



# A LAND WITHOUT WATER

*Climate change, waves of refugees and poor planning are draining water supplies in Jordan.*

BY ELIZABETH WHITMAN

Silt crunches under Reda Al-Younes' shoes as she descends into a sun-baked mudflat in eastern Jordan. She crouches and, with her finger, traces a distant memory of a time when water brought life to this part of the Azraq oasis.

Al-Younes maps out the former channels and pools in the mudflats where she spent her summers more than three decades ago, before she moved to the capital, Amman. She and others in Azraq's Druze community dug wells by hand to extract saline water. Channels guided it into shallow pools to evaporate, leaving salt that the Druze sold, Al-Younes explains, as she follows the diagram with her finger.

With winter rains, the water table surged and the mudflats flooded. The Druze decamped in October for higher ground until May, when the water retreated and they returned to the mudflats. They grazed small herds of cows and sheep in Azraq's lush, spring-fed marshes.

"I loved the oasis," she says, her voice taut with nostalgia.

Half a century ago, Azraq was legendary. Historical photos show ponds flanked by thick clusters of reeds and squat date palms. A shot from 1965, which hangs today in a local lodge, shows a man waist-deep in Shishan Pool. He is fishing, his net suspended in mid-air. All of this — Azraq's mudflats, marshes and pools — depended on reserves of underground water replenished by yearly rains. In the early 1980s, Jordan's government began drilling wells near Azraq and pumping millions of



**Circles of crops in Wadi Rum, Jordan, are irrigated using water drawn from an aquifer.**

allowed the plundering of its water supplies. The combination has rendered Jordan one of the poorest nations on the planet in terms of its water resources — and its struggles offer a window onto the issues that other water-

stressed nations are increasingly facing.

Marwan Al-Raggad, a Jordanian hydrogeologist who taught at the University of Jordan in Amman until last year, fears that the country will exhaust its groundwater in the foreseeable future. “Fifty years from now, we’ll be pumping from the bottom of the aquifer,” Al-Raggad predicts, referring to Azraq. He and a handful of other scientists are scrambling to map Jordan’s remaining water and project future changes, but their efforts are being hampered by a lack of quality data and limited financial support.

Elias Salameh, a hydrogeologist at the University of Jordan, agrees that time is running out. “We don’t have any additional water resources from within the country to be developed,” he said. “Almost everything is captured now.”

### A PARCHED NATION

Most of Jordan is a toasted expanse of desert, where less than 50 millimetres of rain fall each year. Only nine countries in the world receive less annual precipitation than Jordan. And it ranks fifth in nations facing the greatest water stress, according to an analysis released last month by the World Resources Institute.

Steven Gorelick, a hydrogeologist at Stanford University in California, who has done extensive research into Jordan’s water crisis, says that, with so few new options for fresh water, the country “will be centre stage in showing how a semi-arid region deals with the devastating impacts of a warmer and drier regional climate.”

I travelled across Jordan in summer 2018 to explore how researchers are studying Jordan’s water crisis, and to learn how the government is responding. The country’s most precious liquid resources lie in aquifers in a dozen main groundwater basins. Wells that tap the aquifers supply nearly 60% of the water consumed in the country, with the rest coming from surface-water supplies such as the Sea of Galilee and the River Jordan (see ‘Without water’). Some 45% of the water usage goes to agriculture. Meanwhile, municipal water networks lose roughly half their water to theft and leaks.

The aquifers beneath Jordan function like a bank account, albeit with a finite capacity. Rains deposit water into the aquifers, and springs release the excess. Salameh says that Jordanians are depleting their account by extracting much more water than gets added to the aquifers each year. The situation is even more dire for non-renewable aquifers, which rain cannot replenish. Once that water is taken, it is gone.

The government has long recognized that the country is spending its water resources much too quickly. Of Jordan’s 12 groundwater basins, 10 are being pumped at a deficit. Overall, groundwater is being extracted at twice the rate that it is replenished, according to the Jordanian water ministry. At this pace, the looming question for Jordan’s aquifers is not if they will be depleted, but when. It’s a challenging problem, given the available information and the uncertainty of climate change. In official planning documents, the government has acknowledged that it needs to improve its groundwater-data collection, analysis and monitoring.

“Are the values collected from groundwater wells — private and governmental ones — accurate?” asks Al-Raggad. Pumping from illegal wells isn’t accounted for, and natural springs are not all monitored either, he says between sipping coffee and rolling cigarettes during an interview in his office. Near the door stands a flow monitor that closely resembles a rocket-propelled grenade launcher, which, he says with a shake of his head, has led to misunderstandings when he’s working out in the field.

