Federal Ministry
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and Research

MEWAC
Middle East Regional Water Research Cooperation Program

EXALT—Coupling Thermal Desalination and Extraction of Dewatered Salt with Hydroponic Greenhouse Cultivation via Heat Pumps

Middle East Regional Water Research Cooperation Program (MEWAC)

In arid regions of the Middle East, desalinated brackish water is increasingly being used in plant production. Water-saving cultivation methods, such as hydroponic greenhouses where plants grow in special nutrient solutions without soil, are helping to reduce the burden on water resources. In order to keep water losses in the greenhouses to a minimum and ensure that the desalination process is as efficient as possible, the joint German-Israeli-Jordanian project EXALT is developing a new combined process that, with the help of heat pumps, extracts heat from the greenhouse in order to keep it cool; this heat is then used in the desalination process. At the same time, the condensation water produced in the cooling and desalination process can be recovered and used for irrigation.

Sustainable Plant Production Despite Water Shortages

In the countries of the Middle East, some of which are strongly impacted by extreme drought, agriculture is the biggest consumer of water. To secure food production for future generations, sustainable cultivation methods based on efficient water use are pivotal. Hydroponic greenhouse systems, for example, are especially well suited to arid regions. In these systems, plants grow in special nutrient solutions rather than in soil as is usually the case, meaning they need far less water. With the help of desalination, more and more naturally existing saline water in the region can be used for plant cultivation. And of course, solar power, the regenerative energy source used for the desalination process, is in plentiful supply in these regions.

To develop an optimum process combining water-efficient plant production using saline groundwater and surface water with climate-friendly desalination, researchers from Germany, Israel, and Jordan have joined forces as part of the collaborative project EXALT. What the project partners are seeking to do is facilitate plant cultivation in arid regions all year round using a minimum of water and energy.

Closed Loop Cooling Process

At the heart of the combined process developed as part of the EXALT project is a closed loop cooling process which achieves the perfect balance between humidity and temperature in the greenhouse, ensuring the best possible conditions for plant growth. Instead of controlling these parameters using an air exchange system, as is usually the case, a heat pump actively extracts heat from the greenhouse. Thanks to the lower temperatures, the water that evaporates via the plant leaves can condense, be recovered, and reused for irrigation

Test setup to investigate the optimum growth conditions depending on nutrient solution salt concentration levels at the Hohenheim University Phytotechnical Center

Ministry of Innovation, Science & Technology

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Sustainable Water Management

The remaining water needed for consistently high plant production can be covered with salt and brackish water desalination. The energy for this process comes, among other sources, from the thermal energy extracted from the greenhouses, reducing the solar power needs. Plus, the product of this process is dehydrated salt that can be disposed of in a more environmentally friendly manner than the brine produced in conventional desalination processes. The concept developed as part of EXALT does not rely on fertile soil and low-salt water, enabling plant production with a minimum of water and energy, even in areas that are otherwise unsuitable for agricultural production.

To begin with, baseline studies on the latest methods of hydroponic greenhouse farming are conducted in the target countries Jordan and Israel; the locations selected have varying levels of water availability and salinity. The results of these studies are combined with data on the climate and quality of the available irrigation water. Based on the local conditions, the project researchers investigate the optimum temperature, humidity, and light conditions for plant cultivation and energy efficiency in relation to the salt content of the nutrient solution for selected plants. The researchers use the findings to define greenhouse cooling and dehumidification requirements and develop those combined cooling and desalination systems that appear most promising, the aim being to create holistic concepts for desalination and plant production for a total of six case study locations. These concepts are then evaluated and compared and serve as blueprints for later implementation in practice

Global Solution for Arid Regions

Regions that are affected by drought account for some 15 percent of the earth's surface and are home to more than 14 percent of the global population. Even the slightest change in the quantity and distribution of annual precipitation can have catastrophic consequences for the food security of the global population, most of whom are reliant on rainfed agriculture. By developing an innovative method for combining water-efficient greenhouse farming and climate-friendly desalination, EXALT offers a solution for all-year-round plant production in semiarid regions the world over.

