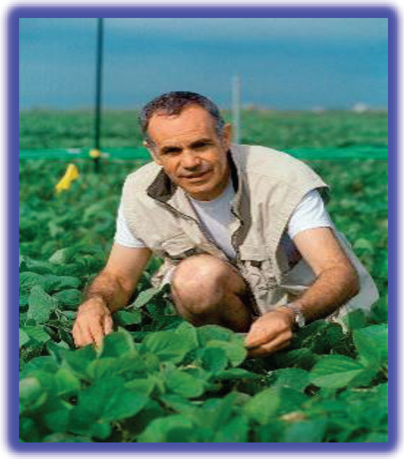
Increasing photosynthetic efficiency through genetic modification for sustainable and future-proofed crop yield improvement



Dr. Steve Long

Ikenberry Endowed University Chair
Member of the National Academy of Sciences (NAS)
University of Illinois, USA/Lancaster University, UK

After several years in which global food supply has improved, shortages are now re-emerging. This increases the probability of repetition of the high food prices of 2007/8 that triggered food riots in many poor countries and possibly the Arab Spring. The United Nations Food & Agricultrual Organization project a worsening situation with global demand for our major crops rising 60% by 2050. This is at a time when the steady increases in yield seen over the second half of the last century are stagnating, or even reversing, under global climate change. The approaches of the Green Revolution are approaching their biological limits, and new innovations are urgently needed if we are to insure against future shortages. It will be shown that improvement of photosynthetic efficiency is the largest remaining opportunity to increase genetic crop yield potential. Its efficiency in crops falls well below the theoretical maximum and has been improved little by centuries of selection and breeding; the reasons for which will be explained. Today photosynthesis is the best understood of all plant processes, allowing us to describe each of its 100+ steps mathematically. Using this as the basis of *in silico* engineering using high-performance computing we have identified a number of points at different levels of organization from metabolism to organization of leaves in field crops where efficiency could be improved. Bioengineering has begun to validate a number of these suggested improvements with substantially greater crop productivity demonstrated in replicated field trials. This will be illustrated with some specific examples, including improvement of the speed with which crop leaves relax non-photochemical quenching (NPQ) during the frequent sun to shade transitisons that occur in crop canopies. Our analyses suggest that such engineering could lead to a >50% sustainable improvement in crop yield potential so providing insurance against future food shortage and avoiding yet further agricultural expansion and destruction of natural areas.

Dr. Steve Long FRS holds the Ikenberry Chair of Plant Biology and of Crop Sciences His research concerns bioengineering photosynthesis toward gaining sustainable increases in crop yield potential and adaptation to global change. He is Director of the multinational Bill & Melinda Gates Foundation RIPE Project which has developed and is developing these technologies for increased photosynthetic efficiency in crops for sustainable yield increases, under climate change. His mathematically guided engineering of photosynthesis led in November 2016 to a demonstrated on farm 20% increase in crop productivity. This year his lab also demonstrated the first single gene manipulation that resulted in a 15% increase in crop water use efficiency in the field. He is Founding and Cheif Editor of the journals Global Change Biology, GCB Bioenergy, and *in silico* Plants. He has been listed by Thomson-Reuters/Clarivate as one of the most highly cited authors on Plant & Animal Biology in every year since 2006 and was elected a Fellow of the Royal Society in 2013 and as a Member of the National Academy of Sciences of the USA in 2019.