### CLIMATE CHAOS

Of the challenges facing Jordan’s water sector, climate change presents perhaps the most uncertainty. Part of the problem is the country’s location. “The effect of climate change on the Mediterranean in general

cubic metres of water annually from the aquifers — underground layers of porous rock and sediment. Farmers began unfettered pumping of their own.

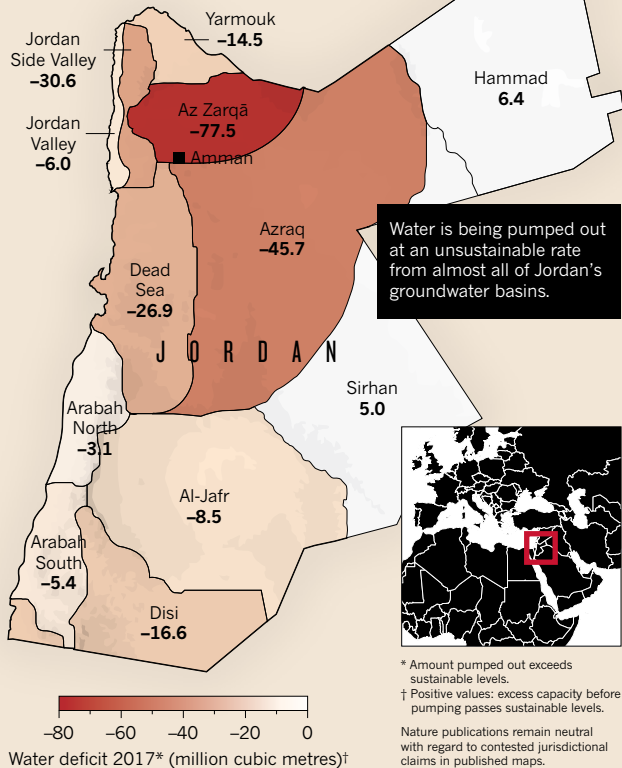
Soon, the aquifer was losing water faster than rains could refill it. In 1987, the springs that fed the two main pools in northern Azraq stopped flowing. By 1990, the pools dried up. Today, the water table has dropped from the surface to tens of metres below ground. This is happening not just in Azraq, but in aquifers across Jordan.

The plundering of Jordan’s groundwater alarms scientists who are studying the country’s current resources and forecasting future changes. Jordan gets nearly two-thirds of its water from aquifers, and the supply is not sustainable, they say. Global warming has already hit the Middle East hard, and projections indicate this region will suffer profound problems in coming decades as rainfall grows more unpredictable, rising temperatures accelerate evaporation and the land grows drier.

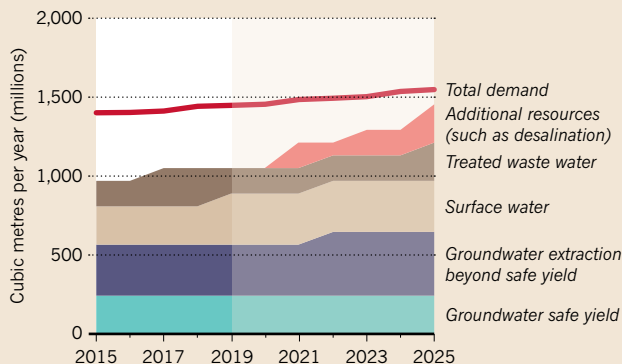
Climate change isn’t the only problem that will stress Jordan’s limited water resources. The country has a rapidly growing population, which has swelled with refugees from adjoining nations, most recently some 660,000 Syrians who have fled civil war, according to the United Nations. And Jordan lacks the rich oil and gas deposits that many of its neighbours have, which limits its ability to pursue expensive options such as desalinating seawater. On top of that, decades of lax policy have

## WITHOUT WATER

Jordan's water supply is one of the world's most vulnerable, and climate change is projected to increase risks for the nation.



Water demand in Jordan outstrips the supply from aquifers, surface rivers, lakes and elsewhere. The country's future plans call for substantial amounts of fresh water to come from desalination and other untapped sources.



— and the Middle East is part of it — is much more severe than any other part of Earth, and we don't completely understand it," says Yochanan Kushnir, a climate scientist at Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York.

That makes rainfall and aquifer recharge less predictable, which greatly challenges efforts to manage resources today — let alone plan for the future. Al-Raggad is among those trying to gauge the impacts of climate change on groundwater in Jordan.

