A paradigm shift in agricultural research to tackle climate change

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Background

Greenhouse gas (GHG) emissions from human activities are the root cause of a global climate crisis, and solutions must now be found to attenuate the negative consequences for our planet. Agriculture accounts for around 25% of total GHG emissions. Carbon capture by means of photosynthesis could play a central role in reducing atmospheric CO_2 emissions. Solutions involving the core trifecta of soils, plants and microorganisms can help us to actively combat the nefarious effects of climate change. Such solutions require strategies which integrate knowledge ideas from multiple disciplines and sectors.

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Further reading

Cissé A. *et al.*, 2023 – Agrobiodiversité et transition agroécologique : Regards croisés de chercheurs et paysans. *Biodiversité des écosystèmes intertropicaux : connaissance, gestion durable et valorisation*.
https://www.plant-act.org/
Hirt H. *et al.*, 2023 – PlantACT! How to tackle the climate crisis. *Trends in Plant Science*, 28: 537-543.

Reducing greenhouse gas emissions, an essential priority

Over the past 150 years, it is estimated that the atmospheric concentration of CO_2 has increased from 280 ppm to 420 ppm as a result of human activities. 20-25% of anthropic GHG emissions can be attributed to agricultural activities. As well as CO_2, agriculture produces significant quantities of methane and nitrous oxide (N_2O), GHGs which are much more potent than CO_2 (>20 and 300 times, respectively) in terms of their warming potential. Although far more potent than CO_2, methane and N_2O also have far shorter life spans (12 and 114 years respectively, compared with anywhere between 300 and 1,000 years for CO_2). Reducing emissions of these two greenhouse gases would thus have an immediate impact on the climate.

What solutions are available to reduce the use of these three gases in agriculture?

A large portion of the CO_2 emissions generated by agriculture come from changes in land usage, and particularly from deforestation for the purposes of livestock farming (to produce fodder or clear land for grazing). Livestock and the fodder they consume are responsible for the equivalent of around 3 billion tonnes of CO_2 each year. In the short term, reducing our consumption of animal-based products is the most effective means of reducing the climate consequences of agriculture.

Methane is the second most important greenhouse gas, in terms of emissions. On top of the methane produced by livestock, aquatic rice production is responsible for 15 to 20% of anthropic methane emissions, due to the decomposition of organic matter in anaerobic conditions by methane-releasing bacteria. Alternative agronomic practices which reduce the duration of anaerobic phases, such as alternating irrigation or aerobic rice farming, can significantly reduce both methane emissions and water consumption. Nevertheless, they will also need to be optimised in order to prevent a decline in yields, and to offset the greater year-to-year variability of yields induced by greater competition from adventive plants (i.e. plants other than food crops), reduced water availability and the presence of pathogens such as nematodes.

Once it has been spread on the fields, a large proportion of nitrogen-based fertiliser is transformed into N_2O through microbial activity in the soil. These synthetic fertilisers, whose production requires large quantities of fossil energies, account for over 2% of GHG emissions. If agricultural practices do not change, demand for chemical nitrogen-based fertilisers will grow by 50% by 2050 if we are to feed the growing global population, with GHG emissions increasing accordingly. In the short term, the use of nitrogen-based fertilisers could be reduced immediately by optimising agronomic practices and providing farmers with pertinent advice. In the short to medium term, a transition to agricultural systems prioritising legumes and pulses, which naturally capture nitrogen from the atmosphere, is a key priority. In the long term, boosting the efficacy of nitrogen uptake and usage by cereal crops (less than 50% of nitrogen-based fertilisers are actually absorbed and used by crops) would allow for substantial increases in crop yields while limiting the use of these fertilisers.

Soils, plants and microorganisms: potential contributors to the attenuation of climate change

As the principal source of carbon and energy for microorganisms living in the soil, plants could be a central pillar of carbon-capture strategies. For example, some plants secrete oxalate from their roots, which is used by microbes in the soil (Hirt *et al.*, 2023). In return, these microorganisms modify the physical and chemical properties of the soil and play an important role in carbon capture by contributing (in a manner which may be positive or negative) to the formation of stocks of organic or inorganic carbon in the soils. The advantage of the latter is that it is more stable, and could thus form the basis of carbon capture strategies to combat global warming. In arid soils and soils rich in calcium and magnesium, we find many microorganisms producing calcium or magnesium carbonate, inorganic forms of carbon which remain stable for decades. These natural CO_2 storage systems could thus inform innovative carbon capture strategies in arid zones, without competing for land resources with agriculture in more fertile areas. Moreover, protecting and expanding forests are often touted as means of capturing atmospheric carbon and creating carbon sinks. The African Union's Great Green Wall (GGW) initiative - which aims to restore 100 million hectares of degraded landscapes by 2030, a band 15 km wide and 8,000 km long running across the southern Sahara from Dakar to Djibouti - is a concrete example of this type of strategy. Estimates suggest that this initiative could capture and store up to 250 million tonnes of CO_2.

A paradigm shift to transform agriculture

A paradigm shift is needed so that plant scientists are not left to work in isolation, seeking partial solutions to global problems. The PlantAct! Initiative, recently launched by a group of experts from all five continents with the aim of operating like a think tank and generating new ideas for attenuating the effects of climate change. The PlantAct! approach is focused on creating opportunities to share expertise between all stakeholders in agricultural production systems, as well as promoting programmes of interdisciplinary research. With more than 100 members across 31 countries, PlantAct! organises regular conferences around the world, inviting international experts to inform and inspire discussions on how best to adapt to climate change. The initiative is especially keen to promote solutions based on practical agronomic adjustments (varying plant varieties, modifying sowing dates, crop rotation based on the availability of water etc.) capable of limiting the impact of climate change on agricultural output (see for example Cissé *et al.*, 2022). Members feel strongly that, in the medium and long term, we need to develop new agricultural systems which are more resilient and better-suited to local conditions, potentially integrating indigenous knowledge and combining it with improved varietal selection. This evolution should enable diversification of agricultural production, with positive consequences for ecosystems, biodiversity and people. In order for agriculture to become more productive and more resilient, research

Screen shot of the PlantAct! website (www.plant-act.org).

must: 1) generate knowledge and innovations which serve to mitigate the negative impact of climate change on agricultural output and bring about positive, lasting change; 2) make the results of research scalable and accessible for users and beneficiaries; 3) increase general awareness of this research across society as a whole.

KEY POINTS

As we face up to climate change and its impact on our agricultural production systems, research must seek to identify integrated solutions based on the interactions between plants, soils and the environment. The soil/plant/microorganism complex should thus be placed at the heart of future strategies to capture and store more carbon in our food production systems, reducing GHG emissions in the process. A paradigm shift is needed to kick-start the transition towards a more sustainable agriculture, and to imagine new solutions for reducing man-made GHG emissions.

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