Khalifa University Science and Tech Review

A quarterly science magazine published by Khalifa University

The Agtech Issue

GROWING GREENER

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Autonomous machines could be the new farmworkers of the sea — **P06**

Feeding tomorrow

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Khalifa University Science and Tech Review

KUST Review is dedicated to publishing authoritative, reliable and accessible information about science, innovation and technology news and trends. Although we report on news from around the world, we highlight advances, innovators and topics of interest from the Middle East and North Africa region. Our mission is to spread knowledge of and enthusiasm for science and technology in the Arab world and beyond through responsible and trustworthy journalism.

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LETTER FROM THE EDITOR

When we think about technology we usually think about the shiny, sterile tech of science-fiction films and clean rooms, all smooth white walls and chrome fixtures.

But one of the most important areas of technology innovation is anything but shiny and sterile: It's the earthy, fertile technology of producing healthful food for growing populations in a challenging era of climate change.

Agricultural technology – or agtech – is especially important in the Middle East, where clean water is scarce and farmable land is also in short supply.

The United Arab Emirates currently imports about 85 percent of the food it consumes. In 2020 its imported-food bill was about U.S.$14 billion, up from the nearly U.S.$10 billion it spent in 2010.

Supply-chain problems of the COVID-19 epidemic put in sharp relief the need to reduce that dependency on imported foods with more homegrown products. And innovators are stepping up to help this desert nation cut short that sometimes fragile and always energy-hungry import chain.

In this issue we look closer at some of the emerging technologies and strategies to bring food production home without straining precious resources.

Senior science writer Jade Sterling investigates the challenges of producing food as temperatures rise; editor Suzanne Condie Lambert checks in with researchers who work with the robots that help run aquaculture farms; and science writer Maggie Kinsella reports on vertical farming.

We also have more of the stunning images and design you've come to expect from KUST Review. You'll find even more in these pages, on our website, www.KUSTReview.com, and on Facebook, Instagram, LinkedIn, X and YouTube @ KUSTReview.

So page, click, subscribe and follow to get the best of our coverage of science in the Middle East and around the world in English and in Arabic. As always, be informed and stay curious.

Dr. Arif Sultan Al Hammadi
KUST Review Editor-in-Chief

IN THIS ISSUE

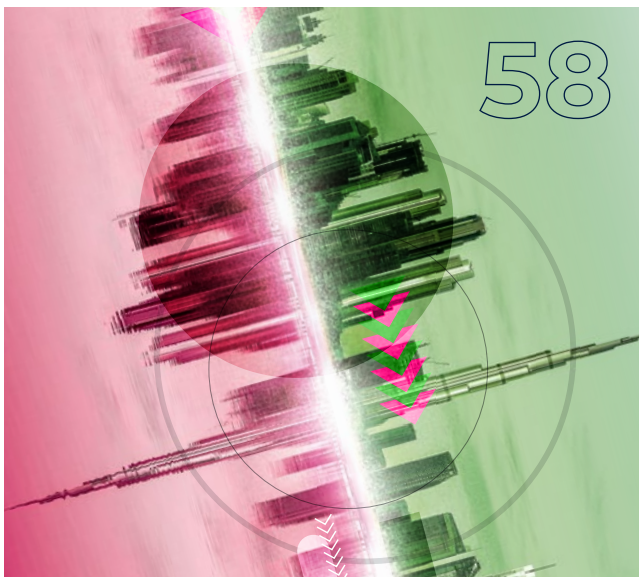
GROWING GREENER

Technology affects individual lives in many ways. But you can't get much closer to home than agricultural technology – which is helping to provide the food you eat with less waste and stress on an already burdened world.

In this edition of *KUST Review* we look at some of the ways farming is changing, from getting more of our groceries from the oceans to growing plants on shelves indoors.

You'll also find stories about how sustainable cities of the future must look to nature and how microgravity can help us build better medicines.

REGULAR CONTENT

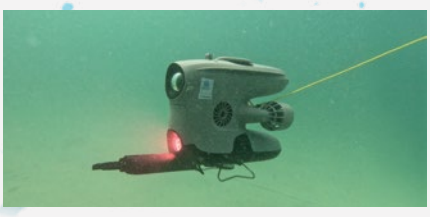


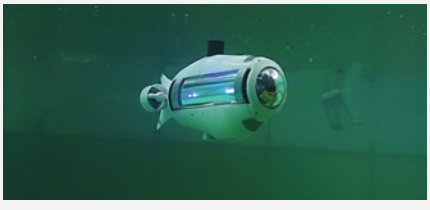
AQUA BOTS

Autonomous machines could be the new farmworkers of the sea

By: **Suzanne Condie Lambert**

BELOW: Aquabots from Khalifa University





In a world hungry for nutritious food, aquaculture is clearly a winning idea.

It isn't a new one, either. Humans have been farming seafood for millennia. In more recent years, aquaculture has expanded to land-based tanks, where farmers raise fish and other seafood. Those tanks, however, take up increasingly valuable space on land and worsen competition for scarce water and other supplies.

This has more farmers looking back to the sea, where space is abundant and water and nutrients are free. Mariculture, the subset of aquaculture in the open seas, however, presents additional challenges. Traditional mariculture relies on intensive manual labor to clean and repair equipment, monitor conditions, inspect nets and care for the plants and animals raised for human markets.

That kind of manual labor is expensive, requiring trained commercial divers who are increasingly spread thin as aquaculture operations expand. It can also be dangerous work for those divers, particularly as farms move out into deeper and more perilous waters.

Mariculture can also pose threats for the environment, spreading disease, antibiotics and parasites or allowing farmed fish to escape and negatively affect native species. Eleni Kelasidi, a senior researcher at SINTEF, one of Europe's largest independent research organizations, thinks those issues could have a common solution: robots.

Putting a robot into the open water can be a bigger challenge, however, than putting a robot on the land. For one thing, Kelasidi says, it's important that autonomous »»

systems do not harm farmed fish and/or damage the flexible structures. This is both an ethical and economic consideration, she says. The ethical consideration: "We cannot harm any living thing and/or let them to escape from the fish farms." The economic: "The fish are the profit of the industry."

Happy fish

Kelasidi and her team have access to industrial-scale fish farms and operate a full-scale research facility to investigate how robots stress or otherwise affect fish using equipment originally designed for the oil and gas industry. They test systems to see how well they function but also to observe how fish react to, say, different colors, sounds or lights.

The goal is to learn what stresses fish and ensure healthier fish stocks and better profits. Another challenge for researchers, she says: making remote operating vehicles "more clever." Humans on the surface currently perform many aquaculture jobs using remotely operated machines, she notes.

"Our job is to cut the dependence from the humans to get the robotic systems to operate themselves. They need to understand their environment and make sure they don't collide with structures," Kelasidi says.

'An exciting frontier'

Self-operating aquatic systems is an issue Lakmal Seneviratne, director of the Center for Robotics and Autonomous Systems at Khalifa University, is working on as well, and he's optimistic. "It's a very exciting frontier in underwater robotics," he says, noting that 70 percent of the Earth is water but humans have explored only 5 percent of that.

Seneviratne and his team are also working on land-based agricultural robots such as "dogs" that can step lightly between rows of crops; "hands" that can gently pick fragile fruits; and robots on rails that can move up and down a field to monitor individual plants for signs of disease or readiness for harvest.

But ocean farms present a different set of challenges for autonomous systems. "The problem isn't that aquaculture is very deep, but (maintaining) navigation and control," Seneviratne says, echoing Kelasidi's concerns.

GPS doesn't work beneath the water's surface and robots have to be able to navigate currents and waves without damaging each other or farm structures.

Cameras, to capture images, and artificial intelligence, to sharpen and analyze those images, are important to managing these conditions, he says.

Looking to nature

But being able to see in the murky depths is only part of the issue for mariculture robotics. The machines also need control.

So researchers are looking at life forms already adapted to aquatic environments for inspiration. Although not specifically designed for aquaculture, the biomimicry could prove useful in ocean farms.

Among the ideas: A team from Harvard and the University of South Carolina in 2021 presented the Finbot, which uses four independently controllable fins.

In 2023, a team from Zhejiang University, China, published results of their Copebot, designed

A UAE TRADITION

Robotics could be on tap to move traditional Emirati fishing techniques into the future.

The robots Lakmal Seneviratne and his team are working on at Khalifa University could eventually be employed to clean and repair hadra – fence traps placed perpendicular to shore – and gargour – fishing traps woven from palm leaves into a semicircular form, he says.

to mimic the copepod, a small crustacean known to escape from predators with explosive jumps.

Their bot, they report, was able to leap out of the water, land on a small pad, transmit data and jump back into the water.

Back at Khalifa University, meanwhile, researchers have other ideas.

"Looking at aquatic environments, many animals evolved flexible or completely soft bodies to improve their swimming capability and adaptability to the intricate underwater world," says Federico Renda, who heads the team.

"For instance, octopuses can squeeze into small apertures to hide or catch prey, and jellyfish developed the most efficient locomotion strategy of all.

"In my team, we take inspiration from soft creatures to build new underwater robots capable of replicating these functionalities while understanding the physical principles involved."

One of KU's designs mimics flagella, the whiplike structures that propel bacteria through liquid to solve another issue with underwater robots: Many are tethered.

While the tethers allow the machines to be operated from the surface, they can also become tangled together.

"Recently, we have developed an untethered underwater robot inspired by flagellate microorganisms capable of efficient and safe locomotion in close proximity to sensible underwater habitats," Renda says.

"Furthermore, each flagellum can be used as a coiling gripper in addition to propulsion, achieving redundancy and multifunctionality, which can significantly simplify underwater operations."

To test robots' ability to navigate choppy waters, Khalifa University built a wave pool that simulates currents.

Stanford University's Oussama Khatib recently used it to run Ocean One, a humanoid robot designed to perform such tasks as monitor coral reefs and offshore oil rigs, through its paces.

SINTEF's Kelasidi would like to see robots replace human divers or assist them on highly risky operations. Seneviratne likewise expects robots to allow human divers to inspect more often and longer. "We see robots as helping divers instead of replacing them," he says.

> **"We see robots as helping divers instead of replacing them."**
>
> — Lakmal Seneviratne

ILLUSTRATION: Abjad Design

Aquaculture's promise and challenges

As the world's population grows and climate change puts more pressure on traditional terrestrial farming, sustainable aquaculture could play a key role, says Naveed Nabi, an assistant professor at Chandigarh University.

"In the present times, when food security is a matter of serious concern, aquaculture has played a key role to mitigate this crisis, supplying about 178 million tons of food in which 20.2 kg per capita is destined for human consumption," he says.

"Aquaculture not only adds resilience to the global food system through improving resource-use efficiencies, but also by diversifying the farmed species."

But he warns that farmed fish present challenges to the environment including fish escapees that harm native species and the spread of disease and parasites.

There's also the issues of eutrophication, in which water becomes overloaded with nutrients, leading to deadly algae blooms; antibiotics in the environment through unconsumed food or fish waste; and threats associated with pesticides.

PHOTO: Shutterstock

RESPAWN

One person's biological trash is researcher's treasure

By: Peter Corridon

Graphics: Abjad Design

My day job can be kind of gross: I'm trying to develop decellularized tissue scaffolds that can be used to make bioartificial tissues. Let's break up "decellularized": "de-" means to remove, and "cellularized" refers to the basic building blocks of tissue structures.

We have a process through which we can remove these cells, leaving behind scaffolding material upon which we can grow bioartificial tissues. Think of it as moving out of your apartment: You'll take all your furniture, but you won't take the walls with you.

We're not just doing this for fun. (It's fun for me – I quite enjoy it.) These decellularized scaffolds can be used in beneficial ways, particularly as scaffolds for transplantable organs and as supercapacitors. Do you know how big a camel's brain and internal organs are? You could fit a lot of energy in there.

I mention camels because we're not generating these tissues from humans. Instead, my team has turned to the idea of repurposing slaughterhouse waste. In the UAE, at least, most of the animals going to slaughter are cows, sheep, goats and camels.

Using slaughterhouse waste to create value-added products is not a new idea: Plenty of research has investigated making biomaterials, fertilizers, biogas and feeds, but we're among the first to consider using this agro-food waste for xenotransplantation and energy-extraction models.

We're not suggesting direct transplantation (you don't want sheep eyes or kidneys, and a camel brain wouldn't fit in your skull) but rather breaking these organs down to their scaffolds and building patient-specific human tissues on top.

Slaughterhouses produce billions of tons of waste that must be discarded or recycled, often at considerable cost. Turning some of this waste into bioartificial tissues and organs can create the basis for industrial-scale efforts that drive circular bioeconomic sustainability and support health-care needs at the same time. There are many more people waiting for organ transplants than there are organs to go around.

I'm not saying it's easy to make transplantable organs from animal bits and pieces. There's a lot to consider, from mimicking native integrity to ethical considerations. But theoretically, I should be able to decellularize a camel kidney, take some of your stem cells, and grow functional kidney units just for you on that camel scaffold that your body could potentially accept, given advances in gene-editing technologies like CRISPR. We're still working on it.

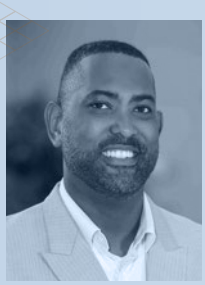
The other thing we're working on is the idea of organ battery packs. It was a bit misleading of me to suggest camel brains for battery storage — we actually use the bones. Maybe the camel skull would have been more accurate.

Supercapacitors have significantly higher capacities than traditional battery systems as well as rapid charge-discharge rates, and low internal resistances. They make great energy-storage systems, particularly in implantable medical devices. Think pacemakers or smart implants.

Supercapacitor structures are made of porous carbon materials due to their high surface areas, availability, electrical conductivity and low costs.

We can make these carbon materials from agri-food biowaste products. Animal bone residue makes excellent electrodes, and using these slaughterhouse leftovers could constitute a renewable carbon source, if not a vegan one.

But for as long as people around the world eat meat, there will be slaughterhouse waste. Our research is using this in a positive way, using each part of the animal. Nothing need go to waste.



Peter R. Corridon is a member of Khalifa University's Department of Biomedical Engineering and Biotechnology and has a Ph.D. in medical biophysics and biomolecular imaging from Indiana University School of Medicine.

GRAPHICS: Abjad Design

WHEN IT COMES TO BIOFUELS, IT MIGHT NOT GET MUCH GREENER THAN ALGAE FROM THE SEA

By: **Maggie Kinsella**

Historically, kelp was harvested and burned to create potash for gunpowder. But now the world is looking to kelp to sustain life — not take it away.

Energy-producing biomass crops typically include soybeans and corn, but the largest subgroup of seaweed also could prove to be a rich resource.

New studies show that giant kelp has potential as the latest in biofuels.

Giant kelp forests are abundant along North America's West Coast as well as southern oceans near South America, South Africa, Australia and New Zealand, and are home to a large number of marine animals and birds.

The billowy algae resemble land forests, like trees towering over the ocean floor, and they typically grow in environments with ample sunshine at the ocean surface and rich in nutrients.

Giant kelp, *Macrocystis pyrifera*, is also one of the largest species of marine algae in the world. It grows quickly; has blades that grow along its entire stem; and can add more than 30 centimeters of leafage daily, sometimes reaching nearly 53 meters. These advantages make giant kelp a clear biofuel winner.

BUT WHY KELP?

It's simple: Kelp grows in the oceans. Currently, 8 percent of agricultural land goes to producing crops for biofuels.

These land crops also require water and can be carbon intensive due to farming and fertilization.

Kelp, on the other hand, takes up no land space, eliminates competition for fresh water and requires no harmful fertilization processes.

Additionally, its low cellulose content and lack of lignins — natural compounds found in plants that give them strength and structure — make it easier to process.

In a 2021 paper in *Bioengineered*, a group of researchers from India and Saudi Arabia foresaw a huge potential for macroalgae as a sustainable biofuel source. The team also identified problems, however, such as seasonal changes in kelp's biochemical values and unpredictability in harvesting enough kelp for the process.

Harvesting coastal macroalgae would also affect the vast array of marine life protected by kelp forests. We would effectively be assisting life above water but harming it below. Removing these coastal forests, then, is not an option. So, let's try growing kelp on farms in the open ocean.

This, however, is tricky business. The trifecta for growing kelp is sunlight, something to anchor to and nutrients that are available near coastlines but not in the surface waters of the open ocean. But how do we give a kelp farm all three in deep, open ocean? »»

Build an underwater, drone-guided elevator, of course. The idea of growing kelp in the open ocean isn't new, but the method of growing it is. Howard A. Wilcox of the United States Navy first proposed the idea in the 1970s, but it was abandoned along with the entire concept of biofuels when oil prices fell after the decade's energy crisis ended.

Now Wilcox's son Brian, co-founder of American company Marine BioEnergy, is picking up where his father left off. Marine BioEnergy developed a method to grow giant kelp in open ocean waters and partnered with a team of researchers at University of Southern California Dornsife's Wrigley Institute for Environmental Studies to test it.

Going up

The test was carried out by an anchored buoy system that acts as a kelp elevator, but the real-deal commercial ocean kelp farms would involve a drone submarine attached to the farm, towing it to make sure the kelp gets what it needs, when it needs it.

The method, known as depth-cycling, aims to let the kelp access surface sunlight in the daytime hours and nutrients of cooler, turbulent, deep waters at night when the "elevator" drops below the thermocline — the layer separating the warmer and cooler waters — to 274 feet. The depth can vary depending on location.

A major concern that usually accompanies any marine exploration or experimentation is the effect on the environment, but these farms are moving to access the nutrients, not surfacing the nutrient to feed the farms. This means no adverse side effects like algae blooms.

Fuel from sugar

Sugar batteries aren't new. This form of biobattery generates an electric current by oxidizing glucose. Khalifa University, however, is looking to couple the chemical process of artificial photosynthesis with a biofuel cell, creating a form of closed-loop circuit.

The output of the artificial photosynthesis would be oxygen and a higher chemical (such as sugar), while the input of the sugar fuel cell is oxygen and sugar. The combination would close the loop: The sugar biobattery releases CO2 and water, which in turn feed the artificial photosynthesis unit.

Creating an integrated power-generation device using artificial photosynthesis presents several challenges, including performance optimization, device design, reaction dynamics and intermediate formation, says KU's Ahsan Ul Haq Qurashi. "A multidisciplinary approach is crucial to tackle these challenges, integrating advanced materials and prototype engineering to create an efficient and effective system."

They would also dive to avoid ships and threatening weather and are designed to protect marine life. Acquired nutrients would be returned to the thermocline via a tube from harvesting ships. The researchers in the test case found that the depth-cycled kelp grew 5 percent daily while the control group grew 3.5 percent.

Also of note: Even though kelp as a fuel source will ultimately release carbon into the atmosphere, that carbon is only what it had already absorbed from the ocean, completing the carbon cycle and achieving carbon neutrality.

"Looking forward, we expect that carbon-neutral energy for all applications will be met with a combination of kelp/biomass fuels, wind, solar, hydroelectric and other technologies, depending on local conditions," says Cindy Wilcox, president and co-founder of Marine BioEnergy.

Can kelp power the world?