He starts by taking the results from global climate models used by the Intergovernmental Panel on Climate Change. Then he scales them down to the regional level, using statistics of past temperatures and other climatic variables to determine how global phenomena affect local conditions, such as rainfall amounts. These regional simulations provide information about how climate change could affect local aquifers in Jordan. In one case, Al-Raggad and Salameh, along with

three colleagues from German and Austrian universities, found that by 2050, an important aquifer in the north could receive 37% less recharge through rainfall than it does today. With continued over-pumping, the amount of water in the aquifer could decrease by 40–90%, according to unpublished work they presented at the European Geophysical Union meeting last year. The researchers found a similar pattern for another of Jordan's main aquifers.

This means that even as Jordan continues to take too much water from aquifers, the amount by which nature refills them is also shrinking. "We need to reconsider the effects of climate change on a yearly basis on our water management," Al-Raggad says.

Many other questions remain. Climate modelling doesn't address the quality of groundwater, which can become too saline to use before an aquifer runs out. And there is considerable uncertainty about the climate projections for the globe — questions that are magnified for any individual country.

Beyond questions about the amount of rainfall, researchers are also trying to forecast how patterns will shift. Haim Kutiel, a climatologist at the University of Haifa in Israel who analyses rainfall in areas around the Mediterranean, says that in studying climate change, when and where rain falls is as important as how much.

Fifty years ago, rain came regularly, starting in mid-September and lasting until late spring. "And that was the rainy season," Kutiel says. Now, the rains are sporadic and unpredictable. "You could have a huge storm in October and then no rain for six weeks," he says.

Ofira Ayalon, an environmental scientist also at the University of Haifa, agrees: "We have to realize that when we're talking about climate change, what used to be the pattern will not necessarily be the pattern."

Uncertainty about climate change affects all parts of the globe, but the problem is particularly acute in Jordan because the country lacks consistent, high-quality data that allow scientists to better understand current conditions, such as how much precipitation is recharging individual aquifers.

"If you can't calculate the recharge, then you can't calculate the effects of climate change on recharge," Al-Raggad says. For his research, he needs to know the intensity, duration and frequency of precipitation over the past few decades, but older data lack that specificity.

"They usually say, 'We received 20 millimetres of rain on this day,'" Al-Raggad says. "But we don't know: was it along the whole day, a few hours, one hour or five minutes? That's a big difference for me, as a hydrogeologist." Denser rainfall means more floods, more evaporation and less recharge, he explains.

Government data have grown more precise ever since the ministry shifted three or four years ago towards monitoring precipitation in real time, Al-Raggad says. But the historical data will remain as they are.

### RIPPLE EFFECTS

All of these trends raise the question of what will happen when Jordan exhausts its dwindling water supplies. Some researchers have warned that water shortages can lead to war and massive refugee crises. In a bombshell paper from 2015, Kushnir and others blamed a record drought in Syria for helping to spark the civil war that began in 2011 (C. P. Kelley *et al. Proc. Natl Acad. Sci. USA* **112**, 3241–3246; 2015). Climate change exacerbated the drought, which lasted from 2007 to 2010, prompting crop failures and a mass influx of rural farming families into cities, thus igniting the war, they argued.

They added that decades-long policies promoting unsustainable agricultural production, which depended on overexploiting groundwater, didn't help. The paper simultaneously drew praise for linking climate change with conflict and criticism for lacking nuance, with other researchers challenging its primary conclusion. Its findings about groundwater drew little attention at the time.

Although researchers don't know why this area is unusually sensitive to changes in climate, they recognize that in any arid region, a drop in rain will have disproportionate impact. "Small changes in rainfall can make a big difference for human beings, and it's been like that throughout history," says Kushnir.

SOURCE: JORDANIAN MINISTRY OF WATER AND IRRIGATION; [HTTPS://GO.NATURE.COM/2L9CJL5T](https://go.nature.com/2L9CJL5T) (TOP); [HTTPS://GO.NATURE.COM/2ZCSW1W](https://go.nature.com/2ZCSW1W) (BOTTOM).



Rising temperatures are happening as Jordan's population is growing rapidly, from less than 6 million people in 2006 to around 10 million today. The country continues over-pumping groundwater, and Ali Subah, secretary-general of the Ministry of Water and Irrigation, blames the need to do so on the sharp increase in the number of refugees.

Since becoming a state in 1946, Jordan has absorbed Palestinians, Iraqis and Syrians, plus smaller numbers of Sudanese, Somalis and Yemenis. More than 750,000 refugees are currently registered in Jordan. That figure doesn't include unregistered refugees or the millions over decades who have settled in the country and gained citizenship.

In an interview in his office at the water ministry, Subah grows animated as he recounts the history of how "refugees make life difficult for Jordan".

