate change in the Arab region (25-28 Oct 2010) – Egypt
6. Introduction to biosaline agriculture: Management of salt-tolerant crops/forages, soil and water (4-6 Apr 2011) Liwa, Abu Dhabi
7. Biosaline agriculture technologies in arid areas (15-18 May 2011) Doha Qatar

8. Biosaline agriculture technologies and its role in the mitigation of climate change in Africa (BADEA) (9-20 Oct 2011) ICBA Headquarters
9. Techniques for the use of treated wastewater in agricultural production and its role in food security in the Arab world (27 Nov to 01 Dec 2011) Amman Jordan
10. Environmental impact assessment and soil and irrigation management associated with the use of marginal water in agricultural production (10-13 Sep 2012) ICBA Headquarters
11. Seed production, maintenance of cultivars and integrated crop management package (2-4 Oct 2012) Tashkent, Uzbekistan
12. Integrated management technologies of saline water (15-18 Oct 2012) ICBA Headquarters
13. Farmers' schools for forage production and utilization techniques under the use of marginal water resources (4-7 Nov 2012) Sinai and Cairo, Egypt
14. Integrated management technologies of marginal water (Treated Wastewater) (17-19 Dec 2012) ICBA Headquarters.
15. Guidelines and methods for socioeconomic assessment and farm surveys (6-9 Jan 2013) Muscat Oman
16. Reclamation of lands affected by salinity in Africa (13-24 Jan 2013) ICBA Headquarters
17. Travelling Training Workshop: Variety selection, seed production, soil and crop management practices and on-farm efficient forage utilization (15-18 Sep 2013) Yemen
18. Irrigation scheduling and water consumption (15-17 Sep 2013) ICBA Headquarters
19. Utilization of soil and thematic maps for agricultural development (23-25 Sep 2013) ICBA Headquarters
20. Plant Genetic Resources in the UAE (28-30 Oct 2013) ICBA Headquarters
21. Production systems of non-conventional forage crops (19-21 Nov 2013) ICBA Headquarters
22. Date palm production systems in saline environments (26-28 Nov 2013) ICBA Headquarters
23. Farmer field schools for rural family empowerment through optimization of forage and animal production (2-4 Dec 2013) Egypt
24. GIS for water resources and irrigation management (8-9 Dec 2013) ICBA Headquarters
25. Economics and productivity of water in agriculture sector (17-19 Dec 2013) ICBA Headquarters
26. Production systems of field and forage crops in the UAE (22-24 Dec 2013) ICBA Headquarters
27. ADFSC field day (15 Dec 2011), Madinat Zayed, Abu Dhabi
28. ADFSC field day (3 Jun 2012), Madinat Zayed, Abu Dhabi
29. Farmers' schools for forage production and utilization techniques under the use of marginal water resources (4 Nov 2012) Sinai, Egypt
30. Farmers' field schools for rural family empowerment through optimization of forage and animal production (3 Dec 2013) Egypt

International Conferences

Sharing Soil Survey of Abu Dhabi Results with International Soil Science Community: In order to ensure the widest dissemination of the research findings of the Abu Dhabi Soil Survey, an international conference in 2010 on "Soil Classification and Reclamation of Degraded Lands in Arid Environment" was held in Abu Dhabi (ICSC2010). The ICSC2010 was attended by over 250 scientists from over 35 countries. The conference also provided the forum for the launch of the Abu Dhabi Soil Survey Report.

Awards

Sharing soil survey of Abu Dhabi Results with international soil science community: In order to ensure the widest dissemination of the research findings of the Abu Dhabi Soil Survey, an international conference in 2010 on "Soil Classification and Reclamation of Degraded Lands in Arid Environment" was held in Abu Dhabi (ICSC2010). The ICSC2010 was attended by over 250 scientists from over 35 countries. The conference also provided the forum for the launch of the Abu Dhabi Soil Survey Report.