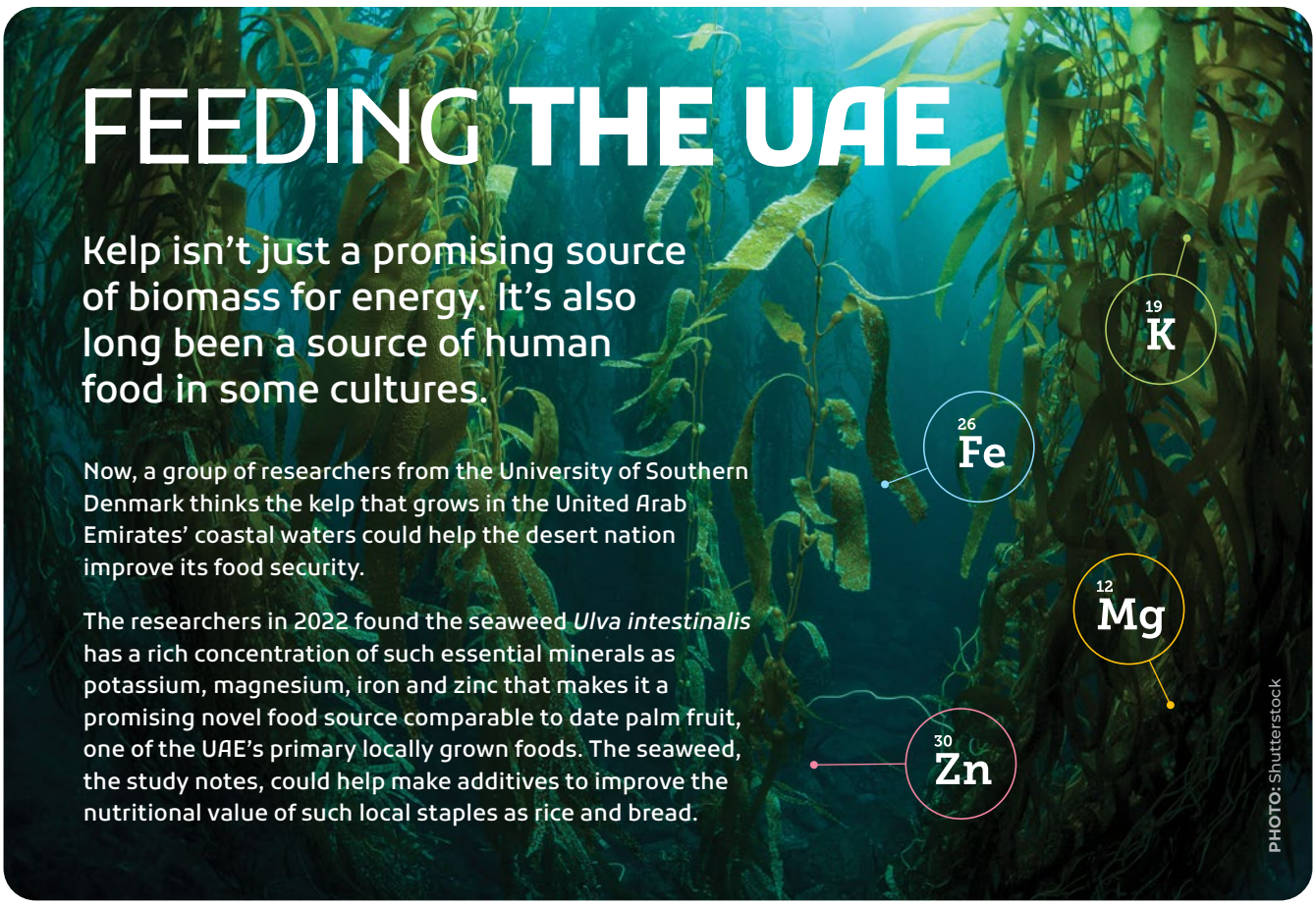
Electric options for long-haul vehicles are limited. Batteries last only so long. They are also heavy, which means decreased load capacity. Liquid fuel, then, is still in high demand.

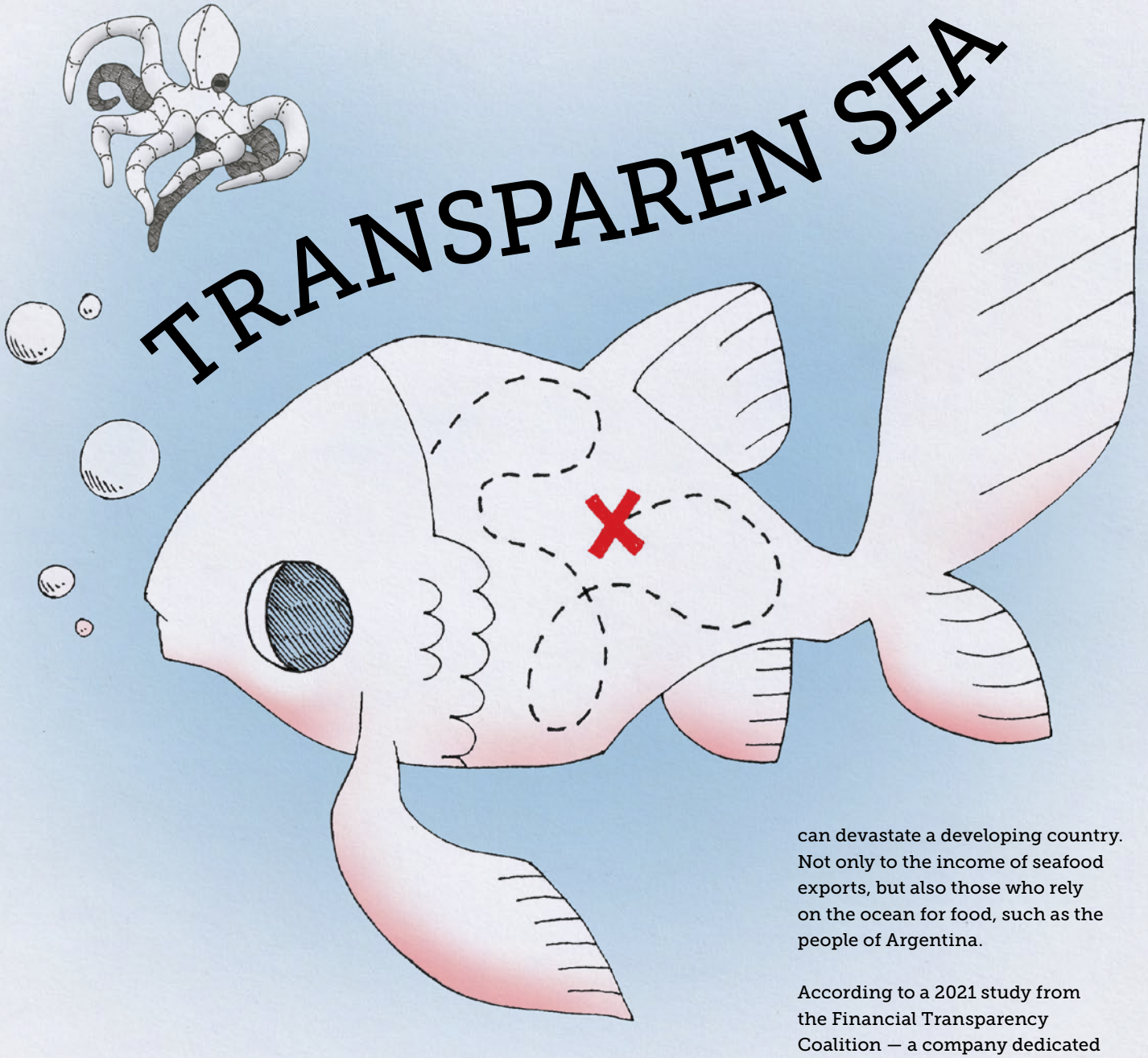
"With 0.5 percent of the oceans under cultivation, we can supply feedstocks for all long-haul vehicles worldwide," Wilcox tells *KUST Review.*

But it's not just for vehicles. Giant kelp can also be digested into methane to power the spinning generators of the electric grid on days of low wind and low sun, she says. Open-ocean kelp farms have the potential to utilize massive open ocean areas to supply an energy feedstock sufficient for the projected peak world population, according to Marine BioEnergy.

There's still a way to go before the world can count on the "kelp elevator" for sustainable fuel, however.

As a group of Irish researchers noted in a 2020 paper in the journal *Energies*, the technology for creating economically feasible biofuels from macroalgae is still on the ground floor. ●





Traceable seafood adds value to a sustainable food chain

By: **Maggie Kinsella**

ILLUSTRATIONS: Anya Lambert

Tracking things is important. We track our deliveries, luggage and phones. But when it comes to tracking where our seafood comes from, it isn't as easy as slapping an AirTag on a salmon. And tracking that seafood is vital not only to economies but human rights and environmental health.

The seafood industry in 2023 was valued at over U.S.$236 billion so the economic impact of large theft can devastate a developing country. Not only to the income of seafood exports, but also those who rely on the ocean for food, such as the people of Argentina.

According to a 2021 study from the Financial Transparency Coalition — a company dedicated to transparency in financial and tax systems — Argentina's waters are plagued with illegal operators.

An estimated 500 vessels are illegally fishing in its waters, and Argentina doesn't don't have the resources to police it.

This equals U.S.$2 billion to $3 billion annually in losses for the country. Globally the annual economic impact is between U.S.$10 billion and $36.4 billion.

Illegal actions might be vessels operating in sovereign territorial waters without permission or a vessel that is legally flying that state's flag but not operating within its laws. Unreported fishing constitutes not only failure to report but misreporting catch volume. Unregulated fishing is any fishing activity outside of conservation regulations or where there may not be regulations in place, but activity is carried out against international regulations that protect not just economies but ocean health.

Nature Middle East reports that fish off Egypt's 1,000-kilometer coast stretching from Palestine to Libya are dangerously overexploited, threatening the health of all marine life in the Mediterranean. Despite making up just 0.8 percent of the world's oceans, the Mediterranean contains 4 to 18 percent of known marine species.

Myriam Khalfallah, who led the study for the Sea Around Us initiative at the Canadian University of British Columbia and the Arab Academy for Science, Technology and Maritime Transport in Egypt, recommends urgent action to better regulate and monitor fishing activity.

Another issue that puts illegal fishing at the forefront is mislabeling. Mislabeling can take place at any point in the supply chain and can be deliberate or unintentional, which makes it harder to trace. Mislabeled information might be anything from seafood species to product origin. This contributes to health risks for the 6.6 million Americans with seafood allergies. And because mislabeling can obscure the origin of the product, it makes tracking forced labor difficult. Intentional mislabeling often masks illegal fishing.

"Up to 70 percent of the seafood export market is in developing countries. In seafood hubs such as Indonesia, Thailand, Vietnam, the Philippines and Peru, slavery and child labor within the seafood industry are widespread.

"With the global demand for seafood consistently increasing, illegal, unreported, and unregulated fishing has ensued in slavery and human trafficked labor," according to a 2022 study published by PeerJ Life & Environment. With so much money to be made from illegal fishing, how do we make sure the fish was sourced sustainably, isn't mislabeled or wasn't acquired via forced labor? It comes down to data and doing the right thing.

> *"Our fish might encounter primary & secondary processors, traders, wholesalers, dealers, distributors and transporters."*

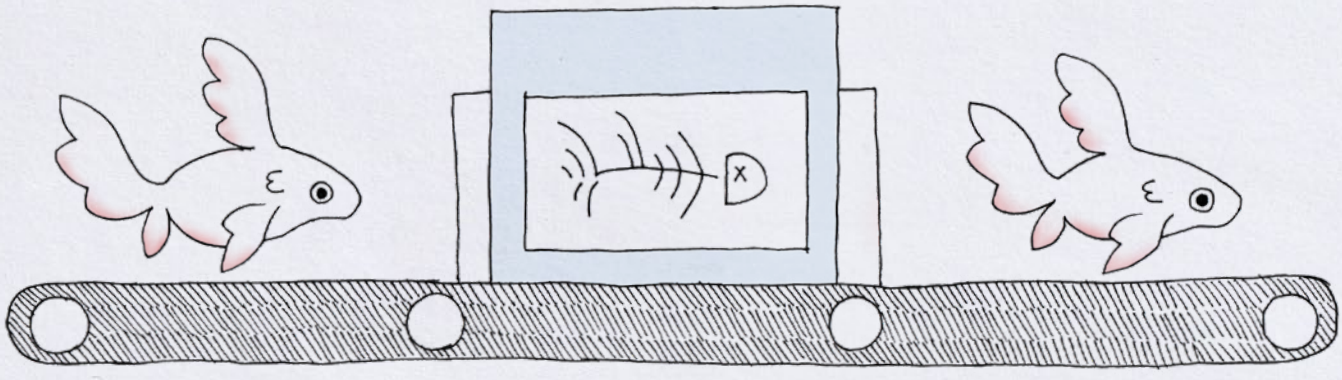
Know your fish

The idea of tracing seafood to ensure regulations are followed isn't new. Its beginnings were paper-based, then digital.

Now technology allows for tracing seafood throughout the supply chain and offers peace of mind to consumers that the fish they're eating was sourced legally, ethically and in line with sustainable practices.

Regulated companies know the journey their product has been on, from ocean to plate, and can share that information with you. A 2021 initiative by five of the world's largest seafood companies called for global regulation and the industry to jump on board.

The United States Food and Drug Administration put this call into action with its Final Traceability Rule, taking effect in January 2026. This requires entities that manage food, anywhere along the supply chain, to provide additional traceability information to those regulations already in existence. »»



How does it work?

One company assisting the seafood industry with traceability is U.S.-based BlueTrace, which offers simple solutions that all but eliminate error along the fishy journey. It begins at the point of catch and concludes with a consumer. In between, our fish might encounter primary and secondary processors, traders, wholesalers, dealers, distributors and transporters.

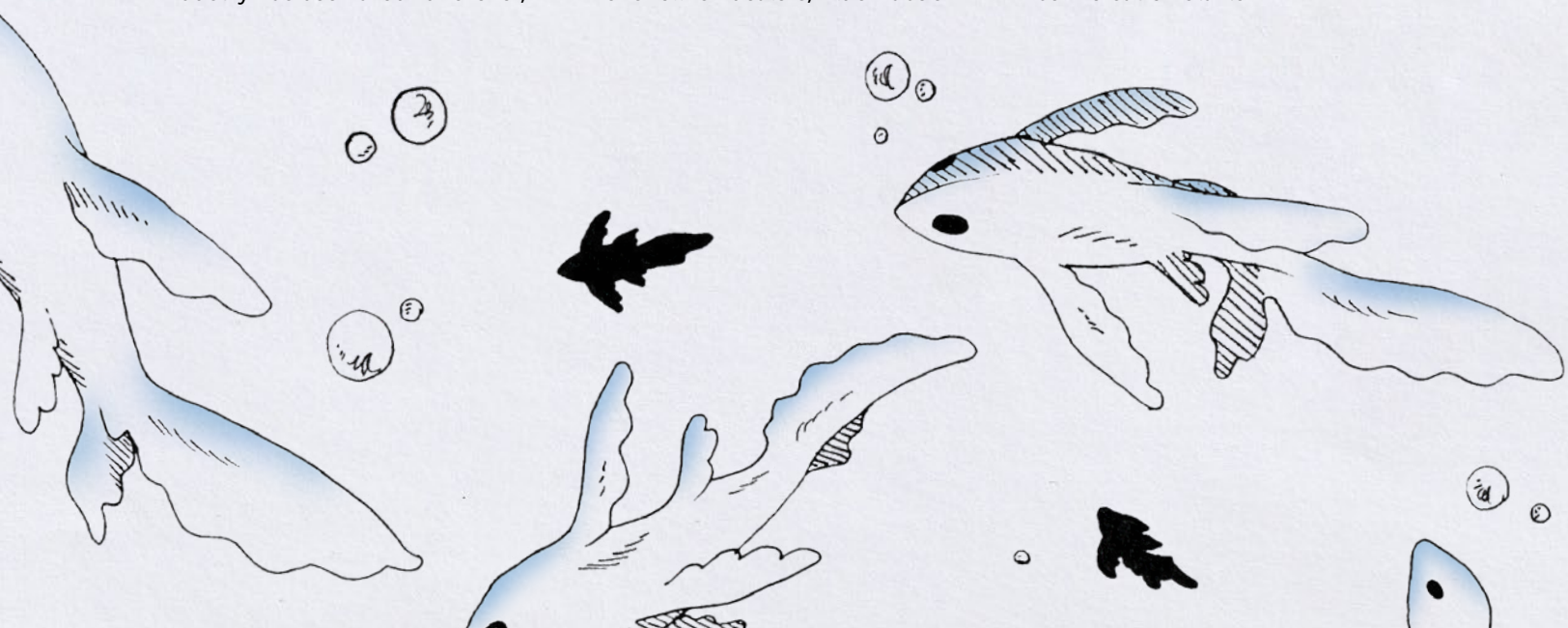
"Regulated companies know the journey their product has been on, from ocean to plate."

The system includes software that can be operated from a mobile phone or tablet in conjunction with an industrial printer that prints spreadsheets, logs and labels on waterproof paper. Labels and tags are equipped with QR codes that receivers, dealers and buyers can scan for details.

Users can also request a PDF that can assist with harvest financial reporting documentation and can be sent on to the receiving end of a shipment to let customers know it's coming. Bonus: All data passed through the app is stored in the cloud.

"Our mission is to simplify the seafood industry," says Chip Terry, CEO of BlueTrace. "The seafood industry has been around forever, and it does a lot of things well, but they are drowning in redundant paperwork," he says. "The lack of visibility into their operations makes it hard for them to scale. Ninety percent of the seafood industry is small to midsize businesses that simply lack reasonably priced tools to do their jobs effectively."

Though the system was designed for shellfish dealers, BlueTrace's over 470 clients use the software to track inventory of species including swordfish, seaweed, groundfish, imported tuna, shrimp and many more. The end of the complicated fish journey might be the salmon en croute you just ordered on your date night. So, the next time you order fish, have a look on the table or menu for a QR code — the story of your dinner might serve as a great conversation starter.



Dubai-based tech developer **provides transparency to the seafood industry**

The seafood industry is wracked with illegal, unreported and unregulated activity. Dubai's Seafood Souq thinks technology can help.

"We build tools for fishers, aquaculture farms, distributors and retailers to ensure that seafood products are transparent in their source and tracking across the value chain," says Fahim Al Qasimi, the company's co-founder and CIO.

The Seafood Souq aims to digitize the seafood industry to ensure responsible trade and procurement from the point of catch to the end consumer using its traceability technology, SFS Trace.

It all begins with data at the source or point of catch. Harvesters use mobile applications to log a catch. The log data include species, quantity, location and time.

Comparable tools are used in fish farms but SFS includes the lifecycle of the fish — data like what the fish has been fed, health treatments and environmental conditions.

Fisheries and ship operators use SFS technology to manage their fleets for compliance documentation, ensuring they meet the regulatory and sustainability standards of Global Dialogue and Seafood Traceability — a non-profit organization partnership between the World Wildlife Fund and the Institute of Food Technologists. The trace audit component of SFS Trace compiles and scores products based on compliance with the organization.

It reviews the data ensuring every stop along the supply chain is substantiated, from catch to consumer.

This is possible because each event in processing, packaging and transportation is captured and stored. Data transmission between systems is secured by Electronic Product Code Information Services.

The company is working with local and international partners to achieve transparency and improve operations, including developing and implementing a digital logbook for South African tuna fisheries.

Closer to home, Seafood Souq is working with Jumeirah Hotels in Dubai to show guests via QR code where their seafood originated and how it came to land on their plate.

UAE supermarkets and caterers are also using the SFS Traceability Audit tool to ensure quality and compliance with the country's sustainability goals.

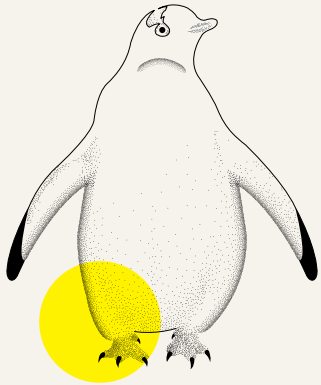
What's next for the Seafood Souq?

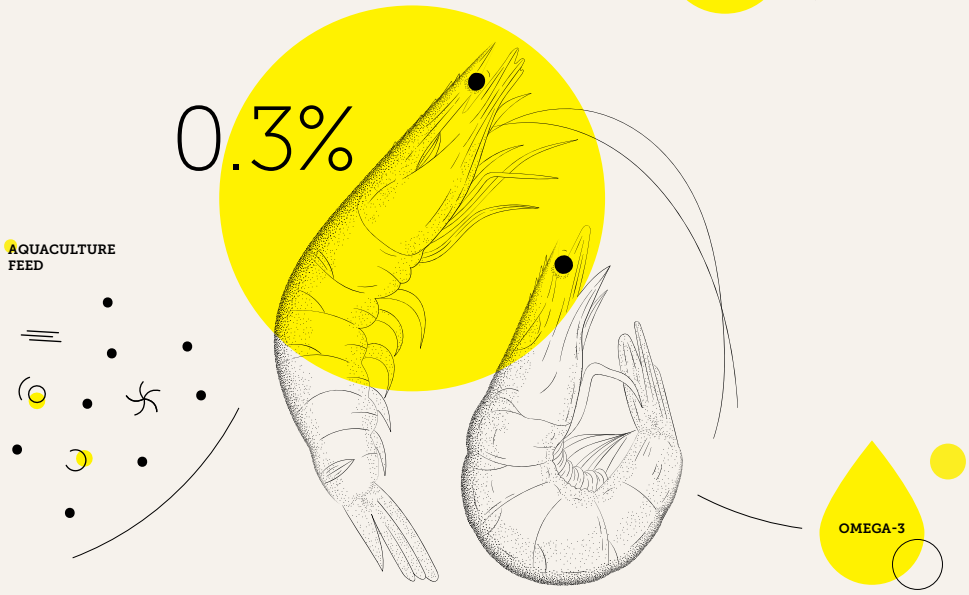
The company is in discussions for pilot logbook tools with UAE fishers. "It is an opportunity for NGOs, the government and the private sector to contribute to more transparency and the protection of fishers' livelihoods.

