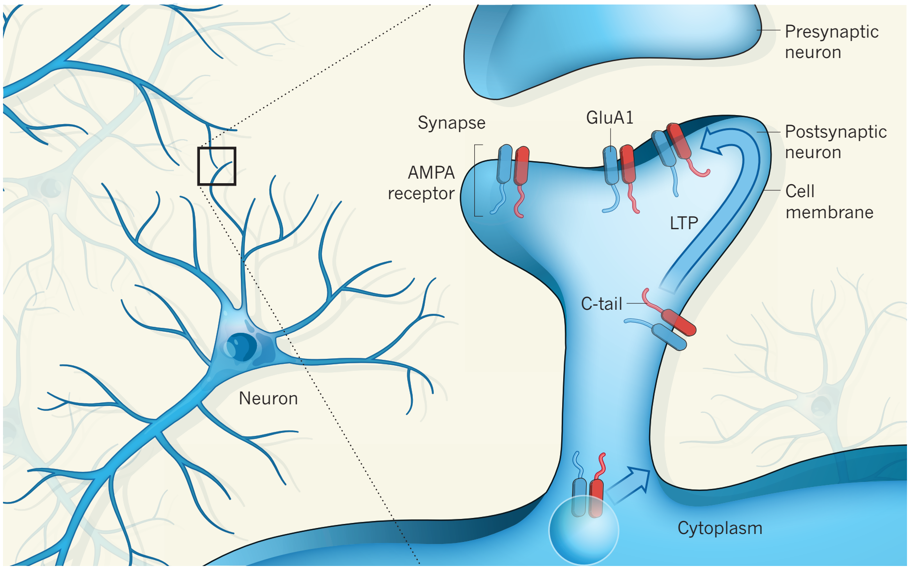


**Figure 1 | AMPA receptors at the synapse.** At the level of neurons, long-term potentiation (LTP) is mediated by AMPA receptors, which are transported from intracellular compartments and elsewhere in the cell membrane to the membrane of the postsynaptic neuron. Surprisingly, Granger *et al.*[1] report that the cytoplasmic tail of the GluA1 subunit of AMPA receptors is not required for this trafficking and thus for LTP. Instead, they propose that any type of glutamate receptor can support LTP, as long as enough of them reach the membrane.

these could include introducing mutations ('knock-in' mutations) into the genes encoding GluA1 and GluA2 to alter their C-tail structure without affecting their expression level. In fact, previous studies[7,8] involving such mutations have shown that the C-tail phosphorylation sites and protein-interacting domains of these subunits are important for several forms of synaptic plasticity, including LTP.

Synapses lacking AMPA receptors may behave differently from normal synapses because loss of some essential regulatory proteins makes them less selective. Are AMPA-receptor subunits responsible for maintaining such crucial proteins at the synapse? It could be that synapses without AMPA receptors — such as those that are prevalent early in development[9] — have lower selectivity for receptors during LTP than do more mature synapses containing AMPA receptors. Alternatively, there may be competition for entering the synapse between different receptors that have different interaction partners at the synapse to control their lifetime there. If that is the case, if a competitor with several such partners, say AMPA receptors, is removed, then other receptors with minimal numbers of partners and interactions could enter and remain in the synapse.

Granger and co-authors' study, therefore, may point to a novel view that synapses are sites of competition: how efficiently a receptor enters the synapse depends not only on its structural components, but also on those of its competitors. Such factors may determine how AMPA receptors get into and out of a synapse during conditions of synapse maintenance and plasticity.

But whatever the mechanism involved, the present study will focus future research on the structural changes that occur at the synapse after LTP. Many scaffolding proteins regulate the complex structure of the postsynaptic density, and, according to Granger *et al.*, structural changes may occur that do not require specific glutamate receptor types. However, the identity of these common scaffolding proteins is not obvious, because most such proteins are known to be specific for AMPA or kainate receptors. In fact, some of the same authors have previously shown that AMPA-receptor-associated proteins known as TARPs are crucial for LTP[10]. Yet the present study refutes those data and shows that even kainate receptors, which do not interact with TARPs, can completely rescue LTP in the absence of AMPA receptors.

