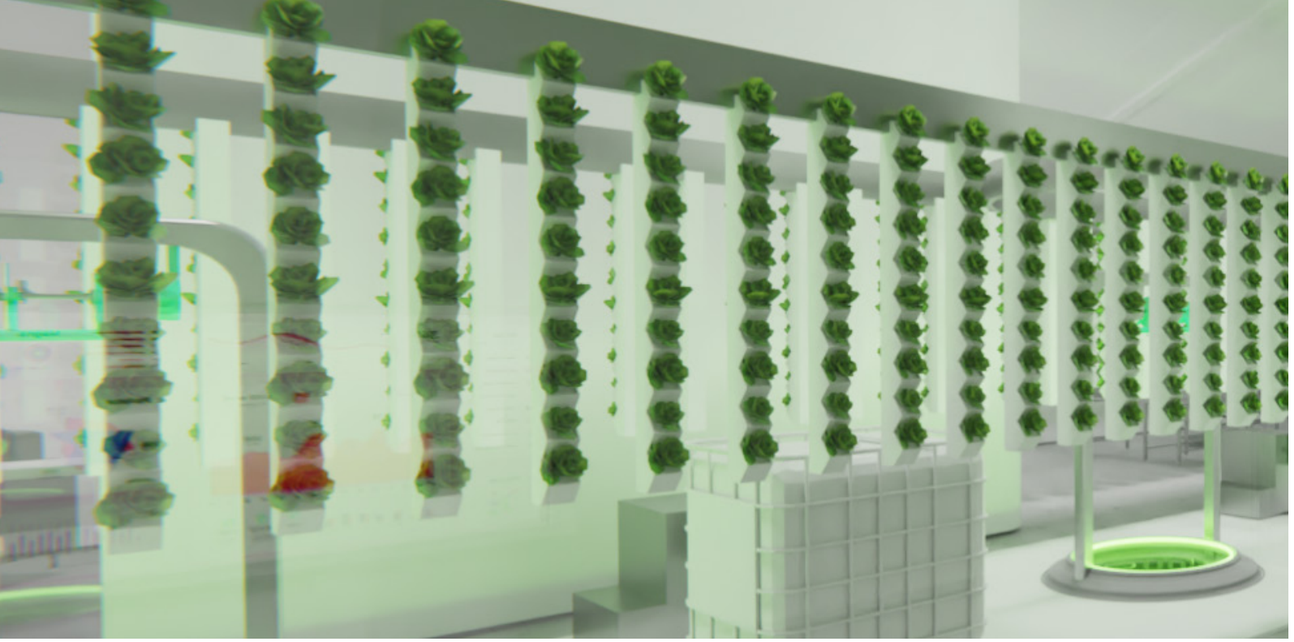
EXPLORE THE POSSIBILITIES

We’re gonna need a bigger farm

Solving global food shortages with subsurface agriculture



In 2022, the population of Earth reached 8 billion and it shows no signs of slowing down its growth - the United Nations estimates that we will reach 10 billion as soon as 2050.

While this population increase is a testament to modern civilization and the advances in healthcare that keep more people alive for longer, it also presents problems. A major one being how to grow enough food for everyone.

Agriculture already takes up 50% of the world's habitable land so it's impossible for it to grow indefinitely in line with the population. And with traditional farming accounting for 70% of global freshwater withdrawals, a water shortage is inevitable at some point if methods remain the same.

Not only is there a limited amount of agricultural land suitable for crops, but climate change is making farming more challenging in some parts of the world. There are already regions where millions go hungry due to unequal distribution, political instability, and environmental changes. If we don't plan adequately for the future, this century could see a gradual spread of food shortages to even the richest, most equal countries. The Earth simply isn't capable of producing enough food for an ever-increasing population.

Not with current farming methods anyway.

What if we weren't limited by the amount of farmland available? And what if we could take the climate and weather out of the equation?

Going underground

GreenForges was founded to combat food shortages by moving agricultural production underground. The idea was initially sparked by much older technology – the water well. This takes up very little space on the surface but provides a steady, regular supply of water. Why not do the same with crops?

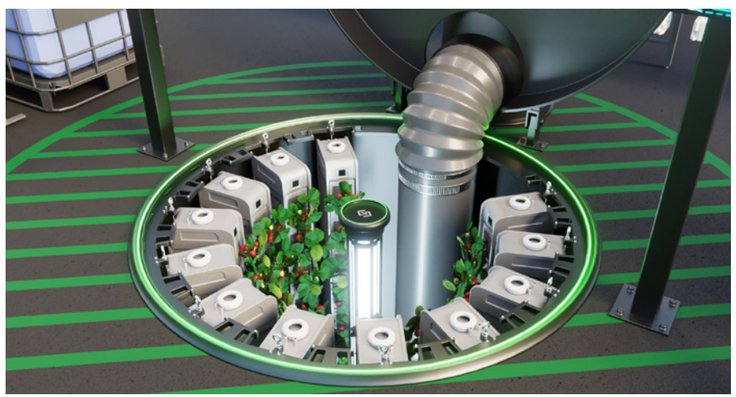
The first designs take their shape from wells – cylindrical vertical shafts with a diameter of 1.5 metres. The current model is 15 meters deep which allows for a surprisingly large number of plants to be grown. These 'forges' are then arranged in a grid system and scaled up as much as needed. Each provides 15 metres of growing space but only takes up 1.5 metres of surface space. Except they won't really be taking up any extra surface space at all as they're designed to be installed within the foundations of buildings. So as the population grows, we can increase both living space and agricultural output at the same time.