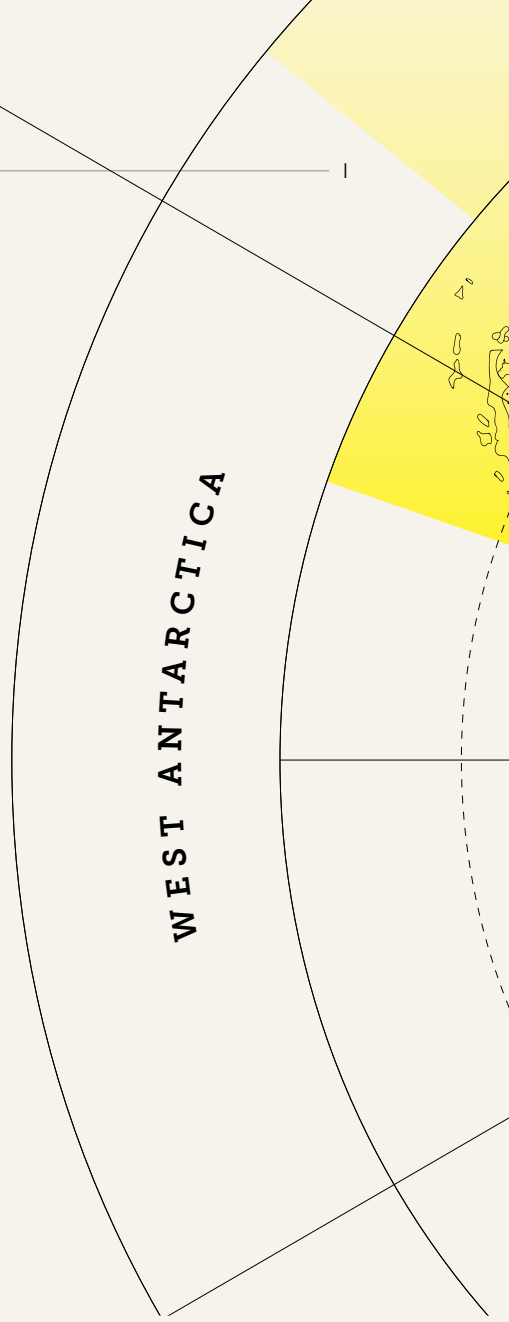
"Conversations with regulators, fishers and the procurers of seafood need to continue to ensure the effective implementation of this project, and Seafood Souq is proud to be the convener (and digital infrastructure) behind these conversations," Al Qasmi tells *KUST Review.*

Why *traceability* matters

By: **Jade Sterling**







In the icy waters surrounding Antarctica, a 10-kilometer stretch of sea is colored a reddish-brown. An Antarctic krill super-swarm floats along, millions of tons of shrimp-like crustaceans feeding on phytoplankton. The World Wildlife Fund estimates there are over 700 trillion adult individuals spanning up to 32 million square kilometers of the Antarctic Ocean, but even a number as high as this isn't enough to keep them from threat.

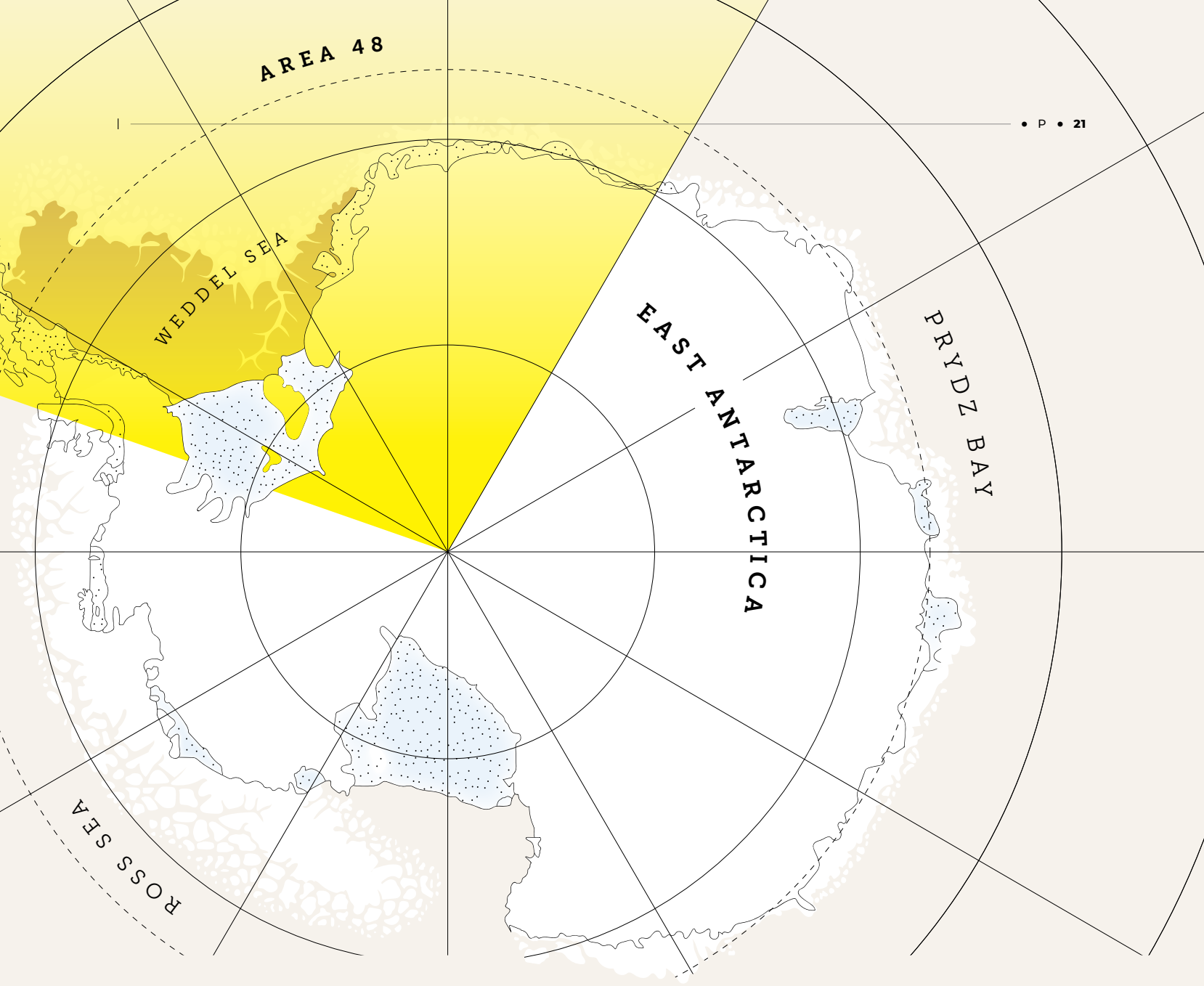
Antarctic krill are other victims of the combined effects of ocean warming and loss of sea ice, further threatened by ocean acidification and increasing interest in the krill-fishing industry. Krill fishing has emerged as a vital industry, particularly in the production of omega-3 supplements and aquaculture feed.

The ecological significance of krill, a key species feeding a multitude of Antarctic life from fish to whales, seals to penguins, underscores the need for stringent traceability measures in fishing practices.

Traceability can ensure the sustainability and ecological integrity of Antarctic waters. Implementing robust traceability systems in krill fishing can help enforce compliance with conservation methods set forth by such international bodies as the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Marine Stewardship Council.

"Commercial krill harvesting in Antarctica takes place mainly in 'Area 48' and is strictly regulated by the CCAMLR," according to Aker BioMarine, a krill-harvesting company. "Only 0.3 percent of the krill biomass in Area 48 is harvested annually by all fishing companies."

These measures are designed to prevent overfishing and minimize



the environmental impact of fishing activities. By tracing the origin, path and processing of krill products, stakeholders can ensure the krill was harvested responsibly, adhering to quotas and protected areas, thereby reducing the risk of ecological imbalance.

"It is critical for globally traded goods to know where sources are coming from," the Aker BioMarine website states. "Our krill-harvesting vessels record the exact location of each krill catch which is associated with each batch of krill oil produced. We can trace our krill oil all the way back to its origins in Antarctica."

Rimfrost is another company harvesting krill for omega-3 supplements. It reports its catch data electronically by satellite on a daily basis both to Norwegian authorities (in accordance with Norwegian requirements for a Norwegian company) and CCAMLR:

"We always know in real-time how much, where and when the krill has been caught. All our products can be traced back to the GPS coordinated and the exact time of catching the krill. Traceability is the answer and technologies are key," Fransisco Aldon, CEO of MarinTrust, writes. "Standardization of data is key." ●

> *We can trace our krill oil all the way back to its origins in Antarctica.*
>
> — Aker BioMarine

GRAPHICS: Abjad Design

Business is Mushrooming

Abu Dhabi's Below Farm grows food from waste materials

By: **Suzanne Condie Lambert**

Mushrooms like cool, dark, humid growing environments. So it may seem strange that Below Farm is cultivating fungi in hot, sunny Abu Dhabi.

But Liliana Slowinska and her partners at Below Farm are using technology and waste biomass to grow their mushrooms inside specially adapted industrial buildings. Although plenty of other companies are farming indoors, cultivating mushrooms presents specific challenges.

"The key here is this: Mushrooms are not plants," says Slowinska, the company's co-founder and business development director. "In fact, they metabolically resemble animals more.

"They digest their food, which is the feedstock we create in the form of a growing medium from locally available materials such as date palm leaves."

These palm leaves come from waste that would otherwise go to landfills. "Then there is the fact that mushrooms breathe out CO2, just like us, and this necessitates appropriate levels of gas exchange," Slowinska says.

Another issue: Also like animals, the fungi don't require watering the same way plants do. "They absorb moisture from the environment, and to that end we maintain variety-specific levels of humidity in each fruiting chamber.

"Overall, growing mushrooms consistently is more complex than other types of produce," Slowinska says. The Below Farm team believes that the operation could be a model for food production in an age of climate change and increased urbanization.

"Businesses like ours are the future of food production," Slowinska says. "As the world gets hotter, drier and more urbanized, there is a dire need for robust and decentralized food systems. The UAE is the perfect training ground for our fungi proof-of-concept farm as we know now firsthand how to grow food in arid environments."

Local businesses have taken notice. Abu Dhabi restaurant Marmellata Bakery uses Below Farm's mushrooms in some of its top-selling pizzas. "We choose Below Farm because their mushrooms are amongst the highest-quality ingredients that we source locally, period," says Marmellata owner Raj Dagastani.

"They allow us to participate in our local economy, they help us build a community of like-minded food professionals, their mushrooms arrive fresh and in their prime, there is less waste produced, less environmental impact, less drama. But most importantly, their mushrooms are delicious."

⊙ **HOME GROWN:** The UAE, which traditionally imports most of its food, has ambitious goals, aiming to top the Global Food Security Index by 2051. Part of the strategy is encouraging local, sustainable food production.

The first phase aims to encourage domestic production of red meat, eggs, poultry, dairy products, dates, leafy vegetables, tomatoes, peppers and aubergine. Another campaign called Ne'ma – Arabic for blessing – aims to reduce food waste. There are about 38,000 farms operating in the UAE.

MUSHROOMING: As an adjective, it means rapidly growing, expanding or developing.

OUTLINES: AI generated, KUST Review
COLORING: Anas Albounni, KUST Review

SHIELDS UP

Radiation-loving fungus might be the key to protecting astronauts

By: **Jade Sterling**

Beyond applying sunscreen before a day at the beach, we generally don't think much about our exposure to radiation. We have Earth's magnetic field to thank for that, but for astronauts who go beyond the planet's protective layer, sunscreen won't quite cut it.

A fungus found growing in the aftermath of Chernobyl, however, might.

Cladosporium spaerospermum is one such radiation-loving fungal species, found on Earth in extreme places, like the remains of the Chernobyl Nuclear Power Plant in Ukraine. While most plants use energy from the sun for photosynthesis, this type of fungus draws its energy from radiation in a process called radiosynthesis.

Researchers believe large amounts of melanin in the cell walls of these fungi protect the cells from radiation damage, with melanin now being explored as a biotechnological means of radiation shielding.

For applications in space, researchers offer different approaches:

Ekaterina Dadachova, professor of pharmacy at the University of Saskatchewan, Canada, wants astronauts to eat more mushrooms; Nils Averesch, research engineer at Stanford, would rather grow a thick layer of fungus on spacecraft and future Martian or lunar habitats. Averesch isn't joking — to bring radiation exposure down to Earth-like levels, a habitat on Mars would need an estimated "2.3m layer of melanized fungal biomass."

Remember: These radiotrophic fungi are already in space. A survey of the environmental contamination on board the International Space Station (ISS) revealed many fungal species on surfaces and in the air, including Aspergillus, Penicillium and Saccharomyces species. Although the ISS still enjoys some shielding from the Earth's magnetosphere, it receives elevated levels of radiation compared with Earth, and astronauts can stay in orbit for up to only a year.

Eat them

"Life emerged on Earth at a time when there was much higher background radiation, and early life forms must have considerable radiation resistance," Dadachova says in her article for *Current Opinion in Microbiology*. "Although current background radiation levels are much lower than in the early days on Earth, earthly life still exists in a field of radiation."

Dadachova highlights the "Evolution Canyon," where the two slopes of the canyon, separated by just 200 meters of open grassland, represent drastically different biomes. The south-facing slope receives 200-800 percent more solar radiation than the north-facing slope, which is temperate and shady. The south-facing slope is populated by many species of melanized fungi, such as *Aspergillus niger*, which contains "three times more melanin than the same species from the north-facing slope."

Melanin pigments are found in all biological kingdoms, suggesting these compounds are ancient molecules that emerged early in the course of evolution. Dadachova's research examines the radioprotective effects of melanized fungi in patients undergoing radiation therapy for cancer treatment and believes there could be potential for protecting people in prolonged space flight.

Speaking about mice fed black mushrooms being protected from high doses of external radiation, Dadachova says: "It's not like you can eat a mushroom and be protected forever, but if you experience a radiation influx while the mushroom's melanin is in your digestive tract, it protects it from really high doses of radiation."

"Very recently, we obtained soluble fungal melanin which can be given after exposure to radiation to mitigate radiation damage," Dadachova tells *KUST Review*.

Dadachova's team fed soluble allomelanin to mice that had been exposed to high doses of gamma radiation. They found the effects of the radiation were mitigated when allomelanin was administered within 24 hours of irradiation.

"Based on these findings, soluble allomelanin derived from a fungal source could serve as an easily sourced, cost-effective and viable countermeasure to accidental radiation exposure," Dadachova says. "This is an important step forward in this melanin and radiation investigation."

Grow them

Stanford's Averesch was part of the research team investigating just how well *Cladosporium spaerospermum* can grow in space. Petri dishes loaded with the fungus were sent to the ISS and oriented so they faced away from Earth. To compare, a number of Petri dishes with the same fungus remained earthside.

The team found the fungi onboard the ISS had a microbial growth advantage, which could be associated with increased radiation in space.

The melanized fungal biomass may have radioprotective properties and could even be used as an energy-storage device on spacecraft.

"Solutions to radiation exposure on interplanetary travel are more restricted by up-mass limitations than any other factor of space travel," Averesch says. "Being living organisms, micro-fungi self-replicate from microscopic amounts, which could allow significant weight savings.

"Biotechnology would thus prove to be an invaluable asset to life support and resource management for explorers on future missions to the moon, Mars and beyond." ●

⊙ **COVER:** AI-generated image of a mushroom in space

⊙ **BELOW:** *Cladosporium spaerosporium*

Very recently, we obtained soluble fungal melanin which can be given after exposure to radiation to mitigate radiation damage.
– Ekaterina Dadachova

COVER: AI generated, KUST Review.
LEFT: Shutterstock

FEEDING TOMORROW

GRAPHICS BY ABJAD DESIGN

Humanity faces one of its greatest challenges as climate change impacts farms

By: **Jade Sterling**

The second United Nations Sustainable Development Goal is a big one: zero hunger. For the U.N., this means, "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture." In the face of unmitigated climate change, this goal becomes even harder to achieve.

"Based on projections of global population growth, 9.7 billion people will need to be sustainably fed by 2050," says Erik Murchie, professor of applied plant physiology at the University of Nottingham. "Economic growth will enrich this population, which will likely lead to increased overall food consumption."

The number of people facing hunger and food insecurity has been on the rise since 2015, according to the U.N., with 670 million people projected to be facing hunger by 2030. The pandemic, conflict, climate change and growing inequalities have exacerbated the situation.

"Maintaining and ensuring food security is a key challenge for mankind that relies on the key pillars of agricultural productivity, access, utilization and stability," says Martin A. J. Parry, professor emeritus at the University of Lancaster.

"The pillar of crop productivity relies on farmers to produce sufficient biomass to feed livestock, as well as provide feedstock to support the bio-economy.

By 2050, the world will need to double agricultural biomass production, and this will need to be achieved on less land and using fewer resources than ever before.

"At the current rates of biomass yield improvement, the world will fall far short of meeting the future productivity demands, and progress could be further hindered by the complexity of climate change and political and socio-economic challenges."

There are many challenges facing future-proofing agriculture. Land, healthy soils and water are key to food production, and their growing scarcity makes it imperative to use and manage them sustainably.

But even responsible and sustainable farming practices will fail to feed us into the future if crops are pushed past their heat tolerances. »»

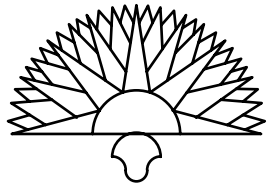
9 700 000 000
must be sustainably fed by
2050

670 000 000
could be facing hunger by
2030

ILLUSTRATIONS: Abjad Design

> **Damage will generally be greater in countries located close to the equator, where temperatures already tend to be close to crop tolerance levels.**
>
> William Cline

Heat Stress:
Temperatures at which optimal plant functioning and homeostasis are impaired, leading to reduced growth, yield, quality and productivity.



If you can't stand the heat ...

Philippe Nacry, research director at the French National Institute for Agricultural Research, explains that increased temperatures from climate change are often negatively correlated with productivity and yield and lead to more frequent and severe heatwaves that affect all crop species:

"**Heat stress** is defined by temperatures at which optimal plant functioning and homeostasis are impaired, leading to reduced growth, yield, quality and productivity."

William R. Cline also points out the damage heat can have on crop yields in an article for the International Monetary Fund:

"Beyond a certain range of temperatures, warming tends to reduce yields because crops speed through their development, producing less grain in the process. And higher temperatures also interfere with the ability of plants to get and use moisture."

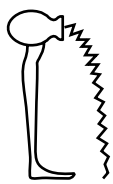
Cline is a senior fellow at the Peterson Institute for International Economics and the Center for Global Development. He analyzed six climate models of changes in temperature and rainfall to identify the likely effects of unarrested global warming on agriculture in more than 100 countries.

"In the long list of potential problems from global warming, the risks to world agriculture stand out as among the most important," he writes.

His study considered climate-model projections into the 2080s to allow sizeable warming and potential damage to materialize but keep the timeframe close enough to the present to elicit public concern. The results weren't good.

