

plastic waste pollution.

- Cultivated at scale, seaweed can grow up to 60 times faster than land-based plants, making it an important carbon sink.
- Local startups are also exploring its potential to make bioplastic that is naturally degradable and even edible, for use in food packaging and other applications to replace plastic.
- For the new generation of seaweed farmers in Indonesia, the plant also offers revenue streams through ecotourism.

BALI, Indonesia — It's just after sunrise here in Bali, and a group of locals are preparing to sail their wooden boats out to a bay off Nusa Lembongan, a small island southeast of the tourism hotspot.

They're neither fishermen nor tour guides. They're farmers, cultivating a watery crop that promises to be part of the solution to the increasingly urgent problem of marine plastic waste that's become woven into the Bali experience for the millions of people who visit the island each year.

"Algae cover a very broad area," says Rama. "I am optimistic. We can develop ecotourism and use the algae in many ways — for example in our spa, where we scrub tourists with seaweed."

Rama, 17, is part of a new generation of Balinese hoping to carry on an age-old tradition of harvesting algae, or seaweed. He looks out at the calm and still waters of Lembongan Bay. The inlet is protected by reefs that absorb the waves some 100 meters (330 feet) off the shore. The water temperature hovers at 28° Celsius (82° Fahrenheit), salinity is at 30‰, and the current flows in just the right direction. It's the perfect place for what grows beneath the surface: *Eucheuma cottonii*, also known as macroalgae or red seaweed. (Despite its name, it comes in shades of red, brown and green.) The seaweed grows in straight lines, attached to ropes stretched between iron rods that run over the sandy bottom.



A seaweed farmer lays out clumps of algae in rows in Lembongan Bay, Indonesia. Image by Jonas Gratzler for Mongabay.

Rama's father, Wayan Suarbawa, is one of Nusa Lembongan's five seaweed farmers — the last remnants of an industry that employed most of the island's 5,000 inhabitants during its heyday in the 1980s. The big blow came in 2014-2016, when the farms were hit by a bacterial infestation that hardened and whitened the seaweed. The disease was triggered by a rise in water temperature and changes in salinity and light conditions — the hallmarks of a changing climate. With their livelihoods devastated, most of the farmers sought out jobs in the tourism industry.

Indonesia was the world leader in the production of *E. cottonii* before 2014, churning out more than 8 million tons a year. Today it's No. 2, after China, but still supplies 38% of the global seaweed market.

But the tide is turning once again in Nusa Lembongan. The local government wants to employ an additional 100 seaweed farmers in Lembongan Bay through a program that hands out 0.8 hectares (2 acres) per farmer to grow seaweed. The waters around Nusa Lembongan could potentially host up to 500 seaweed farmers. Prices are up, along with prospects for *Eucheuma* seaweed, which is used to make carrageenan, a thickener and stabilizer used in foods, cosmetics and industrial products. In countries like Indonesia and the Philippines, the macroalgae is also consumed as food.

Suarbawa says he makes about 15 million rupiah (about \$1,000) a month — six times the minimum wage in Bali — just from selling seaweed to visitors coming from the capital, Jakarta. Suarbawa is also involved in plans for an ecotourism initiative in Nusa Lembongan that will bring tourists to snorkel among the algae.

But the threat of climate change and the potential for another bacterial outbreak still linger over Lembongan Bay. This part of Bali has also lost a number of seaweed farms to tourism developments, clearing of wetlands, and pollution. To ensure a more resilient seaweed-farming industry this time around, the farmers will have to develop more resistant varieties of algae, experts say.

"Climate change and the accompanying El Niño will significantly destroy seaweed farming in Indonesia," says Ketut Sudiarta, a scientist in the fisheries department at Bali's Warmadewa University. "This has happened now. Almost all of Indonesia has failed and most of [the farms] have been abandoned by farmers."

But if the industry succeeds, it could become a weapon in the fight against climate change. The algae grow quickly — 30 to 60 times faster than land-based plants — and absorb carbon dioxide from the water and atmosphere. If cultivated at scale, that makes it an important carbon sink, which can then be harvested and used as a biofuel in place of fossil fuels.