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MEWAC
Middle East Regional Water Research Cooperation Program

TransFresh—Transboundary Freshwater Resource Real-Time Monitoring and Management

Middle East Regional Water Research Cooperation Program (MEWAC)

The Yarmouk River is the biggest tributary to the Jordan River and the groundwater resources in its drainage basin are important transboundary freshwater resources that provides drinking and irrigation water in Syria, Jordan, Israel, and, indirectly, Palestinian territories, too. These resources are extremely important for water management in this region. To date, however, the impact that climate change and increased water abstraction has on water resources remains largely unknown. In an attempt to gain a better understanding of the complexities of the water resource system in the area of the Yarmouk River, the partners in the joint TransFresh project will use data from a transboundary monitoring system to model the resources both above and below the ground and set out relevant recommendations for sustainable management.

Collecting Data to Understand the Complex System

The Yarmouk River is the main tributary of the River Jordan and at the same time an important strategic drinking water resource for Syria, Jordan, and Israel. Owing to the relatively heavy rainfall in the Yarmouk drainage basin, this area is crucial for the ecology of the entire Lower Jordan Valley and the Dead Sea. It is vital for farmland irrigation in the region and since 2020 has been supplying some ten percent of the population of Jordan with water through the Wadi Al Arab System II water conveyance project. Surface water runoff, however, is strictly controlled by upstream dam structures. The only thing keeping the river alive is the groundwater that flows from the Ajloun area of Jordan.

Artesian Mukeihbeh well field (Jordan). In this artesian aquifer, water flows to the ground surface under natural pressure.

At the same time, this groundwater is urgently needed to supply water to the north of Jordan, an area where water resources are under additional pressure owing to the influx of refugees. In some places, this has caused groundwater levels to drop by as much as 120 meters and has left groundwater resources at risk of salination.

The search for solutions for optimized management of the scarce water resources has been further complicated by the political situation in the region. Both the groundwater and surface water resources span Syria, Jordan, and Israel. This makes it difficult to conduct systematic analyses on the complex interplay between the individual systems.

This is where the TransFresh project comes into play. This joint research project uses a custom-developed monitoring system comprising a comprehensive network of monitoring stations along the Yarmouk River and at groundwater bodies in the river's drainage basin. These stations will deliver data on a number of variables: the discharge rate and groundwater movements, the natural interaction between rivers and groundwater bodies, as well as anthropogenic impacts. This concept is the first of its kind to combine groundwater dating tools, i.e., tools that determine the age of the groundwater, and flow path analysis with transboundary online monitoring. The data generated will be used to model the status quo of water resources, enabling recommendations for future water management strategies to be made.

Modeling and Future Projections

To meet their aims, the researchers will be combining a variety of measurement technologies, including methods to estimate the groundwater residence times in the individual groundwater bodies in the Yarmouk Gorge. This will allow them to draw conclusions on groundwater recharge points, transfer times in the aquifers, and mixing of different groundwater components. Given the strong differences in residence times, the researchers will be using what is known as a multitracer approach where different marking substances are used to trace the hydro-geochemical processes in the groundwater. By analyzing the Yarmouk for the presence of certain isotopes, i.e., atoms of an element that have the same chemical properties but different atomic masses, conclusions can be drawn on how the river is impacted by the inflow of groundwater.

All of this data goes into flow models that simulate the temporal and spatial water movements both above and below the ground in high resolution, as well as showing future developments. The researchers involved in the TransFresh project will use this to optimize the management of dams and groundwater resources. This will potentially help secure the availability of freshwater in the region for many years to come.

Improving Water Supply and Relations

TransFresh will play an important role in achieving a stable water supply from the Yarmouk basin over the long term, improving relations between the riparian countries at the same time. Stakeholders and decision-makers will be involved throughout the entire project development process; this will help deliver practical results that are transferable to real-life scenarios. In fact, the key concept behind this project sees the methods developed being transferred to other regions with transboundary water resources.

View of the Yarmouk Gorge

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MEWAC
Middle East Regional Water Research Cooperation Program

GRaCCE–Groundwater Recharge and Climate Change Effects

Middle East Regional Water Research Cooperation Program (MEWAC)

For the countries of the Mediterranean and in the Middle East, in particular, groundwater systems play a significant role in water supply. Climate change, however, is altering the formation of new groundwater, which is exacerbating the water scarcity in these regions. What is needed are state-of-the-art methods that will enable droughts to be detected early and modified water management strategies to be developed. The project participants in the international joint project GRaCCE will be developing a drought early warning system based on the temporal and spatial analysis of groundwater recharge. The new system will factor in the specific conditions in what is known as the unsaturated zone between the earth's surface and the groundwater table. This is crucial in terms of both the quality and the amount of groundwater generated.