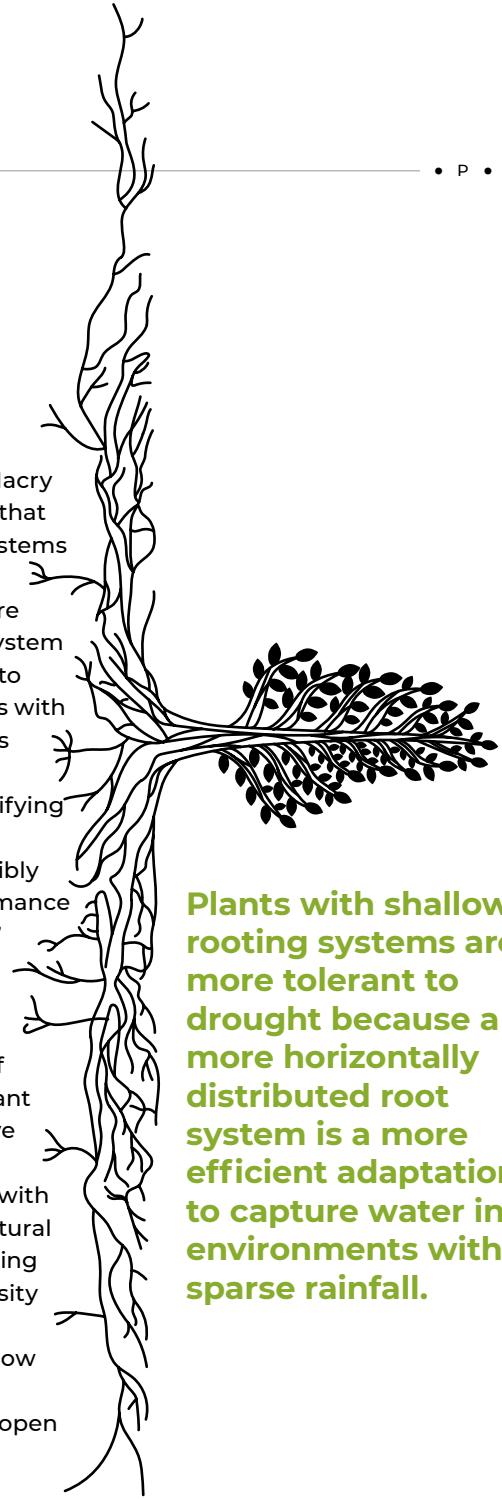
"Whether the impact of climate change is projected by economic or agronomic models, nearly all countries suffer," Cline writes.

"Damage will generally be greater in countries located close to the equator, where temperatures already tend to be close to crop tolerance levels. Country elevation also matters. For example, because of higher elevation and lower average temperatures, Uganda faces smaller losses than Burkina Faso, even though the latter is situated about 10 degrees further north of the equator."



Not a drop to drink

In many ways, increased temperatures and water scarcity go hand in hand.



"Periods of drought and increased temperature events increasingly co-occur in major crop-producing regions, and reduced water availability can have important consequences for heat-tolerance strategies," FNIAR's Nacry says. "We know that water deficit is the abiotic stress that affects crop productivity the most."

The Middle East is hot and dry. Rainfall is sparse and inconsistent, and the UAE is investing vast quantities of time, effort and money into **cloud seeding** to increase precipitation. This is a trend likely to continue across the region and around the world as climate change results in longer periods of drought and more unpredictable weather patterns.

Nacry points out that Europe is already coming to terms with this: "Europe already faces a declining water availability and higher variability in precipitation, both in space and time, translating into increased risks of water stress on crops and significantly impacting European agriculture."

Manipulating local weather is one solution, but researchers are also investigating ways to improve how roots take in and transport water and reduce the number of stomata to regulate water loss in plants.

"Recent studies have shown that roots can sense moisture gradients and direct their growth or position roots preferentially towards increased water availability," Nacry explains. "Other studies show that plants with shallow rooting systems are more tolerant to drought. We think this is because a more horizontally distributed root system is a more efficient adaptation to capture water in environments with sparse rainfall. These examples illustrate the power of natural variation approaches for identifying new and unexpected genetic regulators to dissect and possibly improve root hydraulic performance under agricultural conditions."

Stomata are the tiny pores on leaves and stems. They open and close to control the rate of gas exchange between the plant and the atmosphere. They have been the center of interest for improving drought tolerance, with many studies investigating natural genetic variation or manipulating genes to reduce stomatal density in an attempt to limit water losses. Because stomata are slow to respond to changes in light conditions, they often remain open longer at night, allowing more water to escape.

A research study from the University of Glasgow introduced a new ion channel into the stomata of mustard plants to speed up this response. These plants produced more biomass and conserved more water, especially in the fluctuating light conditions typical of outdoor growth. »»

Plants with shallow rooting systems are more tolerant to drought because a more horizontally distributed root system is a more efficient adaptation to capture water in environments with sparse rainfall.

Cloud Seeding:
A type of weather modification that aims to change the amount or type of precipitation, mitigate hail or disperse fog.

Stomata:
Tiny pores on leaves and stems.

Turning to crops that can handle the salt and still offer nutritional quality could be a solution.

Brackish Water:
Water whose salinity is between that of fresh and marine water.

Groundwater Salinity:
A measure of the content of salts in water underground.

Halophytic:
A plant that grows in salty soil.

Yield Plateauing:
Showing no further improvement in yield per hectare for a crop.

Photosynthesis:
The process by which plants use sunlight, water and carbon dioxide to create oxygen and energy in the form of sugar.

Researchers at the University of Montpellier took this concept a step further to force stomata to close at night, reducing nighttime water loss. Since climate projections predict increased levels of transpiration at night relative to the day, breeding plants that can close stomata at night will help plants retain water.

There are places around the world, however, where quantity of water isn't the problem. Many areas rely on **brackish water** for irrigation or face increased **groundwater salinity** due to rising sea levels. Soil salinization is a serious threat to crop productivity. The situation is worst in arid and semi-arid regions, which usually see higher temperatures too. This results in even more water loss and aggravates the effects of salinity.

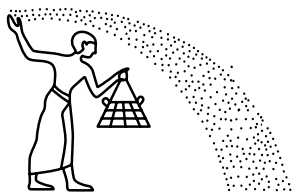
Soil salinization is a serious threat to crop productivity. The situation is worst in arid and semi-arid regions, which usually see higher temperatures too. This results in even more water loss and aggravates the effects of salinity.

Turning to crops that can handle the salt and still offer nutritional quality could be a solution for these areas. Jessica Davies, University of Lancaster, certainly thinks so:

"Given that climate-change predictions suggest that future agriculture will be challenged more due to extreme weather conditions and salinity, the potential of **halophytic** crops should be explored."

Halophytes can grow in salty soils and have developed traits that allow them to withstand salt stress.

"Quinoa in particular tolerates saline conditions and has a high nutritional quality," Davies says. "It is also considered the only plant that provides all the essential amino acids, carbohydrates and lipids in proportions ideal for human and animal nutrition. In addition, it can be used for salt sequestration, giving the crop a dual functionality that allows for a more sustainable use of the soil."



Smart farming or small farming?

Geoffrey Carr writes for the *Economist*. He says if agriculture is to continue to feed the world, it needs to become more like manufacturing:

"Farms are becoming more like factories: tightly controlled operations for turning out reliable products, immune as far as possible from the vagaries of nature. Technological improvements will boost farmers' profits, by cutting

costs and increasing yields, and should also benefit consumers in the form of lower prices.

In the longer run, though, they may help provide the answer to an increasingly urgent question: How can the world be fed in the future without putting irreparable strain on the Earth's soils and oceans?"

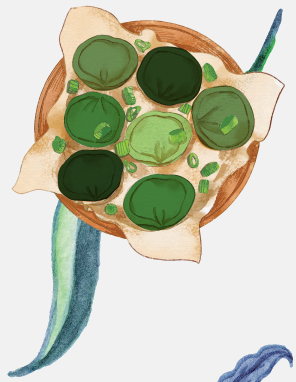
Carr is all for the concept of smart farming, which refers to managing farms using modern information and communication technologies to increase the quantity and quality of products. Sensors, software and robotics connect with advanced data analytics to streamline strategic decisions for an individual plant or the farm as a whole without the farmer even needing to step foot in the field.

"Agriculture has undergone yield-enhancing shifts in the past, including mechanization before the Second World War and the introduction of new crop varieties and agricultural chemicals in the Green Revolution of the 1950s and 1960s," Carr says. "Yet yields of important crops such as rice and wheat have now stopped rising in some intensively farmed parts of the world, a phenomenon called **yield plateauing**. To go beyond them will require improved technology."

University of Lancaster's Parry believes one way to achieve this is to increase **photosynthesis** of ›››

The Diet of Tomorrow

Menus of the future could look very different. Although this list is only a slice of the emerging portfolio of food solutions, here are three ingredients we might see more of:



Seaweed

The algae are often rich in minerals and vitamins. They can be farmed quickly and don't require additional land use: They're sea "weeds."

"Despite the major potential that seaweeds offer, they remain largely understudied and currently still relatively few molecular tools are available to study and possibly engineer them," says researcher Jessica Davies. "Investment in the characterization of their biology, reproduction, growth and development would be advantageous to further leverage their potential and allow aquatic species to become a competitive resource."

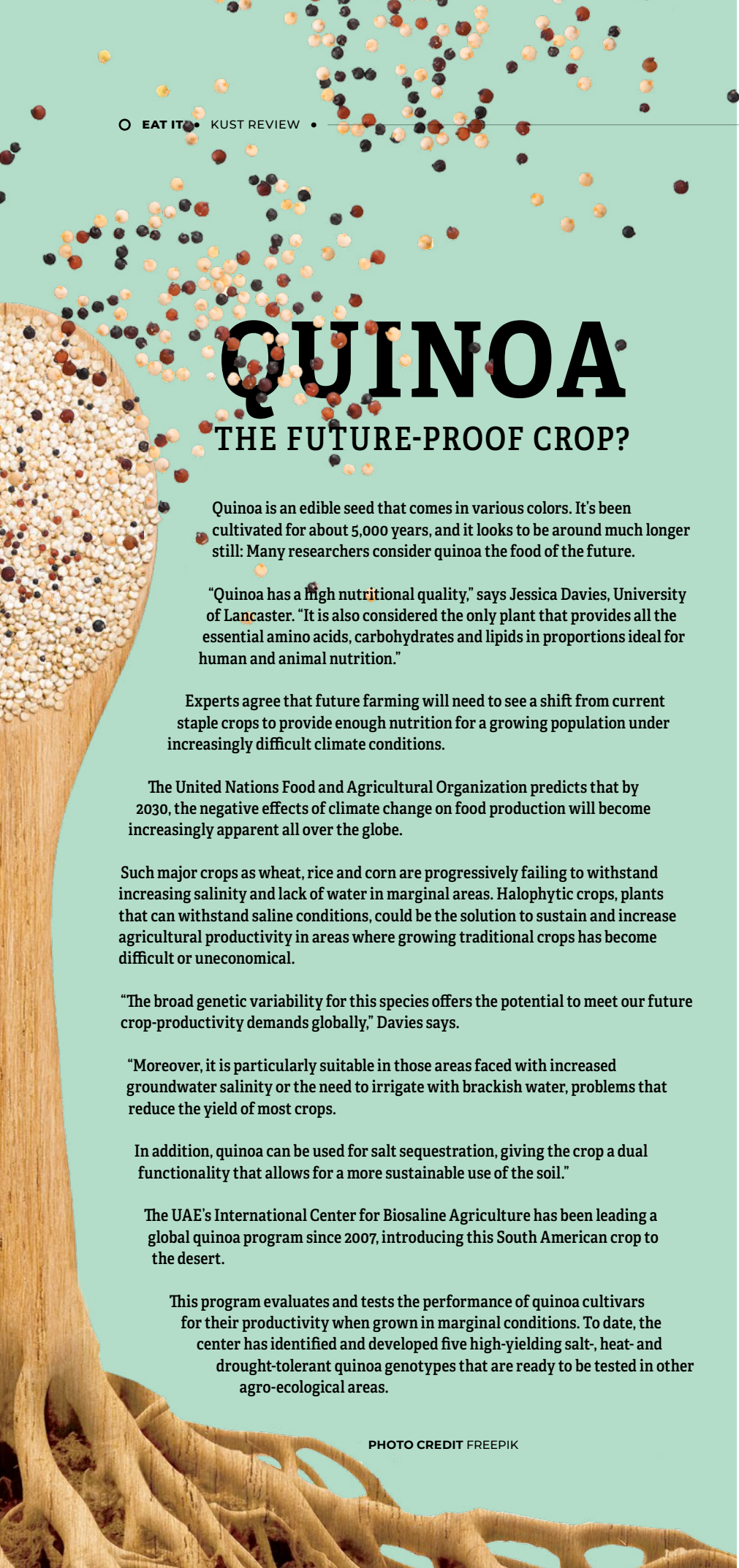
Insects

Entomophagy is already practiced around the world. Many insect species are rich in protein, vitamins and minerals, and there's plenty of them. Insect farming requires significantly less land, water and energy and the animals can be fed on fruit and vegetable waste. Cricket flour is already commercially available, but the "ick" factor may prove difficult for some consumers.

Jellyfish

Human-driven changes to the oceans may be bad news for most marine life, but jellyfish stand to benefit. Jellyfish prefer warmer water: They experience a boost in metabolism, growing faster, breeding faster and living longer. And as the oceans warm, more areas become habitable for the more than 3,000 species of jellyfish we know about. Some societies already eat jellyfish, but as the organisms become more abundant, populations around the world could turn to eating them too. They are nutrient-rich and offer a similar taste and texture profile to oysters.

PHOTOS: FREEPIK



QUINOA

THE FUTURE-PROOF CROP?

Quinoa is an edible seed that comes in various colors. It's been cultivated for about 5,000 years, and it looks to be around much longer still: Many researchers consider quinoa the food of the future.

"Quinoa has a high nutritional quality," says Jessica Davies, University of Lancaster. "It is also considered the only plant that provides all the essential amino acids, carbohydrates and lipids in proportions ideal for human and animal nutrition."

Experts agree that future farming will need to see a shift from current staple crops to provide enough nutrition for a growing population under increasingly difficult climate conditions.

The United Nations Food and Agricultural Organization predicts that by 2030, the negative effects of climate change on food production will become increasingly apparent all over the globe.

Such major crops as wheat, rice and corn are progressively failing to withstand increasing salinity and lack of water in marginal areas. Halophytic crops, plants that can withstand saline conditions, could be the solution to sustain and increase agricultural productivity in areas where growing traditional crops has become difficult or uneconomical.

"The broad genetic variability for this species offers the potential to meet our future crop-productivity demands globally," Davies says.

"Moreover, it is particularly suitable in those areas faced with increased groundwater salinity or the need to irrigate with brackish water, problems that reduce the yield of most crops.

In addition, quinoa can be used for salt sequestration, giving the crop a dual functionality that allows for a more sustainable use of the soil."

The UAE's International Center for Biosaline Agriculture has been leading a global quinoa program since 2007, introducing this South American crop to the desert.

This program evaluates and tests the performance of quinoa cultivars for their productivity when grown in marginal conditions. To date, the center has identified and developed five high-yielding salt-, heat- and drought-tolerant quinoa genotypes that are ready to be tested in other agro-ecological areas.

PHOTO CREDIT FREEPIK

major crops like wheat. Photosynthesis is responsible for more than 90 percent of all biomass on Earth, but left alone, photosynthesis is relatively inefficient.

This is because of the nature of rubisco, the enzyme that helps convert carbon dioxide into sugar. About 20 percent of the time, **rubisco** reacts with oxygen instead of carbon dioxide, reducing the rate of photosynthesis. Parry is working on improving rubisco's catalytic properties to increase photosynthetic rates. Better rates equal better yields.

Amanda Cavanagh is working on the same concept with the University of Essex and the Carl R. Woese Institute for Genomic Biology.

She says as temperatures rise, rubisco has a harder time distinguishing between carbon dioxide and oxygen. When rubisco reacts with oxygen, the plant starts a process called photorespiration, which is energetically expensive and reduces yield. Cavanagh's research focuses on genetically manipulating this **photorespiration** to help crops withstand temperature stresses and mitigate yield losses.

Cavanagh proved her concept in tobacco plants, which are common experimental subjects because they are easy to work with and results

can be seen quickly. Research is underway to use the same genetic manipulation in food crops like potatoes and soybeans.

Shangchiri Reimi, founder of agricultural-services provider My Farming Days, says the UAE is turning to the future of agriculture – one filled with innovative technologies, diverse crops and a skilled workforce:

"The UAE's agricultural landscape has been synonymous with towering date palms and vast stretches of sand for centuries," Reimi writes in a post on LinkedIn. "While dates remain a cherished symbol of Emirati heritage, the story is changing. The UAE's agricultural sector has witnessed impressive growth in recent years.

"In 2023, the sector contributed AED 3.5 billion to the national GDP with this growth fueled by a strategic focus on diversification and a wider range of crops and technologies.

"The vision for the future is clear: a UAE where date palms stand alongside greenhouses teeming with exotic vegetables, fish farms thrive in the desert, and skilled farmers leverage technology to maximize yields."

Improved technology is all well and good but a team of researchers including Wageningen University's Ken Giller points out that farming systems around the world are dominated by small family farms, with more than 70 percent of farms in India and Africa considered "ultra-small" at less than 0.05 hectares.

Giller says future-proof farming may require a reversal of a global trend toward increasing specialization to a recoupling of arable and livestock farming, not least for the resilience it provides:

"Smallholder farms will remain an important source of food and income, and a social safety net in the absence of alternative livelihood security. But with limited possibilities for smallholders to 'step up,' the agricultural engine of growth appears to be broken." Peterson Institute's Cline is also skeptical that technological developments will swoop in to save the day:

"There are those who argue that rapid technological change will raise agricultural yields so much by late this century that any reduction caused by global warming would easily be more than offset. But technological change is a false panacea."

Farmer or plant scientist, everyone involved in the production of enough food for a growing population is combatting major challenges in the face of climate change. To future-proof agriculture, our current ways of doing things will need to be reimagined — and soon.

"The vision for the future is clear: a UAE where date palms stand alongside greenhouses teeming with exotic vegetables, fish farms thrive in the desert, and skilled farmers leverage technology to maximize yields."

Shangchiri Reimi

Rubisco:
A key enzyme in photosynthesis catalyzing carbon dioxide fixation.

Photorespiration:
A process that involves loss of fixed carbon as CO2 in plants in the presence of light.

Getting Clean

Screening wastewater for pharmaceuticals is imperative if we want to sustainably water our crops

By: **Jade Sterling**

With the global population on the rise, the demand for food is increasing. Meeting this demand requires sustainable agricultural practices, including water management. Reusing industrial and municipal wastewater for irrigation presents a practical solution, but while this practice mitigates the environmental and economic burdens of agriculture, it also brings its own significant environmental challenges.

Wastewater is exactly that: water that has been used in the home, a business or industrial process. It's not necessarily clean or the ideal water for agricultural irrigation, but 65 percent of irrigated lands around the world are dependent on wastewater, and 82 percent of these lands are found in regions where less than 75 percent of wastewater is treated.

Wastewater can be polluted with heavy metals or dyes from industrial applications, for example, but a growing concern is pharmaceutical pollution found in both treated and untreated wastewater.

The persistence of pharmaceuticals in the environment is well-documented, and these pollutants have far-reaching implications, including the potential to impact soil health, plant-nutrient uptake and the development of antimicrobial resistance across the wider food chain. The introduction of pharmaceuticals into the environment predominantly occurs through treated wastewater because treatment facilities are ill-equipped to remove these substances. Medications not fully absorbed by the human body are excreted and end up in sewage systems, while improper disposal of medications — down the sink, flushed or even thrown in the bin — contributes further.

Researchers at Dartmouth Medical School, United States, found that the constant release of pharmaceutical waste into water bodies was impacting aquatic life: Estrogen-caused vitellogenesis in male Japanese medaka fish caused more male fish to convert into female fish and led to an increased mortality rate. Further research found an increased prevalence of breast and testicular cancer in areas with drinking water contaminated with pharmaceutical waste.

Wastewater treatment plants are not designed to remove every environmental pollutant possible, but new treatment

⊙ **BELOW:** The World Atlas of Desertification estimates that only 18 percent of cultivated lands are irrigated. But these irrigated lands produce 40 percent of all food.

processes could be introduced to combat the impact of pharmaceuticals. Reducing contamination at the source is one option, and programs for responsible, proper medication disposal and public education should reduce the volume of pharmaceuticals entering the waterways in the first place.

Surveys conducted by University of California-Santa Barbara suggest a willingness among the American public to support these initiatives, but there remains the need to remove those drugs that have already made their way into the water system. Fortunately, there are methods available.

Anaerobic wastewater treatment is deemed to be the most cost-efficient technology for treating organically polluted effluents from industrial use, according to researchers from Kalinga Institute of Industrial Technology, India. Biodegradable material is digested into biogas and "sludge," which can then be removed. Advanced oxidation processes use ozone to remove antibiotics, acetaminophen (paracetamol) and hormones from wastewater. These processes use photocatalysis to remove penicillin and can even be solar-powered. Electrochemical conversion removal techniques can also modify pharmaceutical particles into biodegradable compounds.

