Can underground irrigation help farmers save water and energy and produce more?

An innovative subsurface irrigation system from Tunisia aims to mitigate the effects of the climate crisis on agriculture. It saves energy and water and increases yields. But it has yet to catch on widely.

Author / Photos: Sarah Mersch; Translation: Gretchen Vogel

"It was a bit strange at first that I didn't see anything," admits Sami Chabir. His neighbors look with a mixture of curiosity and skepticism at the dry-looking field on the edge of the highway in Amarat, in southeastern Tunisia near the *coastal town of Gabes*. "They want to see results." That's because neither Chabir nor his neighbors can see the water used to irrigate the olive trees in the 20-acre field. It is clear, however, that the trees are thriving amid the ochre, barren landscape. "I can practically watch them grow," Chabir says. The seedlings planted just two years ago have grown tall. Their leaves are rich green and shiny, quite different from the pale trees in the neighbor's field, which are clearly suffering from heat and lack of water. In the fall, Chabir was able to harvest the first olives from the grove.

Despite drought-plagued summers and reduced irrigation, the olives thrive.

That's in spite of the fact that the 2,700 olive trees that Chabir looks after for his cousin receive less water than those in the

neighboring field. But they received the water underground, and that, the Tunisian is convinced, makes the difference. He has installed buried diffusers on the land, a system of subsurface irrigation in which large amounts of water are supplied to plants at regular but long intervals underground.

A persuasive success rate with young olives

The Tunisian system, which is not yet widespread, was installed by Chabir's cousin Souhail Othmane, who owns the site. He lives abroad and sees the olive plantation as an investment in his homeland. He was convinced by the underground system from the beginning and installed it on the entire property. After two years, Chabir is convinced too. He looks after the trees on a day-to-day basis, taking care of irrigation and harvesting. In the beginning, he says, it was still a bit difficult to know when something wasn't working somewhere in the system, which overall requires very little maintenance. "For example, if the surface is damp or weeds are growing somewhere, I know something must be clogged."

By now, he's gotten the hang of it, he says. It's paying off: After initially buying and planting roughly two thousand trees, the cousins planted several hundred more this spring. Of these, just three or four have failed to take root. An excellent rate, Chabir is pleased to report, and he is already preparing the next section of the field to plant more trees in the coming months.

How the buried diffuser from Chahtech works

The *water diffusors* are palm-sized, shallow plastic containers. They are filled with a quartz granule designed to prevent clogging of the system while facilitating infiltration of water into the soil. Water is supplied to them through a hose and released to the soil through the bottom of the diffuser. Depending on the species, size and age of the plants, two to usually four diffusers are placed, evenly spaced, around a tree at a depth of about 50 cm. This is to guarantee that the root ball develops evenly in all directions and not along a hose as in drip systems. Along with water, liquid fertilizer and oxygen can also be supplied through the system. In addition to the large version used for trees, there are also two smaller versions of the diffusor for vegetable cultivation and for watering potted plants. Chahtech manufactures 95% of the diffusor components in its factory in Tunisia.

Inspired by centuries-old technology

Bellachheb Chahbani invented the underground diffuser. After studying in Belgium and at the Sorbonne in Paris, he began working in the 1980s at the *Arid Regions Institutein* Medenine in

southern Tunisia. There, he began researching the use of water resources even though the *climate crisis and prolonged droughts* were not yet playing such a major role in the country's agriculture practices. Today, Tunisia is among the bottom 25 countries in the world in drinking water resources. More than three quarters of the country's fresh water *goes to agriculture*.

The idea for Chahbani's irrigation system is based on a childhood memory. "I'm from Djerba, and I saw my grandfather bury clay jars next to the olive trees and fill them with water." Gradually, these released the water into the surrounding soil at the level of the roots

Bellachhab Chahbani was inspired by his grandfather's irrigation methods.

This ancient irrigation technique, used in similar ways in many countries in the region, has been proven to work over centuries. But it is prone to breakdowns, and the amount of water cannot be regulated. "The jars break, or the pores of the vessel become clogged with salt deposits. Then the system doesn't work anymore." So at the research institute, Chahbani developed a modern version of the idea, the buried diffuser, as he calls it. Before retiring, he bought the patent for his invention from the institute, developed the technology further and brought it to market.