Collaborations and collaborators in last 5 years, including MoU's

Type of Agreement	Organization	Signing Date	End Date
Project Agreement	Desert Research Center (DRC), Egypt Arab Republic	2009-04-01	No end date
Memorandum of Understanding	The Leibniz-Institute of Vegetable and Ornamental Crops, Germany (IGZ)	2009-02-01	2012-02-01
Project Agreement and Implementation Plan	National Research Institute for Rural Engineering, Water & Forest (INRGREF)	2009-03-01	2012-03-01
Memorandum of Agreement	ECO Solutions AG	2009-04-26	2013-04-26
Memorandum of Understanding	Palestinian National Center for Agricultural Studies (NARC)	2009-06-23	2013-06-23
Memorandum of Understanding	Al Ain Municipality	2009-07-02	2013-07-02
Cooperation Agreement	ACSAD: the implementation of a joint project on safety use of treated wastewater in Biosaline agriculture	2009-06-01	2012-06-01
Memorandum of Understanding	United Nations Environment Programme (UNEP)	2009-06-10	2009-11-30
Cooperation Agreement	Ministry of Environment and Water (MOEW): Integrated plan to preserve water resources in UAE	2009-10-15	2010-02-15
Memorandum of Understanding	Arab Water Council (AWC), the Environment Agency – Abu Dhabi. To host and run the Arab Water Academy	2008-07-06	2013-07-06
Memorandum of Understanding	BITS, Pilani-Dubai (BPD)	2009-11-09	2012-11-09 (extended)
Memorandum of Understanding	AFESD. Funding and support for the project "Adaptation to climate change in the marginal environments in the Arab countries in West Asia and North Africa"	2010-03-15	2010-12-15
Memorandum of Understanding	Farmers Services Center (FSC)	2010-04-19	2014-10-19
Project Agreement	Farmers Services Center (FSC)	2010-06-23	2013-06-23
Project Agreement	GRM International Pty Australia	2010-07-06	2011-07-06
Memorandum of Understanding	Emirates Institution for Advanced Science and Technology (EIAST)	2010-10-21	2014-10-21
Memorandum of Understanding	Desert Research Center (DRC)	2010-10-25	2013-10-25
Project Agreement	The University of California at Davis (UCD) and State of Oregon State University (OSU). Development of A General Model of Crop Response to Water Stress Under Highly Saline Conditions	2010-11-01	2012-08-31
Project sub-Agreement	Masdar Institute of Science and Technology	2010-12-14	2011-05-30
Project sub-Agreement	Masdar Institute of Science and Technology	2010-12-14	2011-05-30
Project Agreement	General Directorate of Soil and Irrigation (GDSI) Ministry of Agriculture Palestinian Authority	2011-03-01	2011-12-01
Memorandum of Understanding	ICARDA (Soil Salinity Management in Central and Southern Iraq)	2012-02-16	2013-02-28
Memorandum of Understanding	Arab Bank for Economic Development in Africa (Badea) for training course on the Techniques of Biosaline Agriculture and its role in mitigating climate change factors in Africa	2011-03-24	2011-04-07

Type of Agreement	Organization	Signing Date	End Date
Project Agreement and Implementation Plan	Kazakhstan Scientific Research Institute of Rice Production (KSRIRP), Ministry of Agriculture of Kazakhstan	2011-08-02	2014-08-02
Project Agreement and Implementation Plan	Tajikistan Academy of Agricultural Sciences (TAAS), Tajikistan - Title of Project: Sorghum and Pearl Millet for Crop Diversification Improved Crop Livestock Productivity and Farmers Livelihood in Central Asia	2011-08-02	2014-08-02
Project Agreement and Implementation Plan	ICARDA/Project Facilitation Unit (PFU) - Title of the project: Sorghum and Pearl Millet for Crop Diversification Improved Crop-Livestock Productivity and Farmers Livelihood in Central Asia	2011-08-18	2014-08-18
Project Agreement	Institute of Desert, Flora and Fauna (IDFF) Ministry of Nature Protection of Turkmenistan on "Improving Livelihoods of Rural Communities under Saline Desert Environments in Turkmenistan	2011-08-18	2013-10-01
Cooperation Agreement	Ministry of Environment and Water: "Developing the standards and federal guidelines used in managing the waste of producing desalinated water in UAE"	2011-12-26	2011-12-26
Cooperation Agreement	Ministry of Environment and Water "to Develop a Strategic Plan of National Agricultural"	2012-03-20	2013-07-20
Memorandum of Understanding	Arab Bank for Economic Development in Africa (BADEA). Training course in the field of land reclamation affected by salinity in Africa	2012-07-17	2012-08-17
Memorandum of Agreement	University of Sharjah, UAE	2012-09-10	2013-03-10
Research Agreement of Understanding	King Abdullah University of Science and Technology (KAUST), KSA	2012-10-02	2015-10-02
Memorandum of Agreement	North-South Center for Social Sciences (NRCS) Ibn Zhor University of Agadir (Morocco)	2012-10-11	2012-11-24
Memorandum of Understanding	The Canadian University of Dubai, UAE	2012-12-09	2015-12-09
Memorandum of Understanding	King Abdullah University of Science and Technology (KAUST), KSA	2013-06-26	2016-06-26
Project Agreement	Aiman Sewerage (Private) Company Ltd. (ASPCL)	2013-08-28	2014-01-31
Memorandum of Understanding	Turret Oriel Limited, UAE	2013-07-15	2014-02-05
Partnership Agreement	Stockholm International Water Institute (SIWI)	2013-09-09	2018-12-31
Foundation Partner Marketing Partnership	Global Forum for Innovations in Agriculture (GFIA 2014)	2013-09-19	2014-02-05
Memorandum of Understanding	Institut National Meteorologie (INM), Tunisia	2013-09-18	2017-09-18
Memorandum of Understanding	Institut National des Grandes Cultures (INGC), Tunisia	2013-10t-08	2017-10-08
Memorandum of Understanding	BADEA. Training on irrigation management of small farms in saline areas in Africa	2013-10-28	2015-10-28
Memorandum of Agreement	University of California on behalf of its Riverside campus (Salinity Forum)	2013-11-07	2014-06-30
Memorandum of Understanding	University of Sana'a, Yemen (WEC)	2014-01-01	2016-12-31
Memorandum of Agreement	Masdar Institute of Science and Technology, UAE	2014-01-19	2015-01-18
Amendment to Collaborative Research Agreement	King Abdullah University of Science and Technology (KAUST), KSA	2014-02-17	2016-02-16