Developing Additional Water Resources

The area of focus in the German-Israeli-Palestinian joint project GRaCCE includes the State of Israel, Jordan, and the Palestinian areas of the West Bank. The entire region suffers from a shortage of water. Irregular precipitation and substantial water loss on the earth's surface due to evaporation mean that water from rivers, lakes, and springs are often not available in the quantities needed, meaning groundwater resources are being heavily overused.

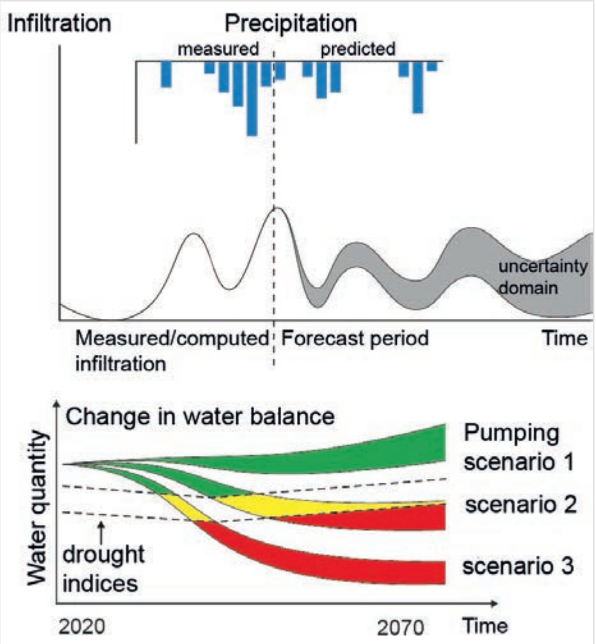
To find out how fast groundwater can regenerate and to create water management strategies based on this information, those involved in the GRaCCE joint project will be developing a new, integrated process for the temporal and spatial analysis of groundwater recharge. A fundamental aspect here is the complex groundwater movements and storage processes in what is referred to as the unsaturated or vadose zone, i.e., the layers of soil and rock between the earth's surface and the ground-water table. Given their importance for storing water, these layers must be factored into water management strategies.

Groundwater Recharge in Complex Rock Formations

Sedimentary rock such as sandstone and limestone are often marked by disturbed rock structures such as joints and faults and possess a porous structure that can store large quantities of water. The groundwater in these rock formations often lie very deep. This means it can take years for groundwater to be renewed through the penetration of rainwater from the surface. Joints and faults, however, allow a certain amount of water to flow through the layers of rock far more quickly, even within just a few hours. This sometimes makes it extremely hard to predict when groundwater recharge will occur. Earlier investigations also show that, in the region under investigation, the rock formations between the groundwater table and the surface of the earth are important in the area of water management because they serve as longterm water storage media, meaning they can be factored into water management considerations for periods of drought.

Rock formations with joints and faults can store water

To describe the process known as rainwater infiltration and groundwater recharge, the researchers in the GRaCCE project will be examining various hydrogeological, geophysical, and hydrogeochemical methods, as well as new modelling approaches. In doing so, they aim to identify the available water resources at monthly time steps. Information from the daily climate models depicting the general development of precipitation and evaporation are also factored into the long-term forecasting models for the period 2020–2070. These results serve as a quantitative basis for predicting water deficits in aquifer resources on the basis of drought indicators, i.e., factors that can be derived from the complex range of processes and can indicate the risk of drought. The groundwater recharge prediction process developed in the project is tested at various sites in Israel and in the Palestinian autonomous territories. Other sites in Germany and Switzerland will be used to validate the processes and models in a controlled environment.



Drought early warning system based on groundwater infiltration and development of adapted water management strategies

Web-Based Toolbox

At the end of the GRaCCE project, the plan is to set up a type of web-based toolbox that includes a drought early warning system and dedicated pumping and storage strategies. The purpose of this is to enable water consumers and local authorities to better prepare their regions for extreme climate events, in doing so reducing water stress. Beyond the Middle East and its aquifer resources, the project findings can be transferred to other hydrogeological and hydrological conditions in other countries.

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