"All the refugees came from an area that is rich with water, and they're not used to rationing water," Subah says. He acknowledges that the country uses an unsustainable amount and that he worries greatly about groundwater. "If we continue as usual, we will lose many main aquifers, soon," he says. Either they will dry out, or they'll become too saline to use.

Asked what the government is doing to deal with the dwindling supply, Subah points to Jordan's 2008–22 national water strategy. That plan called for Jordan to give less water to farmers for free and to stop over-pumping groundwater. Other solutions include using water more efficiently while finding new supplies — such as desalinated water from the Red Sea — to make up the deficit. Jordan has progressed in a handful of those areas, Subah says, such as cracking down on illegal wells and curbing the free water that goes to agriculture, but it has made no progress in others, such as reducing groundwater pumping — a failure that he again pins on refugees.

He argues that Jordan has no choice but to overexploit groundwater. "If we don't overabstract, we can't supply the Syrians or the Jordanians or the refugees in general," he says.

### RED TO DEAD

To Al-Raggad and others, the best way for Jordan to augment its water supply is to desalinate enormous quantities of water through a joint mega-project with Israel, the Red Sea–Dead Sea Water Conveyance

Project. It would bring desalinated water from the Red Sea to Amman, dumping the brine into the Dead Sea through a canal, which would help to stabilize the shrinking lake. Subah also said he hoped that the plan would go through.

Jordan's latest water plan, which runs from 2016 to 2025, expects the Red-to-Dead canal to be finished by 2025, at which point it would contribute roughly 10% of the country's water needs. Some environmentalists despise the project, fearing damage to coral reefs and other species in the Red Sea and unforeseeable changes to the briny Dead Sea. Others, such as Salameh, are sceptical that it will happen at all. Salameh says he is in favour of desalinating ocean water from the Red Sea and pumping it to parts of Jordan, but not necessarily as part of the Red-to-Dead canal.

The proposed canal has stalled multiple times since an agreement was first signed in 2013. The most recent impasse came this spring with Israeli elections, but Roei Shaham, a spokesperson for the Israeli Ministry of Regional Cooperation, says the cabinet was expected to approve the project and a budget once a new government takes office in November.

Subah has similar expectations. "We hope before the end of this year a lot of things will be solved," he says.

Al-Raggad puts stock in treated waste water as another source to tap. "It's not waste, it's a resource," he says.

In August 2018, Al-Raggad decided to leave his post at the University of Jordan and become the executive director of the Inter-Islamic Network on Water Resources Development and Management, a think tank in Amman that has hosted conferences and has been involved in research on water-related issues. He wanted to work on turning waste water into a more significant source of water for Jordan.

In the past, Jordan's decisions on water management have proved short-sighted and divorced from the findings and warnings of scientists, argue critics. And some specialists warn that current policies are not grounded in research. The Azraq oasis is a prime example.

Since the springs in Azraq dried up 30 years ago, Jordan's Royal Society for the Conservation of Nature has tried to restore the oasis. So far, 10% of it has been revived, Hazem Al-Hreisha, the organization's wetland reserve manager in Azraq, says with pride during a tour of the reserve last year.

Al-Hreisha manoeuvres a Toyota Hilux over palm fronds that are bleached greyish white. Reeds tower three or four metres high. He stops near a pool and points to a pipe. Out of it spurts clear, cool water, creating a small stream that feeds the pool. That water, which 40 years ago gurgled out naturally, is now being pumped from the aquifer below.

To Al-Hreisha, this manufactured oasis is a success. Migratory birds once again stop in the pools of water that have returned to parts of Azraq.

Salameh is less enamoured with the revived pools. "They might be useful for bird migration or something," he says, "but not for groundwater."

To Al-Younes, who grew up in Azraq, the restoration is a feeble attempt to revive a place long ago destroyed by lack of foresight. She left Azraq in the early 2000s, following her children to Amman, where opportunity abounded in comparison to the dusty stopover that Azraq has become.

"You have to think about the future, about the people who will live here," Al-Younes says. "Unfortunately, no one thinks this way at all." ■

**Elizabeth Whitman** is a science journalist in Phoenix, Arizona. Reporting for this piece was funded by the Council for the Advancement of Science Writing, The Brinson Foundation and the Overseas Press Club Foundation.

**“IF WE CONTINUE AS USUAL, WE WILL LOSE MANY MAIN AQUIFERS, SOON.”**

ASHLEY GILBERTSON/VII FOR UNICEF/REDUX/EVINE



Refugees fetch water in 2015 in a camp near the Syrian border.