Type of Agreement	Organization	Signing Date	End Date
Memorandum of Understanding	Ministry of Water and Environment, Yemen	2014-02-26	2017-02-25
Project Agreement	International Water Management Institute (IWMI). Ground Water Governance in the Arab World: Taking Stock and Addressing the Challenges	2014-02-28	2016-05-01
Memorandum of Understanding	Al Hashemite Fund for Development of Badia (HFDB), Jordan	2014-03-20	2018-03-19
Collaborative Research Agreement	King Abdullah University of Science and Technology (KAUST), KSA	2014-04-10	2015-04-09
Memorandum of Understanding	Ministry of Water Resources, Republic of Iraq on developing the Uses of Saline Water and Soil in Iraq	2014-03-23	2018-03-22
Memorandum of Understanding	The University of Sydney, Australia	2014-04-11	2014-04-10
Partnership Agreement	American University of Beirut (AUB)	2014-10-01	2018-10-01
Partnership Agreement	ICARDA	2014-10-01	2018-10-01
Memorandum of Understanding	Agricultural Research and Extension Authority - AREA, Yemen	2014-02-27	2017-02-26
Memorandum of Understanding	Palestinian Hydrology Group	2014-02-27	2017-02-26
Memorandum of Understanding	Palestinian Water Authority - PWA	2014-02-27	2017-02-26
Partnership Agreement	Stockholm Environment Institute (SEI)	2014-10-01	2018-10-01
Partnership Agreement	Swedish Meteorological and Hydrological Institute (SMHI)	2014-10-01	2018-10-01

Sponsors, donors and partners

The Center's founding sponsors were the Islamic Development Bank Group (IDB), the Organization of Petroleum Exporting Countries (OPEC), and the Arab Fund for Economic and Social Development (AFESD). The Government of the United Arab Emirates, through the Ministry of Environment and Water (MoEW) and Dubai Municipality provided additional support to launch the Center in 1999. In 2010, the government of United Arab Emirates represented by MoEW and the Environment Agency – Abu Dhabi (EAD) extended the agreement with IDB with major funding provided by the UAE and supplementary core and projects funding provided by the IDB.

From 2009 to 2013 the Center has enjoyed grant funding from the following organizations:

- Abu Dhabi Farmers' Services Center (ADFSC)
- Ajman Sewerage (Private) Company Ltd.
- Arab Bank for Economic Development in Africa (BADEA)
- Arab Fund for Economic and Social Development (AFESD)
- Australian Agency for International Development (AusAid)
- Australian Center for International Agricultural Research (ACIAR)
- Dutch Ministry of Foreign Affairs (MFA)
- European Union (EU)
- International Fund for Agricultural Development (IFAD)
- MASDAR Institute of Technology (MI)

- Ministry of Agriculture and Fisheries in Oman (MAF)
- National Academy of Sciences (NAS)
- OPEC Fund for International Development (OFID)
- United States Agency for International Development (USAID)
- World Bank (WB)

Successful innovation is the result of combined effort. ICBA's work is grounded in collaboration with advanced research institutes, regional, national and international organizations as well as the private sector. Collaboration is critical to successful research and development, and to extending its impacts. Over the past five years, ICBA has had collaborations with the following national, government, international and private organizations.