The casing of the forge is made of specially coated steel that is non-corrosive, antimicrobial, and light reflective. It uses a hydroponic system – water mixed with nutrients and oxygen – in a continuous loop system. Nutrient and oxygen levels are constantly monitored and replenished while at least 90% of the water is recycled back into the system. Not only does this save on water usage but it also creates a barrier to prevent pest contamination.

Temperature and light are fully managed too, giving much more control over plant growth – harvest cycles can be expedited, and more precise and refined flavours can be developed. So, instead of being reliant on the seasons and subject to extreme weather, food production can be maintained at the same levels all year round, whatever is happening in the atmosphere.

Leafy greens and herbs were chosen as the first crops as they require less nutrients, energy, and light, and have faster harvest cycles. They also tolerate variations in the environment much better. This means that GreenForges can iterate on their design much faster, regularly improving the overall performance of their structures while still having a high production success rate.

"In the first two weeks of growth, we assume almost no humidity generation," says CTO, Jamil Madanat. "Evapotranspiration is very low and then increases exponentially in the majority of crops . Also, at different sizes, these crops breathe differently and have different humidity, temperature, and light requirements. Leafy greens and herbs have a much narrower window of variation, so they are easier to work with initially. As we validate each type of crop, we will be able to gradually build on top and add a wider variety."



Simulation-accelerated development

So how did GreenForges go about developing their solution?

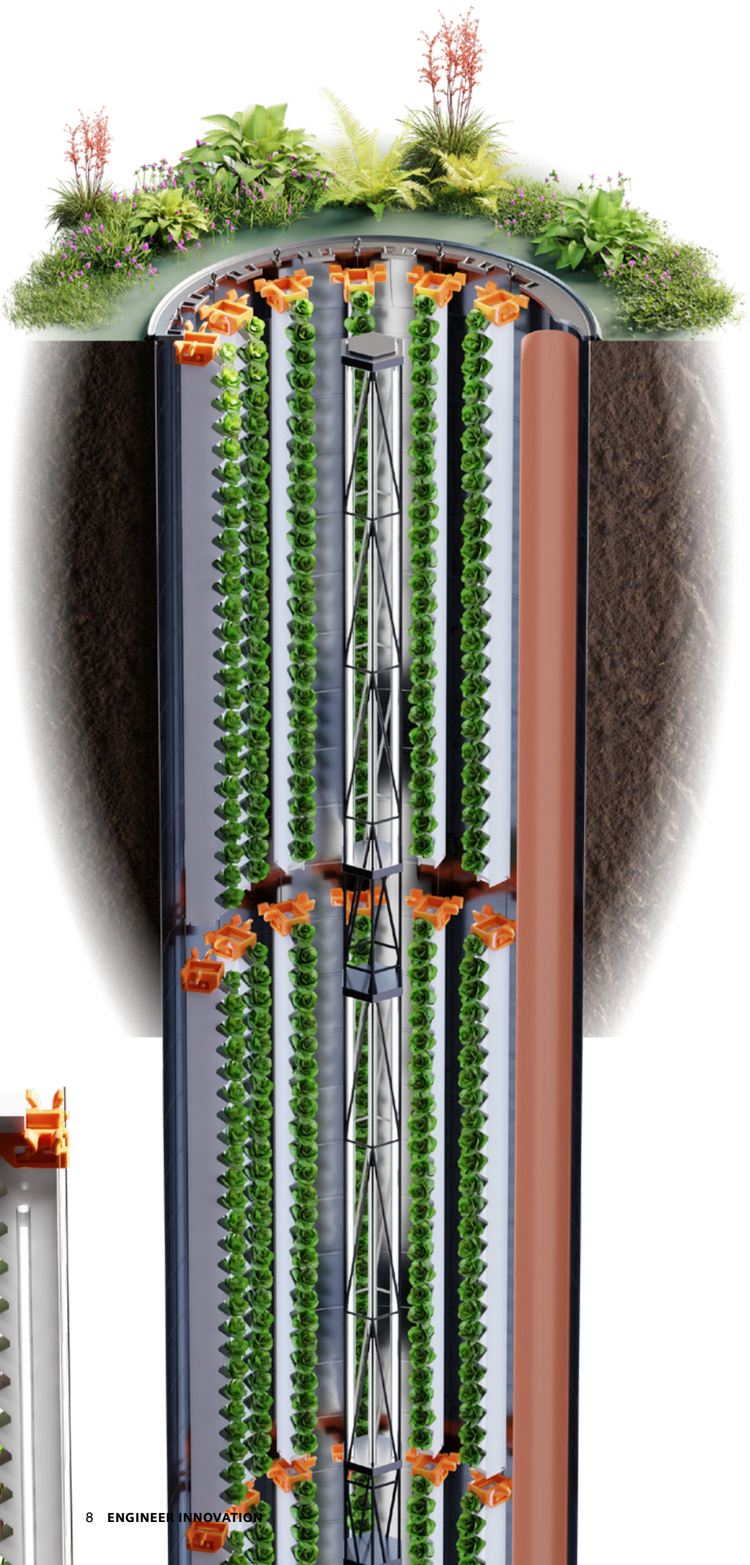
Madanat explains that they split the design into structural, mechanical, electrical, and digital systems. "The biggest challenge was in creating the climate control system," he says. "It must be very finely tuned, especially as we expand to a wider variety of crops. We need to understand how heat transfer happens at different soil levels, with different soil types, and in different humidities."