It could also be the solution to that other environmental bane in Bali: [plastic waste](#), of which Indonesia is the world's second-biggest contributor, after China. Seaweed can be processed to make food containers — biodegradable, edible even — that could replace the conventional single-use plastic containers that account for much of the trash fouling Bali's beaches and seas.

According to Sudiarta, "it's very possible, especially for the big brands," to make the switch from plastic containers to seaweed-based packaging. For now, though, a host of small

companies are p



d cups under  
e-use sachets,

A young woman at an orphanage in Jakarta makes Ello Jello brand edible seaweed cups. The orphanage keeps the profit from the sale of the cups. Image by Jonas Gratzler for Mongabay.

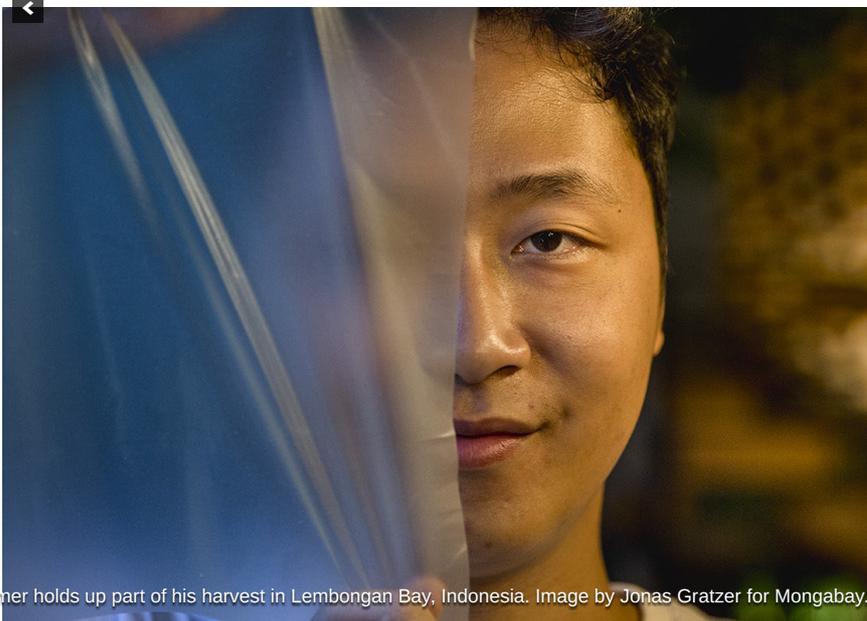
Christian is involved in a 4Rs campaign — reduce, reuse, recycle, replace — that aims to reach a million people with its sustainable goals. Ewovare's social involvement sees youths at orphanages in Jakarta, Bali and Malaysia produce and sell Ello Jello cups and keep the profit. Production is limited at present, about 500 per day, and testing is still going on. But orders have come from 900 companies in 52 countries, and Christian says full-scale industrial production of containers and cups should happen later this year.

"The demand for these products will only increase, and the cost of production will decrease," he says, adding that reactions have been positive and that he welcomes other companies exploring similar solutions.

"We all have the same goal of beating the conventional plastics," Christian says. "The market is enormous and we need many players, so why compete with one another?"

#### Future of bioplastics

One such company is Avani Eco, based in Bali and producing shopping bags (printed with "I am not plastic") from cassava fiber since 2014. It also makes drinking straws from paper and cornstarch, as well as food boxes from bagasse, the dry, fibrous residue from sugarcane processing. The company garnered widespread attention when co-founder Kevin Kumala dissolved one of his bags in lukewarm water and drank it, to emphasize that it was non-toxic and entirely biodegradable.



A seaweed farmer holds up part of his harvest in Lembongan Bay, Indonesia. Image by Jonas Gratzler for Mongabay.

mise due to its versatility and the sheer scale of  
pass \$9 billion by 2024, about 90% of it *E. cottonii*.  
are being explored. These include seaweed as

g Astawa, 33, is one of the island's three newly  
ear to start taking tourists on snorkeling trips on his

business. There are many ways to make money in it."

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