- Abu Dhabi Farmers' Services Center, UAE
- Abu Dhabi Food Control Authority, UAE
- Acacia Institute, Vriji Universiteit, the Netherlands Arab Center for the Study of Arid Zones and Dry Lands (ACSAD)
- Arab League
- Arab Water Council
- AVRDC, the World Vegetable Center
- BioMyc International Corporation, Germany
- Center of Waste Management, Abu Dhabi
- Central Soil Salinity Research Institute (CSSRI), India
- Centre for Built Environment, India
- Centre for Ecology and Hydrology, United Kingdom
- Centre of Ecohydrology, University of Western Australia, Australia
- Centre National de Recherche Agronomique et de Development (CNRADA), Mauritania
- Centro de Investigacion y Tecnologia Agroalmentaria de Aragon (CITA)
- Commission for Scientific Agricultural Research, Ministry of Agriculture and Agrarian Reform, Syria
- Desert Research Center, Ministry of Agriculture and Land Reclamation, Egypt Directorate General of Agriculture and Livestock Research, Oman
- DuPont
- Emirates Institute of Advanced Science and Technology, UAE
- Food and Agriculture Organization, Italy
- GRM International, Australia
- General Commission for Scientific Agricultural Research (GCSAR), Ministry of Agriculture and Agrarian Reform, Syria
- Institut d'Economie Rurale (IER), Mali
- Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso
- Institut National de la Recherche Agronomique du Niger (INRAN), Niger Institut Senegalais de Recherches Agricoles (ISRA), Senegal
- Institute of Desert, Flora and Fauna, Turkmenistan
- Institute of Vegetable and Ornamental Crops (IGZ), Germany
- International Atomic Energy Agency (IAEA)
- International Center for Agricultural Research in the Dry Areas (ICARDA)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- International Institute of Tropical Agriculture (IITA)
- International Rice Research Institute (IRRI)
- International Water Management Institute (IWMI)
- Masdar Institute, UAE
- Ministry of Agriculture, Iraq
- Ministry of Agriculture, Palestine
- Ministry of Agriculture and Fisheries, Oman
- Ministry of Education, Iraq
- Ministry of Environment, Iraq
- Ministry of Water, Iraq
- National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, USA
- National Center for Agricultural Research and Extension, Jordan
- National Agricultural Extension, Research and Liaison Services (NAERLS), Nigeria
- National Agricultural Research Institute (NARI), Gambia
- National Institute for Agrobiological Science, Japan
- National Research Institute for Rural Engineering, Water & Forest, Ministry of Agriculture and Hydraulic Resources, Tunisia
- Ocean Desert Enterprises (ODE), the Netherlands
- Organization for Agriculture in Saline Environments (OASE), the Netherlands
- Palestinian Water Authority, Gaza, Palestine
- Salinity and Plant Nutrition Laboratory, Department of Horticulture, Institut Agronomique et Vétérinaire Hassan II, Morocco
- Suez Environment, France
- Sultan Qaboos University, Oman
- Tajikistan Academy for Agricultural Sciences, Tajikistan
- UAE Municipalities: Abu Dhabi, Dubai, Sharjah
- U.S. Salinity Laboratory USDA-ARS
- United Nations Development Program
- Universities: BITS-Dubai Campus, UAE University, Al-Ain University, University of Uzbekistan, Nevada University, University of Montana

Publications

During 2009 -2013 ICBA scientists contributed to a wide variety of publications including edited books, publications in peer reviewed refereed journals, conference proceedings, scientific magazine and newsletters. In this section publications that relate to ICBA work are presented.

Books and Book Chapters

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ABOUT ICBA

ICBA – The International Center for Biosaline Agriculture is a non-profit, autonomous international agricultural research center with headquarters in Dubai, UAE. ICBA conducts research and development programs that aim to improve agricultural productivity and sustainability in marginal environments.

ICBA's multi-pronged approach to address the closely linked challenges of water, environment, income and food security include research innovations in the assessment of natural resources, climate change adaptation, crop productivity and diversification, aquaculture and bio-energy and policy analysis. ICBA is working on a number of technology developments including the use of conventional and non-conventional water (such as saline, treated wastewater, industrial water and seawater); water and land management technologies and remote sensing and modeling for climate change adaptation. Building capacity and sharing knowledge is an important part of all ICBA does. ICBA's work reaches countries, including least developed countries, in Central Asia and the Caucasus, the Middle East and North Africa (MENA), South and South East Asia, sub Saharan Africa and Gulf Cooperation Council countries.

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