So, one step forward, two steps back. The search for the mechanism underlying LTP is well into its third decade, and it looks as if it will continue to fascinate and elude neuroscientists for the next decade, too. ■

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BIOENERGY

# Biofuel production on the margins

**An analysis shows that fuel made from wild, herbaceous vegetation grown on land currently unsuitable for cultivating field crops could contribute substantially to the United States' targets for biofuel production.** **SEE LETTER P.514**

KLAUS BUTTERBACH-BAHL & RALF KIESE

The governments of more than 35 countries, including the United States, Brazil and members of the European Union, have established policies promoting the production and use of biofuels[1]. This is driven by an interest in becoming more independent of fossil-fuel imports and reducing the climate footprint of their economies. However, the climate benefit of replacing fossil fuels with biofuels is strongly disputed, because of the lack of compelling evidence to show that biofuels are indeed associated with much lower greenhouse-gas emissions than fossil fuels when the full life cycle of their production and use is taken into account. On page 514 of this issue, Gelfand *et al.*[2] report that certain wild, herbaceous vegetation, growing on 'marginal' lands currently unsuitable for arable farming, can be used as a biofuel crop, and does substantially mitigate greenhouse-gas emissions

## 50 Years Ago

*International Tables for X-ray Crystallography*. General Editor: Dame Kathleen Lonsdale — The fifty years which have elapsed since the discovery of X-ray diffraction by crystals have witnessed the development of X-ray crystallographic techniques as a structure-determining tool of unprecedented power and catholicity of application. By it the complexities of mineral structures have been rationalized … and the elaborate architecture of the giant globular proteins mapped out. Fortunately, it was recognized early that this diversity would make discipline in the presentation of results, and uniformity of nomenclature and convention particularly desirable. The first attempt to provide such an authoritative basis was by the *Internationale Tabellen zur Bestimmung von Kristallstrukturen* of 1935. In 1946 the International Union of Crystallography decided on a complete revision and extension of these tables under the general editorship of Dame Kathleen Lonsdale. Two volumes … have already appeared; Volume 3, dealing with physical and chemical tables, represents the completion of the 1946 project … No X-ray crystallographical laboratory worthy of the name will fail to add this magnificently printed and luxuriously bound volume to the two they already should possess. **Struther Arnott**
**From *Nature* 26 January 1963**

## 100 Years Ago

It is not at all difficult to measure the ionisation produced by the radiation reflected by crystals, as indeed Prof. Barkla has already suggested. Using a sheet of mica and a pencil of a few millimetres diameter, I find it possible to follow with an ionisation chamber the movement of the reflected spot while the mirror is rotated. **W. H. Bragg**
**From *Nature* 23 January 1913**

compared with fossil-fuel use — even rivalling the benefits associated with growing traditional biofuel crops, such as maize (corn)*.

When assessing the potential climate benefits of biofuels, it is essential to consider the consequences of land-use change and of fertilization associated with growing biofuel crops[3,4] — particularly any changes in the carbon stocks of affected ecosystems, and in the emissions of nitrous oxide, a potent greenhouse gas produced by soil bacteria. It is also crucial to determine whether the growing of biofuel crops poses local threats to biodiversity, or to water and nutrient cycling[5].

Moreover, because biofuel feedstocks are currently produced mostly on fertile agricultural land, it has been questioned whether useful amounts of biofuels can be produced without threatening food production. The ensuing conflict of interest has been called the "food, energy and environment trilemma"[6]. To be acceptable to society, therefore, biofuel-production strategies must be shown to greatly mitigate greenhouse-gas emissions without jeopardizing food and animal-feed production through competition for land use, and to have a minimal effect on the environment.

Gelfand *et al.* compared the biofuel yields, greenhouse-gas emissions, changes in soil-carbon stocks, and energy consumption associated with field operations for six biofuel-cropping systems in the midwestern United States over a 20-year period. They then used these data in a rigorous life-cycle assessment of the climate benefits of the different systems. Because it is based on long-term data, this is the first convincing analysis of the impact of biofuel-production systems on global warming. By contrast, previous studies relied either on modelling or on short-term studies of a smaller number of systems.