Of course, they couldn't dig hundreds of holes to experiment on – that would be far too inefficient and costly. So, they utilized simulation to refine and optimize the design before anything went underground. As the simulations were so complex, Madanat turned to Siemens partner Maya HTT for their expertise.

Using Simcenter 3D, Maya HTT created virtual prototypes of the thermal and flow interactions within the forge. Specifically focused on energy efficiency and water usage, they predicted the cooling load based on both the conduction to and from the surrounding soil and the heat caused by the lighting.

Carl Poplawsky, engineering services manager at Maya HTT, explains that "you have a temperature gradient as you go down below the surface until the earth reaches a relatively constant temperature. So, you need a heating, ventilation, and air conditioning (HVAC) system to control the temperature and remove the condensation that collects at the bottom."

Simcenter 3D can accurately predict the condensation that collects on the walls as well as the relative humidity distribution throughout. So, Poplawsky and his team were able to simulate all of this to inform the optimum design of the forge before anything was manufactured. "The great thing is that it doesn't require any additional coding," he says. "Straight out of the box the



software can handle temperature gradients and humidity distributions. So instead of drilling hundreds of holes to test on, we're drilling all the holes in a virtual environment and simulating the thermomechanical performance flow performance. GreenForges then only need to drill a couple of actual holes because they'll have a much higher probability of success thanks to the virtual prototyping."

Combined expertise

It's been a close-knit collaboration between Maya HTT and GreenForges. Madanat and his team are the experts in the mechanics of underground farming – they provided Poplawsky's team with all the necessary boundary conditions: the cylinder of earth that each forge sits in, the heat dissipation of the LED lights, the transpiration of the vapour from the plants. Maya HTT then created the simulations that show how all the parameters interact. They can then change the locations of elements such as air ducts, inlets, and outlets in the virtual environment, and simulate how this will affect the performance of the HVAC system.

The simulations found that the effectiveness of the underground farm is heavily dependent on both the soil type and the amount of moisture it contains. It was important to understand how the size of the earth domain around each forge would affect the performance, so a full analysis was carried out to show the temperature with a certain size of cylinder. This also informed how close together the forges could be placed without impacting each other.

As well as predicting the temperature at different depths, the simulations needed to produce a velocity profile of the air. The air pumped around the forge by the HVAC system can't travel too fast as it would tear the leaves off the plants. You can set the force with which it is pumped down the forge, but then you need to understand how fast it will come back up. By accurately predicting this, the simulations can show if the design needs to be adjusted to limit the speed to protect the plants.

First the Earth, and then?

When you start to think about all the possibilities that underground farming offers, it's incredibly exciting.

Consider the acres of farmland currently required for growing crops. If you can move a significant proportion of this below cities, then all that freed-up surface space can be regenerated.

By installing farms within the foundations of buildings, urban development will have a linear relationship with increased agricultural output. Homes of the future could be completely self-sufficient – not only powering themselves with solar energy but providing all the food their residents need. This would also cut the energy consumption of supply chains that transport food from farms to shops and houses.

With stable temperatures beneath the surface, inhospitable areas such as deserts, mountain regions, and extremely cold regions could become food production powerhouses. Communities in these areas will need to rely less on importing food and become healthier and wealthier. There will be no need to sacrifice forests and jungles to create space for traditional farms.

And if this can be successfully proven on Earth, why stop there? With the exploration of the Moon and Mars targeted over the coming years, it seems only a matter of time before off-world colonies are created. Keeping them fed will be one of the biggest challenges, but if they can grow their own food underground that will be one less thing to worry about.

As long as we need food to survive, innovative farming solutions such as this will be vital to life on Earth and beyond. Visit www.greenforges.com for the latest developments and to find out when your food could be coming directly from under your floor.