Another way to remove antibiotics involves composite membranes made from 2D nanomaterials and MXenes. MXenes are a family of 2D materials that can be used as sheets and stacked on top of each other into flexible and stable films.

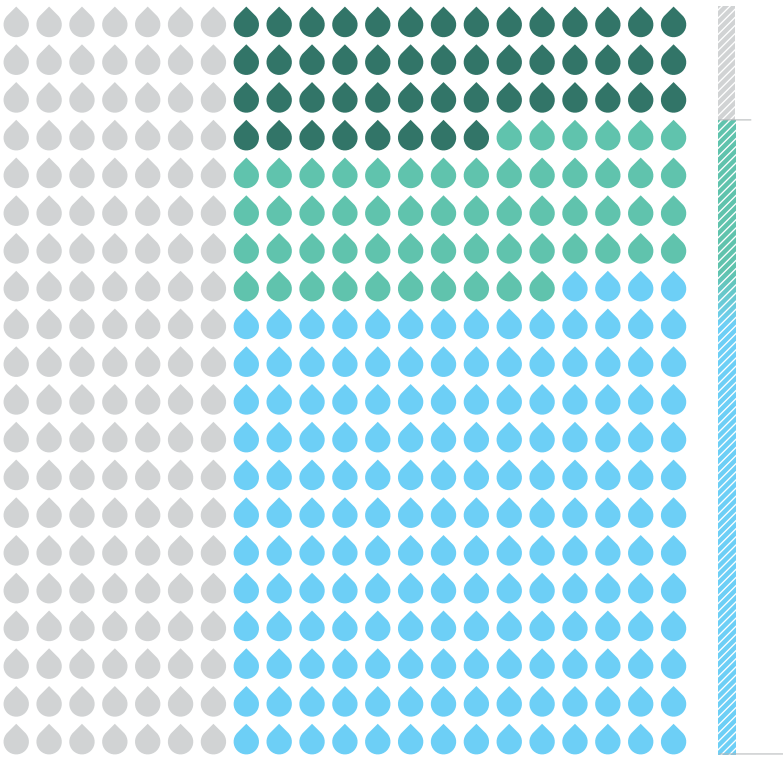
Researchers from Khalifa University designed membranes to tackle the removal of pharmaceuticals from hospital wastewaters. "The excessive release of antibiotics has been alarmingly correlated to the problem of 'superbugs,'" Shadi Hasan, lead author of the a study on the subject, tells *KUST Review.*

Algal-based treatment technologies are also on the rise. Microalgae are already used to remove excess nutrients from wastewater, such as nitrogen, phosphorus and carbon, as a natural disinfection process.

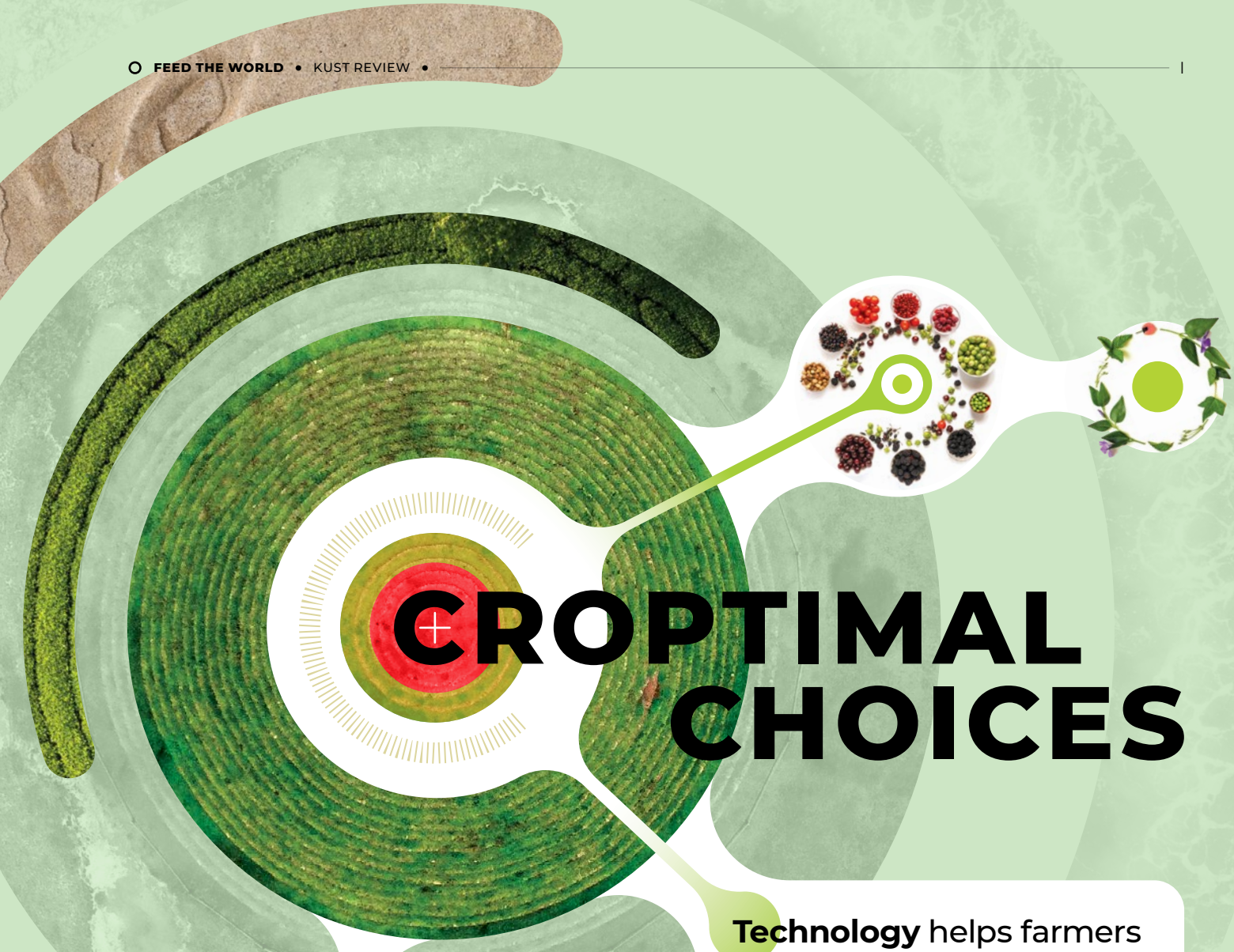
The algal biomass absorbs the nutrients and can then be harvested and used as a bio-fertilizer. Studies have shown algae can absorb lipophilic pharmaceuticals, which could make them a viable alternative for removing certain drugs like artificial hormones from wastewater.

Finally, nanotechnology could have great potential in adsorbing contaminants from wastewater. Silver and titanium dioxide nanoparticles have been applied for disinfection and decontamination of organic compounds, while iron nanoparticles can be used to remove heavy metals. Nano-based technologies could make industrial wastewater treatment more efficient, cost-effective and eco-friendly. ✪

65% of the world's irrigated lands are dependent on wastewater



82% of these lands are found in regions where less than **75% of wastewater is treated**



CROPTIMAL CHOICES

Technology helps farmers move into the digital age

The long haul toward food security begins at the source, and precision farming is capitalizing on the latest technologies to feed the world while ensuring we still have a habitable Earth.

Agriculture has a long list of impacts on the planet from water use to pesticides. And the more we farm, the more impact we make. Fortunately, a revolution in farming technologies is helping farmers maintain yields and honor the land that provides them.

“Good farmers, who take seriously their duties as stewards of creation and of their land’s inheritors, contribute to the welfare of society in more ways than society usually acknowledges, or even knows.

By: **Maggie Kinsella**

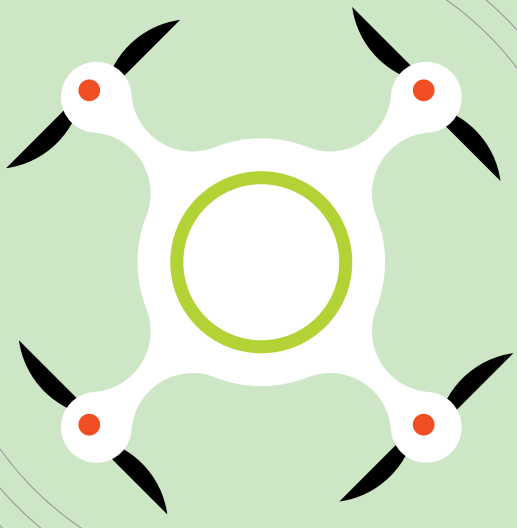
GRAPHICS & LAYOUT:
Anas Albounni, KUST Review
PHOTOS: Envato Elements

"These farmers produce valuable goods, of course; but they also conserve soil, they conserve water, they conserve wildlife, they conserve open space, they conserve scenery," wrote Wendell Berry, American environmental activist, in his book "Bringing It to the Table: On Farming and Food."

Randy Price, precision-farming specialist at Louisiana State University Agricultural Center, says precision farming has ample benefits for farmers, consumers and the environment and presents solutions of how farmers can live up to this standard.

Pesticides protect the crop and the global population's food supply, but they have a significant impact on the environment.

According to a 2023 study out of Chang Mai University in Thailand, "The transport of pesticides from crop-growing regions has resulted in widespread contamination, not only of soils, water bodies, and/or crops but also of the atmosphere via various pathways." Precision farming technology, however, might be a part of the solution.



Send in the drones

Drone technology can help, Louisiana State's Price says. "Drones are allowing farmers and consultants to obtain overhead images of farm fields and land areas at greatly reduced prices over satellite and other methods."

Drones can be fitted with sensors and imaging technology, and this data plays an integral role in active farming.

Among other uses, the data can help farmers identify fungal contaminations, pest infestations or areas of growth congestion.

Identifying these issues early and targeting specific locations eliminates the need to spray entire crops with pesticides — which means less toxicants in the air, soil and food supply. It's better for the land, better for the consumer, less costly for the farmer and safer for farm workers. »»

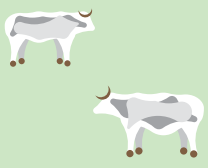
Once the problem is identified, a drone is programmed to spray the affected area with the appropriate pesticide avoiding overuse. Price says the more common precision tools are yield monitors.

This technology allows farmers to determine their crop yield within a specific unit area of their land and perform on-farm analysis, allowing for informed planning and decision-making.

Understanding which areas are underperforming or overperforming is crucial to this process. Monitors and analysis assist irrigation allotment, fertilizer volumes and crop rotation. Research also includes testing.

"They will try different application rates (fertilizer, irrigation, additives, etc.) on small areas of a field, such as twelve rows plot down the whole field, etc., and then use the yield monitor at the end of the year to quickly (and easily) see the differences in that plot," Price says.

Pesticides protect the crop and the global population's food supply, but they have a significant impact on the environment.



Mapping the land

All of this information helps farmers create a prescription map of their land — something Price says is challenging and labor intensive. He says he believes for areas over 3,000 acres, mapping needs to be easier.

The knowledge bases are inadequate at this stage and still required are "systems that will convert remote sensing data into actual disease and pest damage assessments."

He and his team are working to make this happen with automatic flying drones.

"They take off, fly a field, land and recharge automatically," he says, adding that low-level flights that record data at 10 meters from the crop surface allow high-resolution images of plant leaves to be recorded (with location) for automatic analysis with AI and other techniques.

Price's team has been collaborating with several companies to create automated flight platforms for remote-sensing drones and additional yield monitors for sugarcane.

Price says AI will be the major contributor going forward to analyze crop damage and assess pests and disease. This would allow for fully automated treatment by sprayer drones. The drones then would collect the next remote-sensing data for analysis. Assess, treat and repeat.

In addition to crop health, AI offers data-driven decision-making opportunities for soil conditions and weather patterns.

"Over time, precision farming should allow farmers to more precisely treat various areas of land, without over-treating other areas, and create a more sustainable agriculture," Price tells *KUST Review.*

IN THE GREEN HOUSE

While other innovators are focused on open farmland, the **researchers at Khalifa University** are looking at ways to automate greenhouses. "We have a significant community of scholars working in the area," says Lakmal Seneviratne, director of the university's Center for Autonomous Robotic Systems.

Research focuses on using robots, whether drones or mounted on rails, to **collect information about plant health and readiness for harvest**. Machine-learning resources help predict disease and fruit yields and analyze soils, he adds. "Tactile devices (could also) predict fruit ripeness," Seneviratne says.

KU is partnering with UAE agtech giant Silal on a **2,000-square-meter greenhouse in Al Ain**, but commercial greenhouses could easily be hectares in size, he says. For now, the project is focused on strawberries, blueberries and tomatoes.

KU is also partnered with ASPIRE's International Virtual Research Institute for Food Security in the Drylands. "**A lot of investment is happening in the UAE**," Seneviratne says.

IMAGE: AI Generated, KUST Review.

VERTICAL FARMING IS LOOKING UP

Benefits stack up for indoor agriculture

By: **Maggie Kinsela**

Standing at the homestead looking out over the fields was once the typical way to observe farming. Now rather than looking outward, we can look upward at lush, leafy greenery as agricultural innovation stacks sustainability and food security in favor of the environment.

"Indoor farmers do not have to pray for rain, or sunshine, or moderate temperatures, or anything else related to the production of food crops, for that matter," wrote Dickson Despommier in his 2010 book, "The Vertical Farm."

The concept was introduced much earlier but Despommier in 1999 was first to go from ideation to action.

During his tenure at Columbia University as a professor of environmental sciences, he challenged his graduate students to feed vast numbers of people using 5 acres of rooftop space. Over the span of nine years this challenge escalated to a 30-story building to feed 50,000 people.

These were the fundamental, humble beginnings of a blueprint for a commercial vertical farming establishment. The goal: sustainability and food security.

"Vertical farming has considerable potential for global food security. It is a viable solution for producing certain crops under unfavorable environmental conditions. It represents an efficient approach to growing more food with fewer resources and lower environmental impact," Henda Mahmoudi, plant physiologist at the International Center for Biosaline Agriculture, a not-for-profit research center in Dubai, tells *KUST Review*.

How does it all work?

Vertical farming is one method of indoor farming in which rows of crops are planted and stacked in different stages of growth and everything the plants need is controlled and monitored.

There are three types of vertical-farming solutions, and the choice you make for your farm will depend on the facility and the types of plants you intend to grow.

The first is aquaponics. This is a symbiotic, cyclical system for farming fish and plants in which the fish water is filtered and sent up to feed the plants. In turn, the plants oxygenate the water and send it back down to the fish. This system can grow hundreds of plants. »»

It doesn't have to be a large commercial establishment. "Aquaponics is for everyone," says U.S.-based Symbiotic Aquaponic. "Our partners and clients include hobbyists, gardeners, survivalists, environmentalists, educators, schools, nonprofit organizations (and) colleges."

Next is the aeroponic solution, whereby plant roots are fed via a mist of nutrients pumped from a solution. The plants appear to be hanging, but there's a lot going on below.

The planting begins on foam. Once the roots grow downward, they push through a mesh lid into the "fog chamber" beneath. This is where the mist feeds the roots in intervals. Everything is timed so that the plants receive the right amount of nutrition for optimal growth.

The most common form of vertical farming systems is hydroponics, in which a pump circulates a nutrient-rich solution continuously through plant roots.

While these are all different techniques, the primary concept is the same — they are all projects of controlled-environment agriculture technology.

There can't be only one

While farming is typically a climate-specific industry, agtech startups offering vertical farming solutions are popping up all over the world. Like Norway-based Avisomo.

With such optimal growth environments, "Their vegetables are tastier, prettier, more nutrient-packed, and their business model is more competitive than ever before. LED grow lights were the key," Avisomo says.

> "Vertical farming has considerable potential for global food security."
>
> — Henda Mahmoudi

The company offers systems equipped with AI and robotics. Each plant is placed in growth stations and is moved around the facility depending on where it is in the growth stage.

And each station has controls to monitor and adjust irrigation, nutrition and airflow depending on the plant. Avisomo also offers recipes developed in partnership with local farmers.

The company's systems allow for extended automation in which a robot, which resembles a large Roomba, moves trolleys full of crops around the farm upon reception of a cloud command.

The perks

You might think that an indoor facility like this would be a massive water and energy sucker, but it's quite the opposite. Smart energy and water systems and automation provide savings across the board. More than 70 percent of global water resources are used by the agricultural industry, but within a controlled environment, cultivation of indoor vertical farming crops uses nearly 95 percent less water than conventional farming.

And as plants evaporate about 85 percent of the water not used for nutrition, smart water harvesting in these environments uses dehumidifiers that collect the water in the air and reuse it.

All three solutions are soilless, offering further reduction in water use. No soil-born pests or diseases also mean no pesticides.

And there's no soil turnover to release carbon into the atmosphere either

That's a number that adds up. According to the U.S. Center for Food Safety, cultivated soils have lost between 50 and 70 percent of their original carbon stock to the atmosphere in the form of CO2

Additionally, LEDs save energy and costs. These lights don't give off heat like traditional bulbs, which in turn requires less energy and, subsequently, less cash spent on cooling systems.

And they give off more light with less wattage but can be controlled, unlike sunlight, which can burn plants. Bonus — indoor vertical-farm crops can be grown year-round.

It's always harvesting season

At the indoor vertical farm, seasons are non-existent, thus crops are not at the mercy of changing weather, frozen ground, overly wet springs, soil conditions or superstorms.

Predictable harvesting makes it easier to secure buyers for products, ensuring produce reaches its destination well before the shelf life runs out. And crop growth is accelerated, increasing annual yields.

U.S.-based AeroFarms is one of the largest vertical farming companies in the world. Its systems use the aeroponic method and have traditional farming yields beat by a reported 390 times.

At this rate, we might be more likely to feed a growing population that, according to the United Nations, is expected to reach 9.7 billion by 2050.

What's the catch?

Along with the perks come challenges. While traditional farming depends on predictable weather, indoor vertical farms depend on technology. The irrigation system, for example, is crucial to crop outcomes, but what happens if it breaks down?

And one of the primary pitfalls of scaling up this vertical farming is that although the LEDs are cost-effective, they're still more expensive than the sun, which shines for free.

The technology also needs to be adapted to allow more kinds of crops to thrive in this environment. Currently it caters to a limited number.

Tech-driven vertical farming has also been criticized for its potential to affect the soil's CO_2 sequestration.

If we move to indoor farming, how will the soil absorb the carbon without the plants to absorb and store it in the soil? This is a major kink, but it's not necessarily a deal-breaker.

Other types of plants can replace farmed crops. Trees, for example, increase stored carbon volume and eliminate the need for soil tilling, which releases carbon from the soil back into the atmosphere. »»

AS SEEN **FROM SPACE**

Technology isn't just helping farmers till new ground indoors. It's also helping them find suitable agricultural soil from space. "Remote sensing is a powerful tool for assessing soil properties and determining its suitability for agriculture," says Diana Francis, head of the Environmental and Geophysical Sciences Lab at Khalifa University.

Remote sensing can assess such factors as pH, moisture, texture and salinity. Sensors can also detect signs associated with soil fertility.

"Using data from satellites enables large-scale, non-invasive soil analysis that can provide critical information for optimizing crop yields," she says. "This data-driven approach provides highly accurate, location-specific guidance."

CREDIT: NASA/METI/AIST/Japan Space Systems, and U.S./Japan ASTER Science Team.

Rub' al Khali, Saudi Arabia

Is it feasible on a large scale?

"The commercial availability of modular plant factories for installation of vertical farming systems in containers, trailers or cellars was met with great enthusiasm worldwide, marking the dawn of the 'agri-tech' era," says Elke Neumann, associate professor at United Arab Emirates University (UAEU) and director of ASPIRE Research Institute for Food Security in the Drylands (ARIFSID).

"However, investment costs and energy requirements of these units turned out to be high, and some of them were less versatile than originally anticipated, largely restricting the production portfolio to leafy greens.

"Under the impact of the recent soar in energy prices, some plant factories even went out of business," she says.

She says success will come with a cross-functional approach. "We need to bring down the energy consumption and the investment costs of these systems to make it more feasible."

So the ARIFSID team is working toward these goals. "In the UAE, water equals energy because ultimately, as long as you have enough energy, you can produce as much water as you like," Neumann tells *KUST Review*.