Less water, less energy, higher yields

Compared with drip irrigation, which is widely used, the buried diffuser has a number of advantages. Since the water is targeted where it is most needed, directly at the roots, and it does not evaporate as with above-ground irrigation, the system uses only a third of the water consumed by other systems. This saves not only water but also energy. And according to initial studies, yields are also significantly higher.

Sami Chabir's pump uses only 1.5 kW. "With drip irrigation, that's enough for a hundred trees. In our system—5,000," he says. The water is pumped from the well to a small desalination plant and from there to a water tower with a volume of 50 cubic meters. From a height of three meters, it flows, driven purely by gravity, to the diffusers below ground. Since the terrain is sloping with a height difference of seven

meters, this works without any further pumps—and thus saves energy. "We have a water pressure of 1.1 bar due to the slope alone. Here, 0.3 or 0.4 would be quite sufficient," explains Chabir. Compared to drip irrigation, the required water pressure is lower, which also saves energy, even if a pump is needed on flat terrain. "Soon we'll add a photovoltaic system, and then we'll be completely independent," he says.

How much water do the plants receive and how often?

Depending on the age, type of plants and soil conditions, crops are irrigated at a rate between once a month and once a year. Unlike other systems of subsurface irrigation, which continuously deliver *small amounts of water throughout the soil along hoses*, the diffuser provides a large amount of water in a short time and only in the immediate vicinity of the roots. The amount of water depends on the frequency of irrigation. In the case of quarterly watering, a quarter of the annual amount is given, and in the case of annual watering, all at once. The total amount of water is about one-third of what is used in a drip irrigation system.

When it rains, it rains too late and too hard

When Sami Chabir looks out over his neighbor's field, at the trees planted in the 1980s, he sees not only the consequences of the lack of water, but also a round patch of weeds at the base of each tree—the result of drip irrigation. He, on the other hand, doesn't have to weed, and doesn't have other pests. This saves pesticides and labor. Because the soil surface stays dry, no weeds can sprout. And there's another advantage to the underground system: because water doesn't constantly flow through the hoses, they last longer. "Otherwise, when it's over 40 degrees in the shade, wild dogs or wild boars always come in the summer, and they're thirsty. They can smell the water, and they bite the hoses."

Along with olives and citrus fruits, Ahmed Ayed also cultivates other fruits such as guava.

As Ahmed Ayed stands on his piece of land on the Cap Bon peninsula in northeastern Tunisia, a good 300 km north of Chabir's olive plantation, a hard rain begins to fall. A cold wind sweeps across the still-exposed hillside. It's mid-November.

"Way too late. This is only the second rain since March." Normally, northern Tunisia gets its first heavy rains in September at the latest, but for several years the small North African country has increasingly suffered from recurring, long periods of drought. One hot summer has followed the next.

Learning from mistakes

Ayed decided to change his life during the first lockdown in the Corona pandemic. "I was maybe a little late—not understanding until I was 50 that you can't go on like this. But at least my kids will learn." The textile engineer from the capital Tunis, a two-hour drive away, wants to build a new life here near the village of Aksar and become self-sufficient, producing his own energy and food. He started by fencing off a small piece of his land and installing underground diffusers.

"Not everything worked out as expected. I'm self-taught, a beginner," he says. He has planted almonds, apple and pear trees, olives and guavas, and of course various citrus fruits typical of the region. "The kiwi I didn't plant deep enough. That didn't work. I'm trying them again at home in a pot." In addition, he said, the trees grew so quickly over the summer that the original amount of water wasn't enough the next time they irrigated three months later. "I had given 50 liters per tree in June, which was too little." That's when he had to add 100 liters outside the predicted schedule, he said, because he had originally miscalculated. "I should have given 150 liters to the olives from the beginning and 450 liters to the citrus."

Planting is almost complete in the first field, and soon work will begin on a second.

