German researchers directly measure climate change effects using TERENO lysimeters

In Germany, scientists are measuring the effects of tomorrow's climate change with a vast network of 144 METER large lysimeters. The goal of these lysimeters is to measure energy balance, water flux and nutrition transport, emission of greenhouse gases, biodiversity, and solute leaching into the groundwater.

In 2008, the Karlsruhe Institute of Technology began to develop a climate feedback monitoring strategy at the Ammer catchment in Southern Bavaria. In 2009, the Research Centre Juelich Institute of Agrosphere, in partnership with the Helmholtz-Network TERENO (Terrestrial Environmental Observatories) began conducting experiments in an expanded approach.

Throughout Germany, they set up a network of 144 large lysimeters with soil columns from various climatic conditions at sites where climate change may have the largest impact. In order to directly observe the effects of simulated climate change, soil columns were taken from higher altitudes with lower temperatures to sites at a lower altitude with higher temperatures and vice versa. Extreme events such as heavy rain or intense drought were also experimentally simulated.

Georg von Unold, whose company (formerly UMS, now METER) built and installed the lysimeters comments on why the project is so important. "From a scientific perspective, we accept changes for whatever reason they may happen, but it is our responsibility to carefully monitor and predict how these changes cause floods, droughts, and disease. We need to be prepared to react if and before they affect us."

Lysimeters—supersized

Georg says that each lysimeter holds approximately 3,000 kilograms of soil and has to be moved under compaction control with specialized truck techniques. He adds, "The goal of these lysimeters is to measure energy balance, water flux and nutrition transport, emission of greenhouse gases, biodiversity, and solute leaching into the groundwater. Researchers measure the conditions of water balance in the natural soil surrounding the lysimeters, and then apply those same conditions inside the lysimeters with suction ceramic cups that lay across the bottom of the lysimeter. These cups both inject and take out water to mimic natural or artificial conditions."

Researchers use METER water content sensors and tensiometers to monitor hydraulic conditions inside the lysimeters. They monitor the new climate situation with microenvironment monitors and count the various grass species to see which types become dominant and which might disappear. The systems also use a newly-designed system to inject CO_2 into the atmosphere around the plants and soil to study increased carbon effects. Georg says, "We developed, in cooperation with the HBLFA Raumberg Gumpenstein, a new, fast-responding CO_2 enrichment system to study CO_2 from plants and soil respiration. We analyze gases like CO_2, oxygen, and methane. The chambers are rotated from one lysimeter to another, working 24 hours, seven days a week. Each lysimeter is exposed only for a few minutes so as not to change the natural environment."

Moving a lysimeter this big is a delicate process

As noted previously, one TERENO lysimeter weighs between 2.5 and 3.5 tons depending on the soil and the water saturation, so the problem of transporting it without compacting the soil or causing cracks in the soil column caused Georg many sleepless nights. He explains, "We found a truck with an air venting system, which could prevent vibrations in a wide range. We made a wooden support structure, bought 100 car springs, and loaded the lysimeter on this frame. After some careful preparation and design adjustments, I told the truck driver, 'take care, I'm recording the entire drive with my acceleration sensor and data logger so I can see if you are driving faster than I allow." Each lysimeter soil surface level was marked to check if the lysimeter was rendered useless due to transport, and the truck was not allowed to go over a railway or a bump in the road faster than 2 km per hour to avoid the consequences of compaction and cracking.

Problem prevention

Understanding the water potential inside the intact lysimeter core is not trivial. Georg and his team use maintenance-free tensiometers, which overcome the typical problem of cavitation in dry conditions as they don't need to be refilled. Still, this parameter is so critical they installed three of them and took the median, which can be weighed in case one of the sensors is not working. Georg says, "There is a robust algorithm behind measuring the true field situation with tensiometers."

Researchers have free access to the data

Georg hopes that many researchers will take advantage of the TERENO lysimeter network data (about 4,000 parameters stored near-continuously on a web server). He says, “Researchers have free access to the data and can publish it. It’s wonderful because it’s not only the biggest project of its kind, each site is well-maintained, and all measurements are made with the same equipment, so you can compare all the data.” (Contact Dr. Thomas Puetz for access). Right now, over 400 researchers are working with those data, which has been used in over 200 papers.

What’s the future?

Georg thinks 40,000 data points arriving every minute will give scientists plenty of information to work on for years to come. Each year, more TERENO standard lysimeters are installed to enlarge the database. The ones in TERENO have a 1 m2 surface area, which is fine for smaller plants like wheat or grass, but is not a good dimension for big plants like trees and shrubs. Georg points out that you have to take into account effort versus good data. Larger lysimeters present exponentially larger challenges. He admits that, “With the TERENO project, they had to make a compromise. All the lysimeters are cut at a depth of 1.5 m. If there is a mistake, it is the same with all the lysimeters, so we can compare on climate change effects.” He adds, “After six years, we now have a standard TERENO lysimeter design installed over 200 times around the world, where data can be compared through a database, enhancing our understanding of water in an era of climate change.”