How do we use less water, then? In a warm country like the UAE, temperature tolerance of production systems can save water and energy. Crops that can produce yield at elevated temperatures require less water and energy for environmental control.

"Another thing that we need to address is the nutrient-supply side," Neumann says. The ARIFSID team works with aquaponics, combining fish farming and plant production.

Fish require a lot of feed so they can grow quickly, she says. "And like most farm animals they are not very good at utilizing the food. Maybe they utilize around 10 percent and the rest is going into their manure and they release it to the water."

The water then needs to be changed, cleaned or recycled, so they use plants to clean it up.

The water is used as a nutrient solution for vertically grown plants. Once plant roots have extracted the water for nutritional elements, the clean water is returned to the fish.

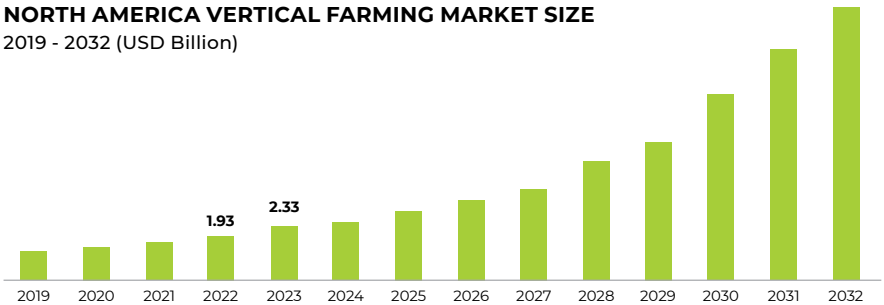
But there's more to it than this. "We have to make sure that this works out economically and also ecologically, environmentally and also from a food-safety perspective.

"How safe is the food that is coming out of such a system if we're using fish poop as a nutrient for plants? Fish can have a lot of parasites, so there is a lot that needs to be done," Neumann says. Additionally, the UAE is heavily invested in reaching climate neutrality.

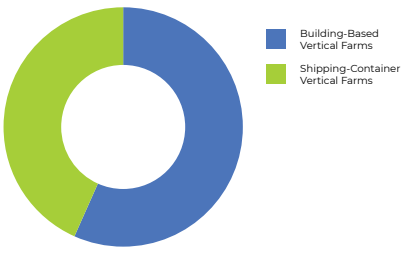
Part of this strategy includes contributing its Circular Economy 2021-2031 policy. UAEU vertical farming initiatives align with this. "To comply with the UAE's circular economy strategy,

Vertical Farming Market Analysis - 2026

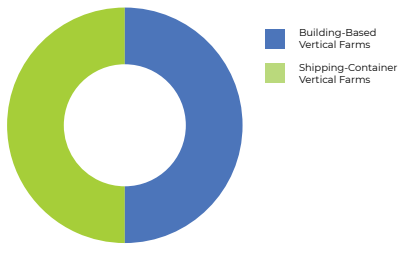
NORTH AMERICA VERTICAL FARMING MARKET SIZE
2019 - 2032 (USD Billion)



GLOBAL VERTICAL FARMING MARKET SHARE
By Structure, 2023



U.S. VERTICAL FARMING MARKET SHARE
By Structure, 2023



strategies for embedding vertical farming systems into a circular food supply chain need to be developed," Neumann says. "This is a considerable challenge in soilless production systems, given the integral role that soil plays in the global element cycles.

"Currently, most vertical farming systems still rely on continuous input of mineral fertilizers with a high carbon footprint."

This research is supported by ASPIRE, the technology program management pillar of Abu Dhabi's Advanced Technology Research Council (ATRC), via the ASPIRE Virtual Research Institutes Program.

ARIFSID, UAEU, Khalifa University and additional stakeholders are developing "food production systems for the UAE that are not only technically but also agro-ecologically advanced and ready to be integrated into urban buildings, food supply cycles, and contemporary lifestyles," Neumann says.

The ARIFSID team is also looking at developing the UAE's indigenous agricultural resources to find new sources of food.

Is it enough?

Though vertical farms offer many positive outcomes for the environment, the consumer and the vertical farmer's pocketbook, you need to have the funds to get your farm off the ground.

And that's not cheap. Vertical farm set-up costs can be up to 10 times more expensive than greenhouses that range from U.S.$2,200 to U.S.$2,600 per square meter.

So, with startup costs, you need to be looking at a long-term return on investment.

While you might think the use of autonomous technology would reduce labor costs, experts are required to tend to these crops, and these different sorts of farmhands are substantially more expensive to employ.

Regardless of those costs and challenges, however, vertical farms appear to be the agriculture of the future.

⊙ **LEFT:** Fortune Business Insights

3D PRINTERS GET COOKING

By: **Maggie Kinsella**

Tech might help you count calories or accommodate special diets

3D printing has long been used in manufacturing and medicine.

But now food companies are using the technology to serve up sustainable practices and customized nutrition.

The food industry is responsible for about a third of global greenhouse-gas emissions, according to the United Nations. And agriculture takes up half of the world's livable land mass and uses over 70 percent of fresh water, per Our World in Data.

But 3D-printed food utilizes more sustainable food sources like algae, insects and plant-based materials, , which can also add valuable protein to a plant-based diet without the "ick" factor. In addition, printing exactly what we plan to eat could mean less waste, less packaging and reduced transport needs.

The process starts with a digital design of whatever you're hungry for. A specialized printer heats the contents for malleability and produces the item layer by layer, much like a piping bag expelling icing. This is the most common technique and is called fused deposition modeling.

As each layer hits the cold surface beneath, cooling for the next layer, it solidifies, and dinner is served.

With customization, food can be created with specific nutrient and calorie content. And when food is printed made-to-order, there's no need to add chemicals to extend the shelf life.

The ingredients are typically food elements like fats, carbohydrates or proteins in the form of purees or pastes. From intricate chocolate work to pasta to plant-based meat, the edible food ink possibilities seem endless.

There's still research to be done, however. "3D printing of food waste to generate new foods can be challenging. The ingredients need to be processed such that the materials are rendered safe from microbiological contamination.

"They also need to maintain excellent taste and texture when converted into new food," says Bryan Quoc Le, food scientist and author of "150 Food Science Questions Answered."

"Possibilities may be to convert food waste into dried powders and transformed into 3D-printable edible inks. Other options could include using food waste as a 3D substrate from which mushrooms or other edible fungi can be grown," he tells *KUST Review.*

According to Allied Market Research, the 3D printing food market is expected to pass U.S.$15 billion globally by 2031, up from U.S.$226.2 million in 2021.

DESIGN: Rawan Ghonim, Khalifa University
IMAGE: Shutterstock

CYBERPUNK

Do androids dream of electric plants?
From wearables for leaves to rose cyborgs, researchers are trying to weave electronics into greenery.

By: Jade Sterling

There's a human phenomenon known as "plant blindness." Used to describe the human perception of plants as mere background noise, plant blindness was a useful evolutionary trait that kept the brain from being overwhelmed by the sheer volume of green surrounding us. But an evolutionary disregard for plants will need to be overcome as we turn to the natural world for solutions to our modern problems.

Anna-Maria Pappa is a researcher at Khalifa University. She says measures to enhance plant productivity and nutrient content are urgently needed — as is a fundamental understanding of plant development and how plants acclimate to environmental stresses:

Plants are increasingly becoming victims of human-caused climate changes, she says. But the classic kind of research in plant sciences that might offer answers can be invasive and may disturb the way plant cells communicate with each other.

Her potential solution? "Real-time, non-invasive plant sensing can be achieved by placing sensors either on the surface of the plant or inserted inside them. Amalgamating plants and electronic materials makes it possible to combine electric signals with the chemical processes of the plant."

Pappa calls this futuristic technological concept "e-Plants." Her research uses conjugated polymers — a kind of organic semiconductor — to create electronic devices for bridging the gap between the biotic and the abiotic. Recent research has seen organic electronic materials used in biologically relevant ion sensing, ion pumps and neural activity transducers in humans.

They more seamlessly integrate with complex biological systems and offer more effective signal transduction of biological events. For e-Plants, they can be either "wearable," where they are placed on the surface of leaves or stems, for example, or implantable.

Conjugated polymers are mixed conductors. The electronics surrounding us in our daily lives use electrons as the dominant charge carrier; biological systems use ions. Conjugated polymers can use both, which makes them perfect for direct coupling with biological systems.

Plus, they're flexible and light. The ease and versatility of integrating flexible polymers instead of hard metals into delicate biological structures is an obvious advantage on top of their other inherent advantages over conventional electronics, Pappa says.

"As in conventional bioelectronics devices, plant-integrated bioelectronics enable bidirectional communication through sensors that can translate plant biosignals to electronic readouts and actuators that can modulate their biological functions," Pappa explains.

"The combination of ionic and electronic carriers aids signal transduction not only for sensing, but also for converting electronic signals into the specific delivery of chemicals. This could be a key measure for enhancing sustainable farming, which is the main pillar of the fast-growing agricultural revolution we are now facing."

FLOWER POWER

Pappa's research focuses on developing hydrogel materials from those polymers that can augment plant seeding and growth in environments that are not that favorable, but that's not the only avenue for e-Plant technology.

A team of researchers from Sweden's Linköping University went down the implantable route, developing a molecule that can be absorbed and polymerized inside the plant, creating long threads throughout that conduct electricity.

Similar to dyeing a flower by feeding it a solution with food coloring, the researchers dissolved a molecule called ETE-S into a solution that was transported through the vascular system of a rose. The ETE-S polymerized throughout this network, turning it electronic.

They weren't trying to sense anything across this rose, rather turn it into a supercapacitor, a fast-charging energy storage system that could be the future of batteries.

"The plant's structure acts as a physical template, whereas the biochemical response mechanism acts as the catalyst for polymerization," Eleni Stavrinidou, the team's principal investigator, writes in *Applied Physical Sciences*.

"Plants are renewable, large-volume and high-performing machineries that represent an untapped source for the production of advanced materials, electronics and energy technology."

Research is also investigating harvesting electricity from photosynthesis. »»

"Plants are renewable, large-volume and high-performing machineries that represent an untapped source for the production of advanced materials, electronics and energy technology."

— Eleni Stavrinidou

IMAGES: AI-generated
DESIGN & PROMPTS: Anas Albounni, KUST Review
TEXTURES: Envato Elements

During photosynthesis, plants use sunlight to split water atoms into hydrogen and oxygen. The electrons released are used to combine with carbon to produce sugars, but researchers at the University of Georgia have developed a way to interrupt this pathway, capturing the electrons before they can be squirreled away into sugar molecules.

Ramaraja Ramasamy led the team in manipulating the proteins contained in thylakoids, the structures in plants responsible for capturing and storing energy from sunlight.

The modified thylakoids were then immobilized on carbon nanotubes, which act as electrical conductors, funneling the electrons from plant cells and out along wires. A team of researchers at the University of Cambridge discovered something similar. Using ultrafast transient absorption spectroscopy (lasers at speed), the team observed electrons moving through the photosynthetic process.

They identified what they described as a "leaky pathway": The cell in which photosynthesis starts was leaking electrons. Gathering these electrons could be a way to generate renewable energy from a self-generating, carbon-sequestering source — a truly green energy. While the photosynthesis process has been honed over millions of years of plant evolution, it could always be better.

Michael Strano is a self-described "plant hacker" at MIT. In 2014, his team managed to insert nano-machines into a plant's chloroplasts. Before this (literal) breakthrough, there wasn't a way to penetrate the cell wall of the structures used by plants for photosynthesis. Strano's team coated their nano-machines with electrically charged molecules, which were absorbed by the chloroplasts.

They weren't doing this just to see if they could. Chloroplasts use chlorophyll, a pigment that absorbs blue and red light and reflects green — hence, greenery. If a chloroplast can be "re-wired" to absorb a wider range of light wavelength, theoretically, it should see a boost in productivity. Strano's nanobionic plants produced 30 percent more energy from sunlight than their control counterparts.

Combine this plant hacking with the techniques to harvest electrons and we could have veritable power plants at our disposal for all our energy needs.

FEED THE WORLD

The interplay between nanobionic approaches and electroactive plants, what Pappa calls "biohybrids," could have large implications for agriculture, making plants a technically advanced system to tackle and adapt environmental stresses beyond their natural capacity, as well as to better complement modern urban ecosystems.

"Current research in this area is only the tip of the iceberg," Pappa says. "This is despite the significant advances in the fields of bioelectronics and materials sciences, mainly for human applications." Pappa's own previous research has been focused on developing bioelectronics for in vitro applications in drug design and so-called "membrane-on-chip" devices that use conducting polymer electrodes and transistors to interface with human cell membranes.

"Considering the advancements in bioelectronics, material sciences, synthetic biology and artificial intelligence, a few plants could be used as model indictors to understand the fundamentals for optimizing and correlating productivity on a larger scale," she says.

"Although they might appear as science fiction, plant-integrated technologies could be the future of not only agriculture, but also modern urban ecosystems, as light-emitting, energy-generating or -storing, -sensing and -communicating biohybrid plants," Pappa says. "We need to harness the potential of plants if we want to realize the goal of zero hunger by 2030." ●

Dream date

Sap could make date palms even more important to food security

Sap extracted from date palms has long been a rich source of extra nutrition before and after fasts for people in North Africa. Fawzi Banat and his Khalifa University team in collaboration with UAE University would like to see those nutritional benefits extended to the emirates and other parts of the world.

The researchers had a few problems to overcome, however, before date sap can find its way onto store shelves: First, the extraction process often kills the towering plants, which in the Middle East are culturally and economically significant. Second, the sap quickly turns to alcohol, limiting its appeal in Muslim markets. The team has an answer for the second issue – a chemical added to the sap that prevents fermentation – and is working on the first.

Banat wants to make sure the collection process doesn't harm the date palms, but the researchers now know what time of day and how often they extract it matters. They're perfecting the process, learning how deep to drill and what part of the palm to drill into. But perhaps the most important question: How does it taste? "It's sweet and delicious. It is very good," Banat says.

Palms aren't the only UAE native plants on Banat's radar, though. He's also looking at Sidr trees. The fruit is rich in antioxidants, and the leaves are a promising source of surfactants, which might be extracted for shampoos and soap. "Research is ongoing but we're on the right path," Banat says.

ILLUSTRATION: Envato Elements

SMALL WONDERS

Agriculture and the environment turn to microgrids for backup

By: **Maggie Kinsella**

ILLUSTRATION: Abjad Design

The phrase “good things come in small packages” is proving true as agriculture turns to microgrids — small-scale powerhouses that could offer farmers much-needed energy without the use of fossil fuels. The food and agriculture industries are responsible for approximately 30 percent of the world’s energy consumption and 22 percent of global greenhouse-gas emissions.

Disconnecting from the larger power grid and running off a smaller grid powered by green energy sources like solar or wind can reduce the agricultural carbon footprint, save on cost, protect from cyber threats and even serve as an extra income stream.

Microgrids are energy distributors that serve a small geographical area like a college campus, hospital or farm.

> **Microgrids promise a climate-safe, sustainable, and inexpensive way for rural communities.”**
>
> — Renewable Energy World

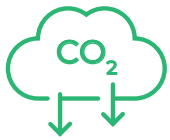
They can operate autonomously or can be a hybrid model that disconnects from the main power grid and continues to function in “island” mode when needed — such as in the event of a power outage due to a storm or in the event of a cyber attack. »»

Microgrids are revolutionizing agriculture and environmental sustainability

Agriculture's energy and emission impact:

30%

Of the world's energy consumption is attributed to the food and agriculture industries.



22%

Of global greenhouse-gas emissions come from these industries.

Microgrids' economic impact:

$11.1T

Global food & agriculture industry worth 11% of global GDP.

8 hours per day

Duration of power outages in some countries like South Africa due to load shedding.

After an attack, a hospital, for example, could detach from the main grid and keep running.

Microgrids, when connected to the main grid, can also balance power supply and demand by using complex computational techniques using real-time data analysis.

Two-way communication between a microgrid and the main power grid means it can take power or give it, based on over-supply or a required injection. This symbiotic relationship offers stability to both.

And if you have excess energy, you can sell it back to the main grid. Depending on tariff rates you could end up with extra cash. But the microgrid can also be an autonomous entity receiving its power injections solely from green energies.

In this case, the grid can receive energy — say, from solar panels — store it and supply it, with zero reliability on the main grid.

Agricultural-industry leaders, farmers and food suppliers can now turn to this more reliable, cost-effective and sustainable energy source to maintain uninterrupted operations.

Bigger isn't always better

Microgrids may be smaller than the traditional power grid but in a big way, they are a reliable source of power during unexpected outages and can mitigate interruptions to business continuity.

The ability to disconnect from the main grid and run off stored energy allows communities or businesses including farms and food suppliers to operate when the main grid is inaccessible.

They're also resilient, able to modify and recover from severe and sudden disruption. Plunkett Research's 2023 statistics report estimates the global food and agriculture industry to be worth U.S.$11.1 trillion, which equates to 11 percent of total gross domestic product. Losses during downtimes therefore, can be catastrophic.

Dairy farmers, for example, require power for milking, processing and storing the product. An electricity shutdown effectively means a business halt and potential for spoilage.

And in countries experiencing an energy crisis, agriculture takes a significant hit.

South Africa, for example, protects its main grid by load shedding. This means power is temporarily shut down when demand comes close to shedding the grid of what it has to offer in order to avoid grid failure. These outages can last up to eight hours per day.

Though this protects the main grid, shutdowns wreak havoc on agriculture. "It is beyond dispute that every sector of the South African economy has suffered from the impact of rolling blackouts.

But agriculture has suffered disproportionately," says Christo van der Rheede, chief executive officer of AgriSA, in an article for the *Daily Maverick*.

So a country that experiences extensive outages would seem a perfect fit for microgrids.

"A technology of the future, microgrids promise a climate-safe, sustainable and inexpensive way for rural communities to harness their own resources and meet their communal needs," says *Renewable Energy World*, which covers news and trends in the renewable-energy industry.

The problem is, while microgrids might offer security and save money over time, it takes funding to make the switch. And not everyone has this kind of money.

Is it worth it?

Countries like Australia are less vulnerable to power loss than developing countries that experience many power outages throughout the year, but increased cost of power could be incentive enough to invest in an energy shift. And switching to green energy means significant cost savings.

Tania Chapman, general manager of farming operations at Nutrano Produce Group, one of Australia's leading producers of fresh fruit, says it's complicated to maintain earnings among rising energy costs and maintaining governmental sustainability guidelines.

"If I look at one of our sites the annual bill is around $110,000 currently for the electricity, putting in solar would cost me $120,000 and it would reduce the electricity bills by around 25 to 30 percent," she tells ABC Rural. Adding a microgrid into the solar mix could be significantly better.

With global temperatures on the rise, the volume and severity of extreme meteorological events can be catastrophic to not only large industries, but vulnerable infrastructures like those of developing countries or remote communities.

And access to the main energy grid can be unstable, which also limits socioeconomic development. Microgrids are less costly than extending the main grid, so many countries are investing in their rural communities.

It's not only a cheaper option but it also allows governments to meet commitments and goals set forth in the Paris Agreement. Tax breaks can also help offset the costs of renewable-energy equipment.

> **Good things come in small packages.**

As of 2019, there were 4,500 microgrids globally, but the market is expecting a major growth spurt in the coming decade as governments are keen to mitigate financial risk and develop rural areas.

IN THE HEART OF A NEW CITY

By: Jade Sterling

Experts say technology helps as urban areas grow, but it shouldn't be the focus

As technology advances and people flock to cities, we are increasingly living in a data-driven urban world: the smart city.

The definition of a smart city? There's no single agreed-upon definition, but a working approach would focus on a framework of information and communication technologies all working together to support the overwhelming growth of urban centers.

It's the Internet of Things, but citywide. Millions of sensors capture billions of real-time data points. Having everything connected and talking to each other and providing streams of data at all times offers the potential to improve efficiency and cut costs:

Cities can improve energy use, streamline services, facilitate traffic flow and even reduce air pollution. A digital foundation makes a city more functional, more responsive and, ultimately, a better urban environment.

Sounds great. But as smart cities become not only real but normal, there has been pushback. Farah Naz is an award-winning climate-change strategist working with infrastructure-design and engineering firm AECOM Middle East. She's been steering sustainability and innovation in the built environment across the region, and the term "smart city" doesn't work for her anymore.