Logging becomes cheaper than irrigation

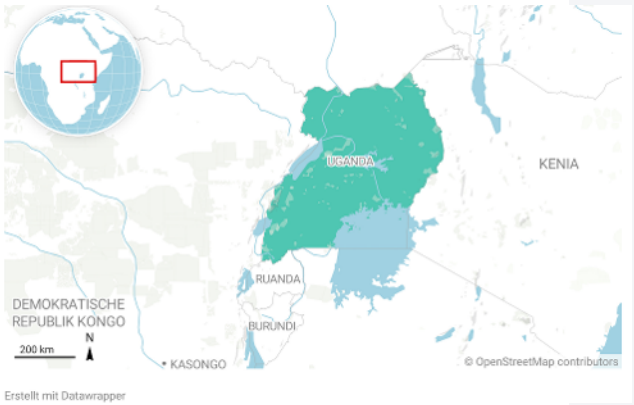
Empirical data on irrigation rates for fruit trees, unlike olives, are still scarce for the underground diffuser. "Citrus trees need a lot of water. I researched on the internet how much they need at what size, and then reduced the amount by two-thirds, because nothing evaporates. That's how Mr. Chahbani explained it." And that's how it worked, he says: The plants that survived his rookie mistakes are now thriving.

As extreme weather conditions increase, so does the market

for the underground diffusers: In Tunisia, traditional rainfed agriculture is failing in more and more places. This affects some 800,000 hectares nationwide, almost half of the land used for fruit and olive cultivation. "Some of the farmers here at Cap Bon are already cutting down their olive and citrus trees," Ayed tells us. For them, it is more profitable to sell the wood than to irrigate the trees. Meanwhile, prices for olive oil are rising rapidly. "Fourteen, 16, 18 dinars per liter. In a few years it could be 30," he fears. The winter harvest for peas is also likely to fail this year. These have to be sown by October 20 after the first rains. But this year it didn't rain until November. After the heatwave summer with crop failures, two of Ayed's neighbors now also want to use the diffusers.

"In Uganda there was a terrible drought, especially in the northeast, in Karamoja, where more than 200 people are reported to have died as a result."

Mpindi Abaas, Journalist/Community member, Uganda



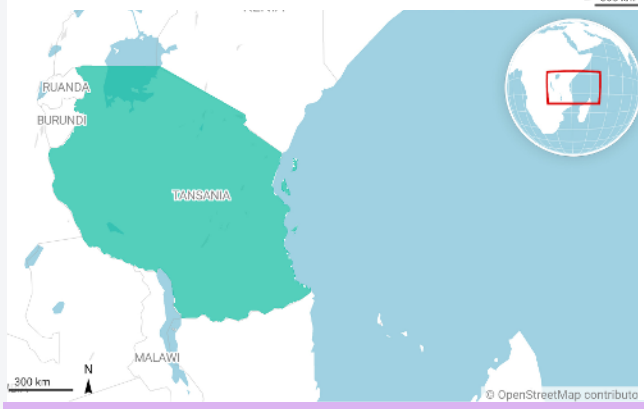
When it does rain, it often leads to flooding because the soil is so dry that it cannot absorb the water. Although there are hundreds of micro reservoirs in northern and central Tunisia, in winter, they are not used for irrigation and the surplus water is discharged into the sea. As soon as it gets warmer and the water is needed, it quickly evaporates. "Tunisia loses large amounts of available fresh water this way," explains Bellachhab Chahbani. It may seem contradictory at first glance, he says, but it is best to irrigate during the rainy season. If the excess rainfall were collected and used for underground irrigation with the diffuser, the trees could easily survive the summer with the available water capacity. This could also be practiced in other regions, for example in sub-Saharan Africa, where floods alternate with periods of drought

"The security problems we face can be traced back to the drought in northern Nigeria. It leads farmers and herders to fight over fertile land."

Aishatu Ella-John, Policy and advocacy Development worker / Community Member, Nigeria

"As the rains decrease and the droughts get worse, they want to look for other methods like desalination. But that is expensive and not possible in all areas."

Nour Trabelsi, Student / Community Member, Tunisia



"Currently Tanzania is suffering from a lack of rainfall, which affects water resources. The problem also affects the power supply, since our production is largely from hydroelectric power plants."

Robert Katikiro, Employee of an NGO / Community Member, Tanzania

What studies and empirical data are available?

Data are available mainly from olive cultivation, and occasionally also for dates and fruit trees. These are all positive, not only in terms of yield but also in water and energy consumption—and the associated cost savings.

