Directed Evolution of Biological Carbon Fixation Working Group (DEBC-MIT)

THE PROBLEM

Agriculture is the second largest source of human emissions and occupies 50% of all habitable land, or 37% of total land area on earth. Agricultural demand is also projected to increase by 50% in the coming decades, while climate change is projected to drastically reduce the yield and predictability of agriculture, making it even harder to meet this demand. Without immediate intervention, these two macro drivers will accelerate the clearing of new land, further devastating wild habitat and creating hundreds of gigatons of new emissions.

OUR SOLUTIONS

We propose an agricultural paradigm shift, both creating new forms of adaptive agriculture and bolstering the sustainability and climate-resilience of existing food, fiber, fuel, and energy sources in two synergistic ways:

1. **Cyanobacteria as a new form of agriculture**: Cyanobacteria grow millions of times faster than plants and dozens of times faster than microalgae. Engineering of these cyanobacteria as a source of key food using synthetic biology will enable food production from less than 0.0005% of land area in a fundamentally more climate-resilient way. In this manner, a new “crop” can be produced in one day and using far less inputs than traditional plant agriculture.

2. **Making today's agriculture more climate resilient**: CO_2 fixation is the rate-limiting step of photosynthesis and becomes even less efficient under rising temperatures. Enhancements to Rubisco, the enzyme mediating this central process, will both improve grain yields and provide climate-resilience to crops needed by 2050. Our team has created new directed evolution methods tailored for this enzyme that transform our ability to improve Rubisco and have already uncovered promising mutations in preliminary screens. Deployment of improved Rubisco into crop plants is considered a "holy-grail" of agriculture, with potential to usher in a second green-revolution.

The immediate need to enhance food production from photosynthesis demands a biotechnology solution. Our working group provides the most advanced and comprehensive pathway to meet this need within five years.

THE IMPACT

	Carbon Impact (GT CO_2eq)		Land Area Impact (MM ha)	
	10 year	**30 year**	**10 year**	**30 year**
Cyanobacteria: Producing vegetable oils & sugars	0 – 9	48 – 85	0 – 21	106 – 191
Improved Rubisco: Enhanced crop plants	35 – 49	127 – 187	96 – 132	344 – 506

Implementation of our technologies could reduce anthropogenic CO_2eq by 175–270 gigatons over the next 30 years and reduce land usage requirements by 450–700 million hectares from the agricultural sector. Through partnerships with leading academic (University of Illinois at Urbana-Champaign) and industrial collaborators (Subitec GmbH) we will accelerate these profound impacts in the shortest possible time frame.

VALUE

Primary productivity from agriculture is the foundation of virtually every economy. Climate change risks robbing the livelihoods of ~2 billion subsistence farmers due to biological vulnerabilities outlined in our proposal. The destabilization of global commodity markets for crops due to heat waves additionally threaten the stability of food and energy prices everywhere.

OUR TEAM

The faculty team is composed of leading experts and innovators with a unique track record of forward thinking in biotechnology, now bringing novel approaches to climate science. Moreover, we have in place the collaborators needed for scaling beyond the lab to gold-standard field trials and industrial-scale bioreactor implementation. The major financial need is simply support for personnel and supplies to pursue the project aims, as our labs are already prepared to execute this research.

CONCLUSION

The immediate need to enhance food production from photosynthesis demands a biotechnology solution. Our working group provides the most advanced and comprehensive pathway to meet this need within five years. We have positioned our solution structure such that additional support from government and industry can expand our solutions to a wider range of species, more complex evolution campaigns, and scaled pilot and field trials that will amplify our impacts while reducing our timeline drastically.

The answer for the future of agriculture is immediately needed; we have already started.