"There's this peculiar problem with the whole idea of smart cities," Naz tells *KUST Review*. "It became all about efficiency, and humans just took a backseat. Sure, our lives are more efficient now but smart cities aren't elevating our livability in any way."

Naz would much rather we focus on net-zero cities. "We need to future-proof and adapt, not automate and optimize. We need to think beyond the definition of a 'smart city' to a city able to deal with any future climate scenario."

> "We have to find solutions to make our cities more resilient and our buildings more sustainable."
>
> — Farah Naz

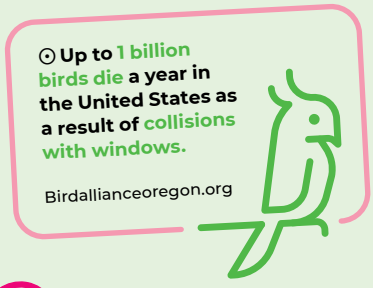
The issue of livability and sustainability resonates with Joachin Rodriguez too. Rodriguez, director of academic research at RMA Advisory, a smart cities advisory firm, specializes in the relationship between society and technology. He is a professor at the Autonomous University of Barcelona and has spent much of his career helping unlock the potential of the world's cities. He's the ideal advocate for a smart city, yet he's not happy with where we've ended up.

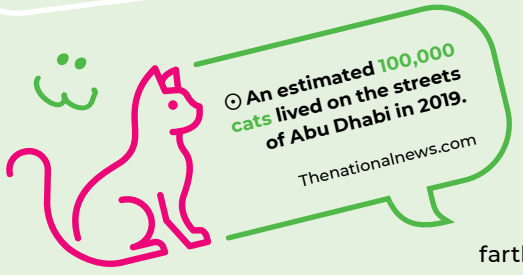
Rodriguez defines a smart city as the best attempt to recover the connection between human activity and economy and nature: "One of the key aspects of the amplification of the concept of a smart city is the recognition of non-humanistic holders — all those elements of an urban space that aren't human but are citizens."

By this, Rodriguez means the pollinators, fungi and plant life that reside alongside us. In a race against a "catastrophic" horizon, Rodriguez insists we need to embed more nature into our cities: "The human-centric approaches of the past aren't working anymore. We need to enhance life and preserve nature and use technology to support this."

Hira Sheikh, researcher with the Design Lab and Digital Media Research Centre at the Queensland University of Technology, Australia, calls this "the striking absence of nature in smart city discourse" in her 2023 *Digital Geography and Society* paper and points out the need to rethink human exceptionalism and reimagine cities as "more-than-human" places.

She's talking about the pollinators, fungi and plant life too. "When we think about smart cities, we usually »»





imagine a city filled with sensors and dashboards providing urban stakeholders with information about a city's citizens, infrastructure, environment and their interactions for the purpose of making better government decisions," Sheikh says. "Humans understand the urban realm through design and planning categories, such as housing, mobility or street lighting.

The negative consequences of these design and planning categories — such as deforestation due to housing development, noise pollution due to urban mobility, and light pollution from street lighting — are known to contribute to population decline among many species."

Naz agrees with the sustainability focus, but thinks people should still be at the heart of the city. "We are in a climate emergency. We have to find solutions to make our cities more resilient and our buildings more sustainable and we can even turn to the old ways to do that.

You don't need anything more high tech than a thermal camera to see where building insulation may be missing, and you don't need to look farther than ancient palaces in Nepal or Indonesia to realize you need thick walls to keep the cool in and the heat out."

Naz says the biggest failure of smart cities is the fact they are predictive and data-driven, but the data and their insights are not being used effectively to make our lives better: "Technology should be used to make cities more resilient and mitigate from a climate perspective, but what I'm finding is all this has to be people-centered and -focused."

Smart cities aren't just a research concept or futuristic ideal. Many are already active and expanding rapidly: Think Dubai, London, Copenhagen, Amsterdam, Seoul and Oslo.

Futuristic projects do exist — Neom's The Line, for example — but ambitious ventures aside, smart cities are here and now. For researchers, architects, engineers, city planners and policymakers, the only futuristic aspect is designing and implementing future resiliency. "The rise of the geological age we know as the Anthropocene is intimately tied to the drive for technological progress in the service of human advancement," Sheikh says. "Digital technologies often used to acquire data about different social and environmental factors are integral to the pursuit of human progress.

In recent decades, the same digital technologies and data born out of an anthropocentric worldview have been put to service to promote environmental conservation and governance."

She points out that these digital technologies can be used more consciously to "bring forth the deserving stories of diverse urban species" and "make space for nonhuman beings in cities."

"We didn't have any ecological awareness before but now we do," Rodriguez tells *KUST Review*. "Temperatures are rising and some areas will be uninhabitable. We can't build cities putting humans first anymore. We have to prioritize our relationship with nature and understand nature as the epicenter of our use of technology."

A single London planetree in East Boston, Massachusetts, with a diameter of 24 inches provides these benefits every year:

1,843 kWh
Energy conserved

3,244 Gallons
Stormwater filtered

3,145 Pounds
Carbon dioxide stored

3 Pounds
Air pollutants removed from the neighborhood

U.S. Forest Service

"Nature is much smarter than we are," Rodriguez says. "The path to building smart cities is nature-based solutions and biomimicry. Forget IoT, forget hyper-connectivity, we should be investing in nature."

Again, Naz would like policymakers to not forget the humans though. Cities are for people, she says: "If we are not learning from the feedback loop from our cities — where and why things are going wrong — and optimizing our governance and investment, then we don't actually have a smart city.

We need to be responsible in our use of technology, conscious about the insights we get and use them to optimize policies. We need a new social contract for our cities and business models. Our existing ones don't really work to create future-resilient cities."

Community-planning and -development consultant Mary Graham said in a 1999 paper "the most basic question for any human group, despite advances in technology, remains the same: How do we live [together] without substantially damaging the environment?"

What will the city of the future look like? No one truly knows. But if you ask Naz, Rodriguez or Sheikh, the smart cities of the future will be sustainable — and this is non-negotiable.

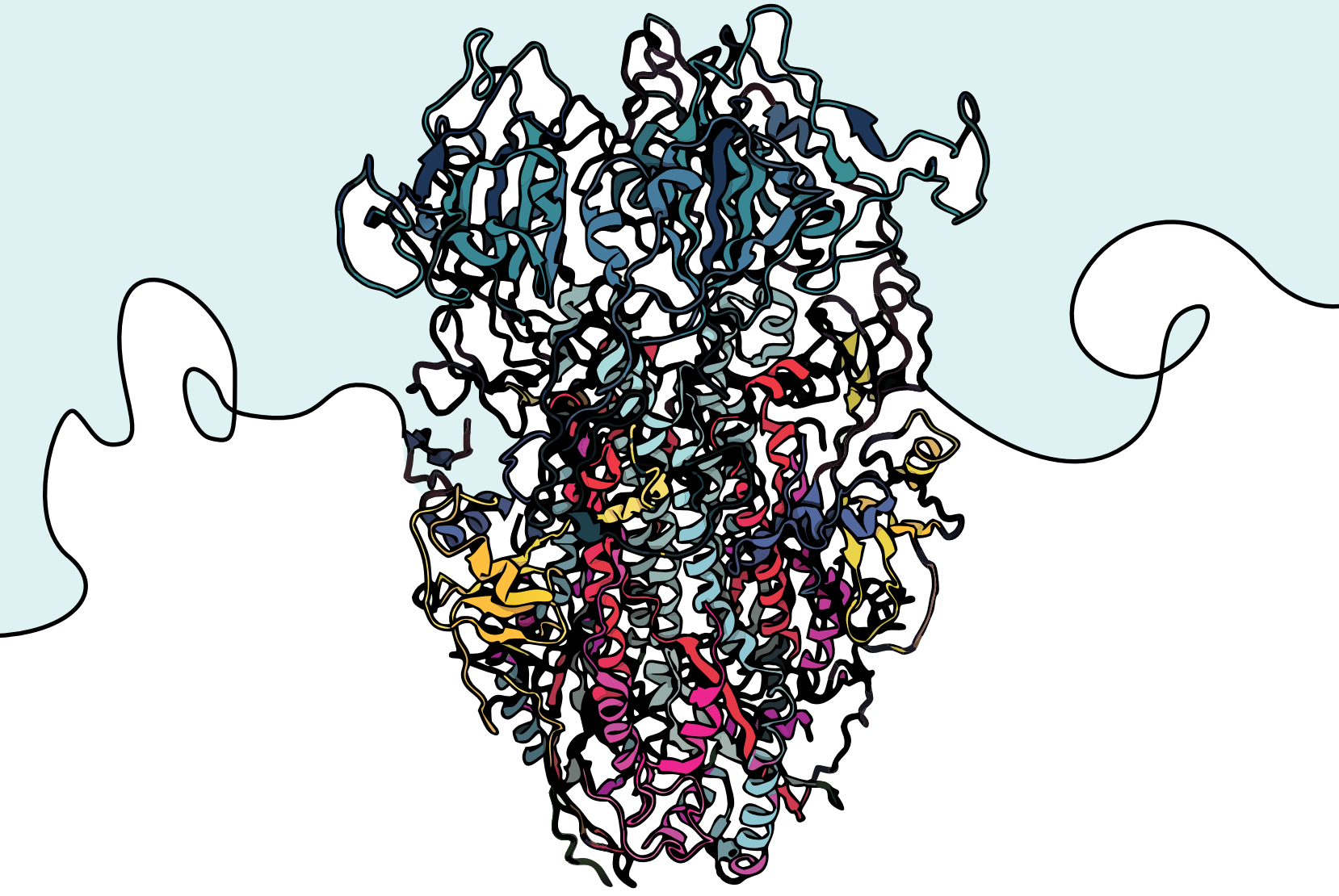
A bird's eye view

Queensland University of Technology's Hira Sheikh points to a nonhuman design approach suggested by designers Mathieu Andries and Mathis Morin that aims to avert the millions of bird deaths caused every year by windows in city buildings that birds cannot see.

To create windows that are visible to birds, Andries and Morin proposed adding to the glass calcite minerals that are invisible to the human eye, but emit UV waves visible to birds.

As Andries and Morin demonstrate, by attempting to see the world through a bird's point of view, the design of buildings might be unlearned and relearned.

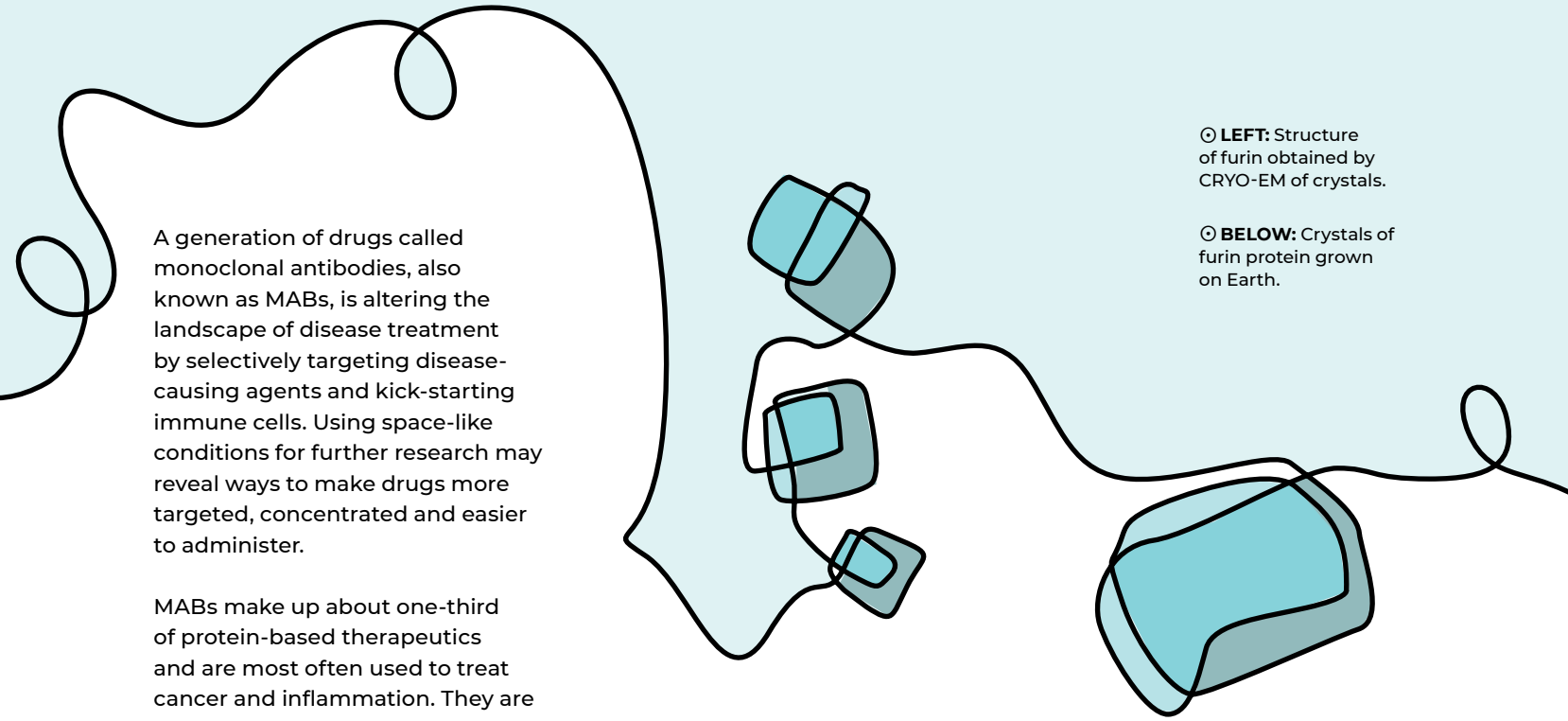
ILLUSTRATION ABOVE: Maya Albounni
PHOTO & ICONS: Shutterstock
DESIGN & LAYOUT: Anas Albounni, KUST Review



LAUNCHING MEDICAL RESEARCH

Microgravity could make the drugs you need work even better

By: **Maggie Kinsella**



⊙ **LEFT:** Structure of furin obtained by CRYO-EM of crystals.

⊙ **BELOW:** Crystals of furin protein grown on Earth.

A generation of drugs called monoclonal antibodies, also known as MABs, is altering the landscape of disease treatment by selectively targeting disease-causing agents and kick-starting immune cells. Using space-like conditions for further research may reveal ways to make drugs more targeted, concentrated and easier to administer.

MABs make up about one-third of protein-based therapeutics and are most often used to treat cancer and inflammation. They are widely regarded for their ability to target the specific protein of a pathogen and stop it from invading more cells.

This means the therapy is tailored to the patient's disease. The problem, however, is that patients need to get these drugs in large quantities over extended periods of time.

Proteins are too small to study under a microscope, so growing them into crystals lets researchers get a better understanding of their 3D constitution.

Their makeup reveals how each protein works and how it contributes to disease scenarios. Once we understand this, drugs can be developed that mesh with the protein and fight the disease.

As well as being an important category of therapeutics, proteins are themselves drug targets. Drug companies need high-resolution protein structures to design suitable drugs. This is where microgravity comes in. Earth's gravity can inhibit the growth and quality of crystals by affecting how the molecules position themselves on the exterior of the crystal. This makes space or a space-like environment ideal for this type of research.

AN INVOLVED PROCESS

David Sheehan, professor of biochemistry at Khalifa University, has been working on a method of crystalizing proteins for 12 years.

His proteins are awaiting the arrival of vacuum chambers that mimic microgravity in a collaboration with Sean Shan Min Swei of the Department of Aerospace Engineering.

While turning proteins into crystals might seem like a cool magic trick, the process is quite involved. And many of the victories in successful crystallization can be attributed to time, patience and a lot of luck.

Sheehan says initially, the protein is purified or separated from anything that might inhibit crystallization, like fatty materials from cells. The pH level is maintained for an optimum growth environment, and salt might be added to increase the ionic strength — or concentration — of the solution.

Other precipitants like polyethylene glycol or organic solvents, which decrease the protein solubility, are added. Then, the conditions are manipulated in a variety of ways, such as adjusting the temperature or exposure to gravity.

"The chemical additives and pH combined make up a condition. Most proteins only give crystals in a small number of conditions, so it is necessary to screen thousands of conditions to find the small number that will yield usable crystals," Sheehan tells *KUST Review.* And then it's a waiting game — crystals might form in a week, a year or not at all. »»

Sheehan says researchers spend most of their time watching and hoping for a crystal, but most won't see it: "When and if a crystal appears, then you've got a project."

In his case, the crystals responded well to the addition of nanoparticles. While most of these types of experiments might typically result in one or two crystals from thousands, Sheehan's team grew 15 crystals out of a panel of 16 proteins studied.

"We found one formulation that worked better than the others. So, then we used that nanoparticle with about 200 conditions," he tells *KUST Review.* This is unheard of, he says. And he knew they were on to something significant.

JOURNEY TO MICROGRAVITY

The project has a long history.

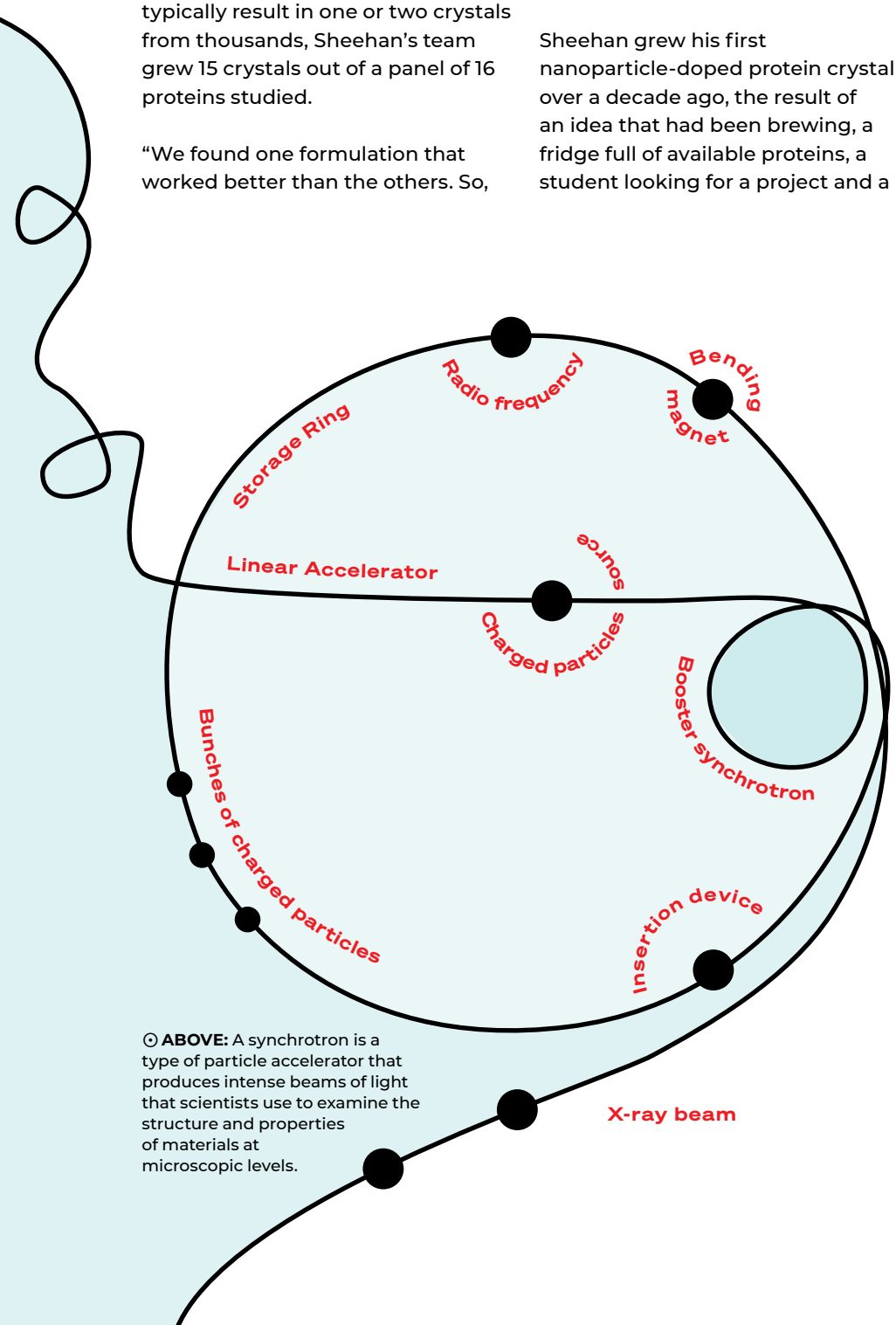
Sheehan grew his first nanoparticle-doped protein crystal over a decade ago, the result of an idea that had been brewing, a fridge full of available proteins, a student looking for a project and a friend with access to a synchrotron, a machine that uses electricity to create intense X-ray beams to study matter's chemical and structural properties.