The authors show that all the biofuel-cropping systems investigated are net sinks of atmospheric carbon dioxide if fossil-fuel offset credits are included in the analysis. These credits are the sum of all the $CO_2$ emissions potentially avoided when fossil fuels are replaced with biofuels, taking into account both the production and the combustion of the fossil fuels[7]. Surprisingly, the researchers found that the greenhouse-gas mitigation of wild, perennial, herbaceous vegetation (Fig. 1) — specifically, successional vegetation, which naturally regrows in marginal areas such as abandoned, low-productivity arable land — was markedly higher than that of intentionally grown crops, including maize, alfalfa, poplar and a maize–soya bean–wheat crop rotation, and that energy production was comparable. Moreover, Gelfand *et al.* show that moderate levels of nitrogen fertilization could further boost biofuel yields of the wild vegetation system by about 50%, with only a marginal increase in nitrous oxide emissions.

*This article and the paper under discussion[2] were published online on 16 January 2013.


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**Figure 1 | Wild biofuel crops.** Gelfand *et al.*[2] report that wild, successional, herbaceous vegetation, such as that pictured, is an effective biofuel crop that has a greenhouse-gas-mitigation capacity rivalling that of traditional biofuel crops.

A big advantage of such native successional systems over other biofuel crops is that they can be productive despite the soil and climate restrictions typically found in marginal lands. This suggests that marginal lands could be a viable alternative to fertile cropland for biofuel production — which would be extremely useful, given the limited land resources[8,9].

To explore the regional implications of their study, Gelfand *et al.* used a computational approach to identify suitable marginal lands for biofuel production across ten states of the US Midwest. More specifically, they used information from a geographical database in a biogeochemical model to estimate the effects of soil and climate on biofuel yields.

One constraint on the production of biofuels is the need to minimize the energy consumed by the collection and transport of the crop. Gelfand and colleagues show that, given the distribution of marginal lands in the US Midwest, optimal biofuel production would be achieved if biomass is collected from within a region of 80-kilometre radius around refineries. Such a production strategy could yield approximately 21 billion litres of ethanol per year from 11 million hectares of marginal land. This is about 25% of the target mandated by the US Department of Energy's Biomass Program for cellulosic biofuel production in 2022 (cellulosic biofuel is that produced from lignocellulose, a major constituent of wood and grasses). It equates to an expected fossil-fuel offset of roughly 40 teragrams of $CO_2$ equivalents each year (1 teragram is $10^{12}$ grams) — the same as the $CO_2$ emissions from 10 million medium-sized cars, each with an annual run of 20,000 km.

So would a native successional biofuel crop be all good? Perhaps not. Gelfand and co-workers' study does not explicitly answer the question of whether all the marginal lands identified as suitable for biofuel production could be used without harming biodiversity and the environment. Moreover, land that is fallow today might be needed in the future for agricultural production, to offset the demands of the world's growing population.

Another question raised by the study concerns greenhouse-gas mitigation: for the biofuel-cropping systems under consideration, the authors found that, apart from fossil-fuel offset credits, increases in soil-carbon stocks are the major driver of climate benefits. But the rate of increase of soil-carbon stocks will slow down with time, so that the stocks reach an equilibrium level within a few decades[10]. It therefore seems that comprehensive assessments of the long-term climate impacts of biofuels will require the quantification of spatially and temporally explicit soil-carbon sequestration potentials. ■

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SOLAR PHYSICS

# Towards ever smaller length scales

**Determining the real scale of structures in the Sun's corona has proved difficult because of limited spatial resolution. Now high-resolution imaging has allowed dynamic structures on scales of 150 kilometres to be observed.** **SEE LETTER P.501**

PETER CARGILL

The origin of the Sun's outer atmosphere, the corona, is a long-standing scientific problem of great interest and complexity. Why does a star with a surface temperature of roughly 5,700 kelvin have an outer atmosphere with temperatures in excess of 1 megakelvin, and why does the corona exhibit phenomena such as flares? The answer lies in the energy contained in the Sun's magnetic field, which fills the corona, as inferred from coronal images at extreme ultraviolet and X-ray wavelengths. How the magnetic energy is dissipated in the corona and sustains its temperature is controversial, but comes down to a determination of the spatial scales of coronal structures. On page 501 of this issue, Cirtain *et al.*[1] identify dynamic structures on scales of 150 kilometres, which represents a major constraint that theories must now confront.