In scientific studies in Tunisia and Qatar, the system was tested during the cultivation of *tomatoes* and *peppers* in greenhouses. It was compared with other irrigation techniques in terms of yield, plant health, and salinity of the upper soil layer. Among other things, it was demonstrated that both fungal infestation and root rot in the tomatoes were significantly lower compared to drip irrigation. In the case of peppers, the yield was the same as with drip irrigation, but significantly less water was used and the soil quality improved. Other field trials with different vegetables such as eggplant are currently underway in Uzbekistan.

Another trial comparing different positioning of the diffusers was conducted in Tunisia *in a date plantation*. Here, a yield increase of 37% was achieved with optimal positioning, although salt accumulation on the surface was sometimes a problem due to the use of relatively mineral-rich water.

Sluggish subsidies

In the agriculture ministry, he is dismissed as a hobbyist, a tinkerer, says Bellachhab Chahbani, half amused, half angry. "I developed the underground diffuser when I was doing research at a government institute. And the institute patented it." So it would seem that the ministry should automatically recognize the technology. The fact that he nevertheless had to fight for years to get the government to subsidize farmers'

use of his system and pay half the costs, as it does for drip irrigation, annoys him. But recently, he says, he has gotten several applications through. He hopes that will make it easier for future users of the system.

Sami Chabir checks the irrigation system that has been installed for the next section of field to be planted.

"Our application was approved a long time ago," Sami Chabir says among his olive trees in Amarat. The ministry's inspectors were very pleased with the result, he says. "It's only that the subsidy has still not been paid." He laughs with a shrug. He doesn't seem really surprised about it, and unlike other farmers, his cousin was able to prefinance the system. Chabir takes some leftover olives off the trees. They are black and small, but plump. They harvested the trees, which were only planted in the spring, for the first time in the fall and pressed oil—as an initial test. Already, the young olives are yielding as much oil as a full-grown tree normally does, he says happily.

How much does the buried diffuser system cost?

A diffuser costs just under 7 dinars, about 2 euros. With four diffusers per tree, the initial investment is between 9 and 12 euros, depending on the soil conditions. For the irrigation of one square meter of tomatoes in the greenhouse, the investment is about 2 euros. In theory, the Ministry of Agriculture in Tunisia subsidizes half the cost of the buried diffusers.

For many of his customers, the installation has paid for itself quickly, in some cases after just one year, says Bellachheb Chahbani—through higher yields, faster plant growth, lower water and energy consumption, reduced need for fertilizers and pesticides, and less labor. In addition, farmers in the south of the country who had to set up desalination plants in order to be able to use the groundwater at all were able to purchase much smaller and cheaper plants than would have been necessary for a different type of irrigation system.

Sales markets outside Tunisia

Chahbani has received plenty of awards for the buried diffuser system over the past two decades, both in Tunisia and at the highest international level, for example from the World Bank, USAID or UNESCO.But these have not yet translated into much interest by farmers in its use.

In Tunisia, drip irrigation dominates the market, and because

of the economic crisis, which has been worsening for years, many farmers are reluctant to make new investments. Today, Chahbani's factory is far below its production capacity of 5 million diffusers per year. "Right now, we produce about 30,000 diffusers a year," he says.

In California, olive growers have been using his diffuser successfully for years. In a pilot project in Uzbekistan this spring, he trained employees of the innovation center there how to use it. The effort was financed by the United Nations Development Program (UNDP). The initial results from field tests are promising, he says. Successful completion of the project after 2 years could open doors for him internationally, Chahbani hopes. He is also eyeing the Gulf states and sub-Saharan Africa. Ideally, the retiree would like to hand over the commercial and administrative work of the family business and concentrate entirely on the further development of the system. The smart version should be ready for the market in 2 years. Then, for example, soil moisture can be measured and sources of error can be detected in the system and monitored via cell phone.

Sami Chabir has already dug more planting holes on the Amarat site. A strip at the edge of the field is still empty. He plans to plant a total of 5,000 olive trees here. For now, wooden sticks serve as placeholders for where the seedlings will be planted. The water hoses have already been laid, so he only has to put in the young trees and the diffusers themselves. He points to the other side of the highway, which is crossed by a narrow bridge. In the distance, an ocher-colored empty field can be seen. "That's another 20 acres, too." Room for 5,000 more trees. As soon as the current field is planted, he will continue there.

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