The student experimented with two nanoparticles, different from the ones used on the recent project: "The crystals grew very quickly and in the presence of a nanoparticle, they were larger, they grew faster, and they really grew. And that worked with both nanoparticles," he says.

The stars (or crystals rather) aligned, and Sheehan and his student were soon transporting proteins to Dublin to a crystallographer friend who agreed to take them to the Paris synchrotron.

A synchrotron is about the size of a football field and is an ideal way to determine the three-dimensional atomic structure of a protein.

It generates very intense X-ray beams that pass through a protein crystal and are scattered by the protein's electrons. The crystal is rotated and a second scatter pattern is obtained. From these scatter patterns an atomic-level structure can be calculated, Sheehan says.



ABOVE: A synchrotron is a type of particle accelerator that produces intense beams of light that scientists use to examine the structure and properties of materials at microscopic levels.

FOCUS ON PROTEINS

But why are we so focused on proteins? Why not other molecules? Proteins are the worker bees of a cell.

They play an essential role in most biological systems and are responsible for most cellular functions. They are responsible for the shape, the interior design,

production, cleanup, general upkeep and communication of cells.

This makes them of great interest for targeted drug development, Sheehan says. There are more than 130 protein-based therapeutics on the market, and the next step is to make them even better.

Current drugs for diseases like cancer, for example, require patients to take them for lengthy periods.

Patients might sit in a clinic, hooked up to an IV for hours at a time to ensure they get the right concentration of treatment. These treatments can go on for months or years. Imagine if patients could receive a simple injection in a doctor's office.

And this type of drug development is dependent on research like that of Sheehan and his team. Furin, for example, is a potential antiviral drug target for treating COVID-19.

Aside from the contributions to science, fighting disease and improving patient care, it could also mean a commercial venture.

"This could be very big," Sheehan says. "I can see two options for commercialization, one of which is to market this as a crystallization screen and the other a start-up offering this as a service to pharmaceutical companies, biopharma and scientists around the world who have proteins they want to structure."

With the team's current success rate of more than 90 percent, it's promising. Sheehan and his researcher Salma Sultana Syed have patented their screen in the USA, UAE and Europe.

They are exploring creating a start-up to be called ProScreenix after incorporating a vast number of additional proteins into their research and changing up the nanoparticles using their current screen.

This will create a more difficult problem, but test the method against a more robust array of challenges and hopefully improve the success rate. If you can't take your proteins to space, bring space to your proteins.

Success is also dependent on microgravity, so Sheehan's team will use space-simulation chambers that mimic these conditions, offering faster crystallization time and higher-quality crystals.

The team is also hoping to acquire a robot that will help increase the number of conditions from 160 to approximately 1,000 and increase the number they can test daily.

"At this point, when you get to that stage, you're in the zone of talking about having a center for excellence," Sheehan says.

Now they just need the right investors.

According to Allied Market Research, the protein therapeutics global market value is expected to reach U.S.$566.6 billion by 2030, up from U.S.$283.64 billion in 2020.

Another protein

Creating crystals isn't the only way to study proteins. Emirati geneticist Habiba Al Safar and her team at Khalifa University recently looked at dozens of non-genetically modified varieties of wheat and measured their gluten content.

Gluten is the protein in wheat flour that helps give breads and cakes their texture and flavor. But some people can't tolerate it, experiencing such symptoms as bloating, migraines and diarrhea.

The team selected varieties with naturally occurring low- and high-gluten content to be studied further at United Arab Emirates University. The goal: encouraging cultivation of top performers in the UAE to give consumers the best options on both ends of the gluten scale.

A Hot Topic

Predicting the impacts of temperature surge on humans

Climate change is undeniably affecting the Earth. But how will those changes affect us and our neighbors near and far? We asked our experts: What are the anticipated implications of rising temperatures for human societies?

PHOTOS: Unsplash

Rising oceans put lives and economies in peril

Elizabeth Philips
is an environmental Consultant with GHD Global Pty Ltd. with industry experience in Canada and consulting experience in South Africa. She holds a B.Sc. from the University of Calgary.

Today we can see that rising sea levels are negatively affecting coastal ecosystems and communities, ushering in a wave of unprecedented challenges. Over the past century, sea levels around the world have risen on average 23 centimeters, and this number is increasing every year. Research published in February 2022 shows that sea level rise is accelerating and projected to rise by 30 centimeters by 2050.

Sea level is controlled by both water temperature (thermal expansion) and melting ice caps and glaciers. Due to climate change, the oceans as well as the atmosphere are getting warmer.

In the past century, the oceans have become about 0.1 degree Celsius warmer. This does not sound like a lot, but warmer, expanding oceans caused about half of the rise in sea level in the past century. The other half can be attributed to melting ice caps and glaciers.

Rising sea levels are going to have a serious impact on people around the world. The global ocean covers close to three-quarters of the Earth's surface, and around 40 percent of the world's population lives within 100 kilometers of the coast. Densely populated cities like Shanghai, Jakarta and Hanoi are in danger of flooding from even a small rise in sea levels. If the flooding is too much, vulnerable populations may be displaced temporarily or permanently.

Higher sea levels are eroding coastlines, resulting in the loss of land and habitat for plants, animals and people. Coastal erosion also causes loss of infrastructure, including homes, roads, agricultural land, ports, airports and power plants or at least making them more susceptible to damage and disruption.

Some of the world's most visited beaches are suffering coastal erosion. It happens faster when supercharged storms repetitively hit beaches, chipping away at the coastline. Over recent years, we have seen increased frequency and severity of storm surges during hurricanes and tropical storms, leading to more severe flooding in these coastal regions.

As sea levels rise, salt water will contaminate freshwater sources, the water we drink. It will also make things more difficult for farmers, plants and animals and will have a huge economic impact on coastal areas. Many ocean species are in decline because of pollution and warming seas. Coastal ecosystems, such as mangroves here in Abu Dhabi and coral reefs, suffer significantly due to submersion and habitat degradation.

The economic consequences and global implications are huge. Coastal economies, especially those dependent on tourism and fisheries, may suffer from the loss of infrastructure and the decline in natural resources.

Displaced people and disrupted economies can have global effects, influencing trade, food supply chains and international relations.

Addressing the multifaceted impacts of rising sea levels demands a comprehensive global response. Sustainable coastal development, adaptation measures and efforts to mitigate climate change are essential to helping our coastal communities and the planet. »»

Here's how agriculture weathers new challenges

Tarek Kapiel
is assistant professor of plant biotechnology, botany and microbiology at Cairo University.

Rising temperatures have a number of anticipated implications for human societies, but one of the most critical for the UAE and other Arab nations is their effect on food security.

The agricultural systems of Arab nations, with their arid and semi-arid climates, are vulnerable to disruption in several ways.

Changes in precipitation patterns: Rising temperatures can alter rainfall patterns. In some regions, this may result in more frequent and severe droughts, negatively impacting soil moisture levels and crop growth. In other cases, intense rainfall can cause soil erosion and waterlogging, further affecting agricultural productivity.

Droughts: Higher temperatures can exacerbate drought conditions by increasing evaporation rates, reducing soil-moisture content and intensifying water scarcity.

Droughts can lead to decreased crop yields, reduced livestock productivity and increased competition for water resources. Such disruptions in agricultural production can result in food shortages, price increases and economic instability, with potential implications for social unrest.

Increased pest activity: Insects, fungi and other pests thrive in warmer conditions, leading to increased infestations and crop damage. This can further reduce crop yields and necessitate the use of more pesticides, which may have environmental and health consequences.

The implications of rising temperatures for food security vary across the UAE and other Arab nations due to differences in climate, geography and agricultural practices. In arid regions, such as the Arabian Peninsula, water scarcity is already a significant challenge, and rising temperatures can compound this issue.

Coastal areas face additional risks due to the potential for sea-level rise and saltwater intrusion into agricultural lands.

Fortunately, there are potential solutions. These include:

- **Improving water-management practices,** including increased water efficiency, desalination and wastewater reuse.
- **Promoting sustainable agricultural practices,** such as precision farming, organic farming and agroforestry, to enhance resilience to climate change.
- **Investing in research and development to develop drought-resistant and heat-tolerant crop** varieties suitable for the local climate.
- **Enhancing agricultural infrastructure,** including irrigation systems, storage facilities and transportation networks, to reduce post-harvest losses and improve market access.

In the meantime, the implications of rising temperatures on food security have sparked ongoing policy debates in the UAE and other Arab nations.

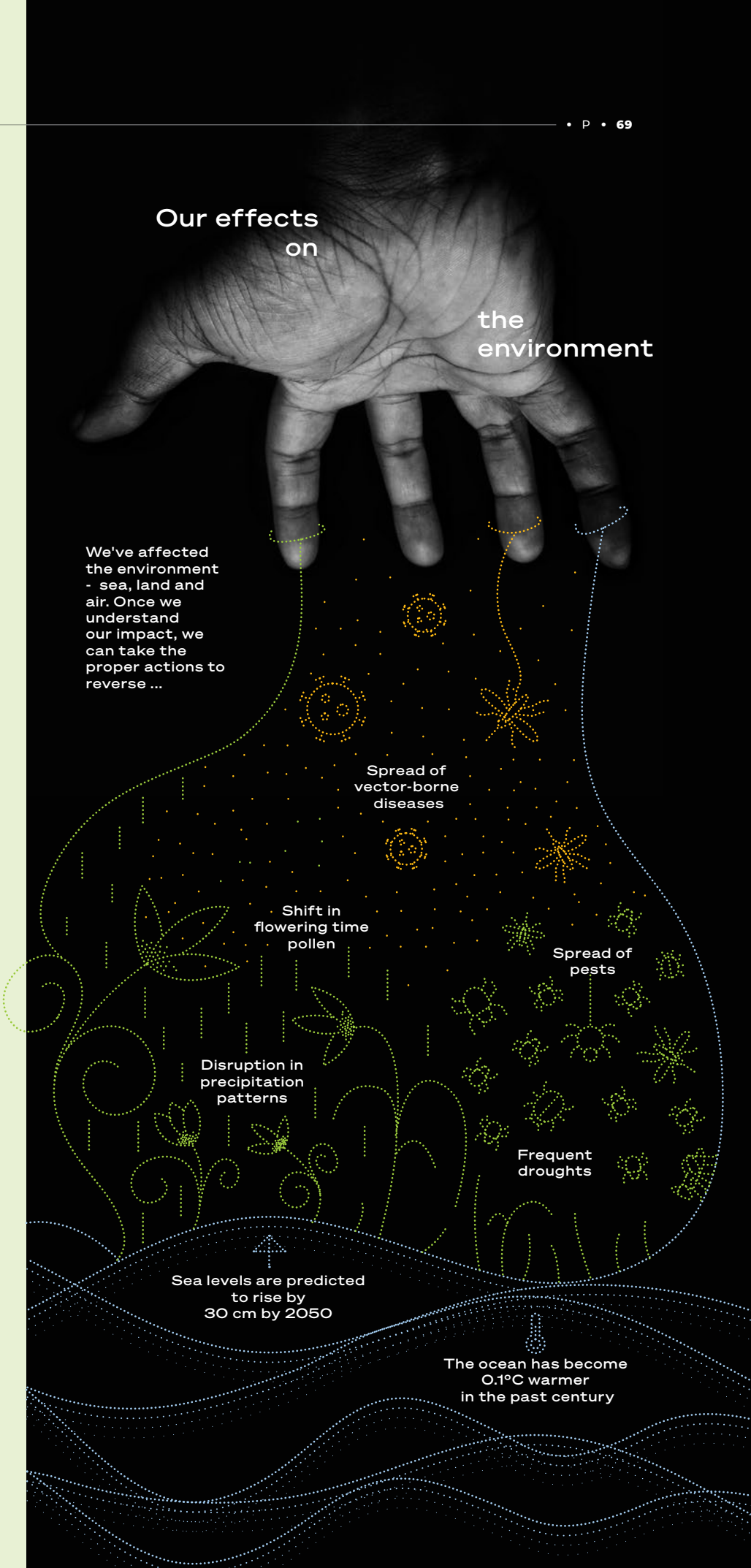
These debates revolve around issues such as balancing agricultural development with environmental sustainability; promoting

> **The UAE and other Arab nations can enhance their resilience and ensure food security for their populations in the face of rising temperatures.**

climate change adaptation and mitigation measures; encouraging international cooperation and knowledge sharing to address common challenges; and integrating traditional knowledge and local practices with modern technologies and innovations.

Understanding the regional variations, exploring potential solutions and engaging in ongoing policy debates are crucial for mitigating the adverse effects of climate change.

By adopting sustainable practices, investing in research and development and fostering international collaboration, the UAE and other Arab nations can enhance their resilience and ensure food security for their populations in the face of rising temperatures. »»



There's a human cost to a warming world

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Throughout Earth's history, only creatures capable of adapting to environmental shifts have survived. This principle presents a stark challenge as we face the escalating threat of global warming.

As the planet heats up, we must confront its myriad implications on human health.

Scientists have dedicated immense effort to studying these complexities, revealing a range of potential health risks.

These include heat-related illnesses, compromised water and air quality, rising rates of vector-borne diseases, and threats to food safety and nutrition.

In global climate action at COP 27, parties renewed commitment to limiting global temperature rise to 1.5°C. The Intergovernmental Panel on Climate Change (IPCC) report assessed the impacts of a 1.5-2 degrees Celsius increase above pre-industrial levels and the potential consequences if we fall short of maintaining the global average temperature increase of less than 1.5°C.

One of the direct risks is increased heat-related illnesses and diseases, particularly to vulnerable populations like the elderly, pregnant women, children and urban residents.

Cardiovascular diseases top the list of heatwave-related fatalities, followed by dehydration, hypertension and respiratory and cerebrovascular issues. A chilling estimate suggests that a 2 degrees Celsius increase could make heatwaves, such as the one that struck Pakistan in 2015, frequent occurrences.

> **Embracing climate mitigation and adaptation strategies is crucial to protect human health.**

Another threat is an escalation of infection with vector-borne diseases, especially in tropical regions like Africa. Increased heat could lead to an increase in mosquito populations, thus escalating the risk of malaria, dengue and other vector-borne infections.

Warmer temperatures would also cause a shift in flowering time pollen initiation in allergenic plant species, and continuous exposure can worsen allergic responses in predisposed individuals. Those health risks will exert extra pressure on the health-care system.

Embracing climate mitigation and adaptation strategies is crucial to protect human health. Transitioning to a low-carbon future presents an opportunity for both sustainability and economic growth. By acknowledging the threats and taking decisive action, we can forge a healthier, more secure future for all.

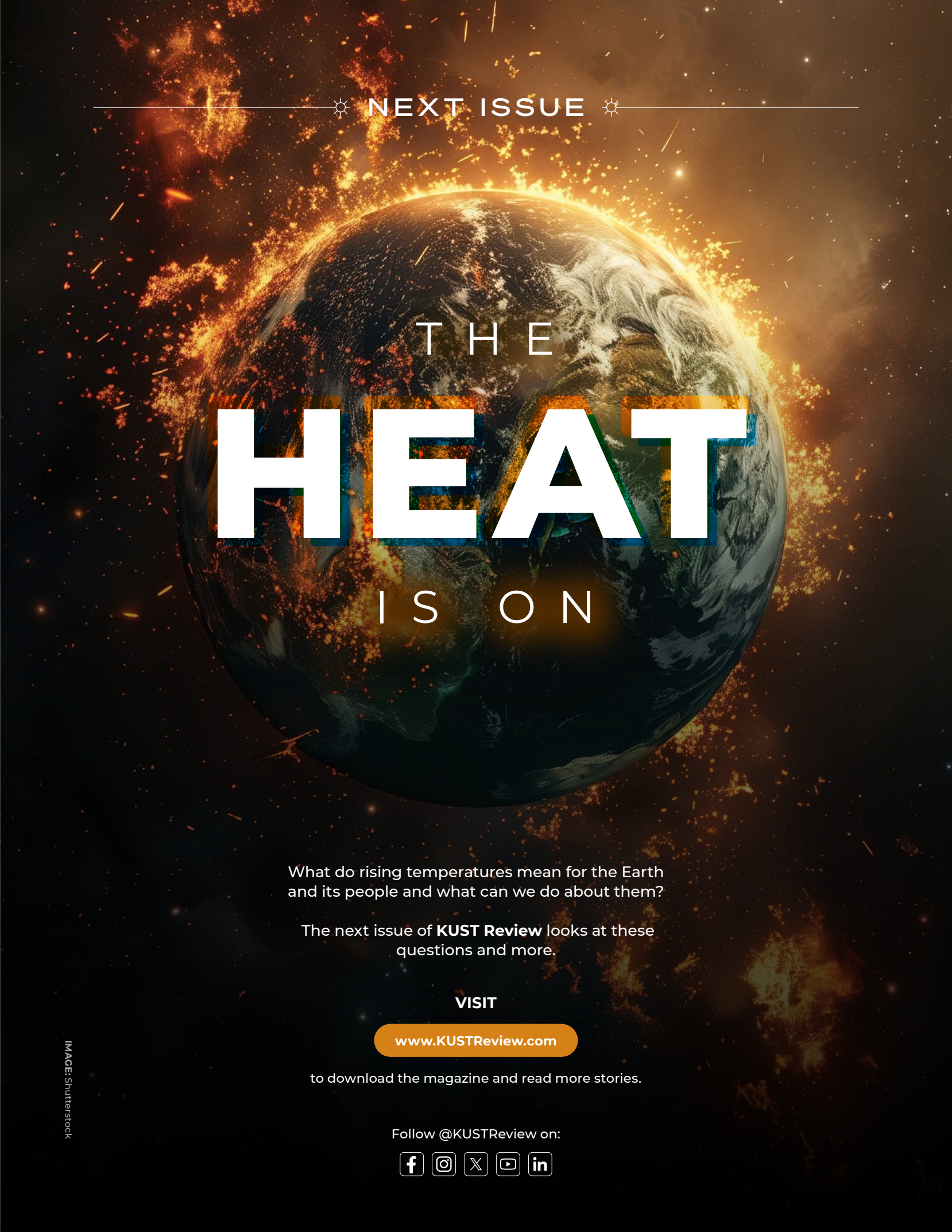

IMAGE: Shutterstock

Cultivating Change

Here are some of the innovations that took humanity from hunter-gatherer societies to modern times.

21st CENTURY
VERTICAL FARMING

Crops grown in vertically stacked layers in controlled indoor environments allow for year-round production, reduced water usage and urban food security.

LATE 20th CENTURY-PRESENT
PRECISION AGRICULTURE

GPS, remote sensing and data analytics allow farmers to use water, fertilizers and pesticides more efficiently and sustainably.

LATE 20th CENTURY
GENETICALLY MODIFIED CROPS

Genetically modified organisms (GMOs) allowed for crops with enhanced traits such as pest resistance, drought tolerance and increased nutritional value.

MID-20th CENTURY
GREEN REVOLUTION

Developing high-yielding varieties of crops, along with agricultural techniques and synthetic fertilizers and pesticides, led to a dramatic increase in food production worldwide.

19th-20th CENTURIES
MECHANIZING AGRICULTURE

Machinery such as tractors, combine harvesters and threshers reduced labor requirements and increased productivity.

1701 CE
THE SEED DRILL

Jethro Tull's invention mechanized the process of planting seeds, leading to more uniform seed distribution and higher crop yields.

CIRCA 3000 BCE
THE PLOW

A more efficient way to till soil enabled higher yields and larger-scale cultivation.

CIRCA 6000 BCE
IRRIGATION SYSTEMS

Mesopotamian and Egyptian civilizations developed sophisticated techniques to control water flow and supply crops. In UAE's Al Ain, the Aflaj system has been conducting water through underground tunnels for about 3,000 years.

CIRCA 10,000 BCE
DOMESTICATED PLANTS AND ANIMALS

Einkorn wheat is believed to be the first domesticated plant. The first domesticated animals were likely dogs, goats, pigs and sheep.