Before 2012, the best spatial resolution of the solar corona was obtained by NASA's Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory spacecraft, which was launched in 2010. The instrument resolves scales of about 900 km and looks at several wavelength ranges corresponding to different temperatures. However, images of the visible solar surface at a resolution of 100 km show distinct magnetic and plasma structures, and so the question arises as to whether structures with these scales are also present in the corona.

In their study, Cirtain *et al.* used the High-resolution Coronal Imager (Hi-C), a new extreme-ultraviolet instrument that was launched on a rocket on 11 July 2012 and obtained roughly 5 minutes of data before re-entering Earth's atmosphere. The instrument looks at coronal plasma with temperatures of around 1.5 MK, and is capable of spatial resolution at least five times better than the AIA: the Hi-C can resolve scales on the order of 150 km. To place this in context, it took more than 30 years to improve the spatial resolution from the few thousand kilometres obtained by instruments on NASA's Skylab observatory to that obtained with the AIA. The Hi-C instrumentation performed up to expectation, and images of the Sun show unambiguous structure at the desired resolution — a huge achievement.

A striking feature of Cirtain and colleagues' results is the dynamic structures visible at the limit of resolution, clearly evident by comparing images from the Hi-C and AIA in the paper's Supplementary Videos 1 and 2 (ref. 1). (The reader should also look at other aspects of the videos to note how much else is happening on these small scales, as is also evident in Fig. 1.) The dynamic behaviour of the observed structures is interpreted as evidence for 'magnetic braiding', an effect in which small bundles of magnetic field become wrapped around each other owing to plasma motions at the solar surface[2]. Whether this is in fact the case is unclear, but there seems little doubt that magnetic-field dissipation on a fundamental scale is seen, with different field elements interacting with one another through magnetic

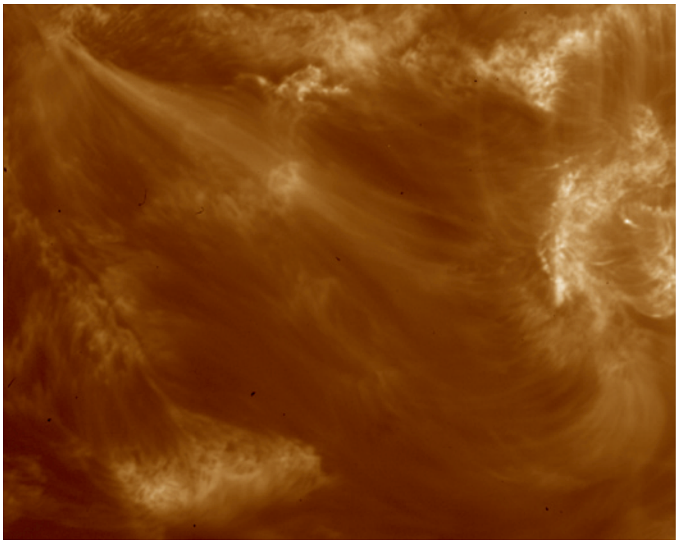

**Figure 1 | Small structure in the corona.** The image is a sub-field of the entire field of view observed by the High-resolution Coronal Imager (Hi-C) and analysed by Cirtain and colleagues[1]. It shows the solar corona at a temperature of roughly 1.5 megakelvin over a dimension of 154.6 × 123.7 arcseconds, or 112,000 × 90,000 km. The strands running from top left to lower right are believed to outline the magnetic field in the corona, as are the other structures in the image. The remarkably fine structure is visible everywhere and constitutes the major advance achieved with the Hi-C. (Image prepared by J. Cirtain and A. Winebarger.)