Article 1

NOVEL AGRIFOOD TECHNOLOGIES & THEIR ROLE IN SUSTAINABLE DEVELOPMENT: ADDRESSING CLIMATE CHANGE, POVERTY, & HUNGER
INTRODUCTION

The world’s food systems are facing a multitude of development challenges. These challenges could threaten the world’s ability to produce enough food for a growing global population, amid a changing climate.

Critical issues such as greenhouse gas emissions, biodiversity loss, and inequality require a transformation of our food systems to ensure food security, alleviate poverty, and mitigate climate impacts.

These challenges affect every person and every region, but their implications are most noticeable in the lower- and middle-income countries which produce much of the world’s food,¹ and employ most of the global agricultural and food production workforce.²

Sustainable food systems are essential to sustainable development. Working in over 100 countries on food and agricultural commodity systems, UNDP has recognised that an integrated and collaborative multi-stakeholder approach, with innovation as a key lever and smallholders at the centre, can effectively address the interconnected challenges of global food systems.

The importance of innovation is acknowledged globally, with a recent wave of technological innovation that promises to revolutionise conventional agriculture and food production. These novel agrifood technologies are being enabled by advances in diverse areas such as artificial intelligence, biotechnology, satellite imaging, and the ‘Internet of Things’.

In this context, this article will further explore the promising field of novel agrifood technologies, highlighting their significance in addressing contemporary challenges. It outlines the technologies involved and discusses ways for advancing them in development contexts.

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1. WHAT ARE NOVEL AGRIFOOD TECHNOLOGIES?

Let’s define what we mean by the terms ‘food systems’ and ‘novel agrifood technologies’, as used in this article series:

- **Food systems** encompass all actors, and their interlinked value-adding activities, engaged in the primary production, processing, distribution, and consumption of agrifood products.

- **Agrifood products** for human and animal consumption originate from crop and livestock agriculture and aquaculture, and from other non-agricultural sources such as microbial fermentation.⁶

- **Novel agrifood technologies** encompass innovative technologies and technology-driven methods for producing agrifood products that have not previously been in common use.

Novel agrifood technologies can be leveraged to improve the efficiency and productivity of conventional farms, while also enabling primary production of food in unconventional settings such as crowded urban environments or arid desert regions. The field also includes technological innovations that valorise waste from food systems into useful products and ingredients.

The table on the next page (Table 1) outlines several of the key subcategories within novel agrifood technologies⁷ including those that we will examine in deeper detail in future articles in this series.

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⁷ This is an original table produced by the authors, based on a taxonomy used by Cleantech Group, a climate innovation consultancy. This table is not intended to provide an exhaustive landscape of all novel agrifood technologies innovation, but to highlight key areas of interest. Note that the subcategories described here are not mutually exclusive, so different technologies and applications of those technologies may occupy multiple subcategories.
# Table 1: Novel Agrifood Technologies – Select Subcategories & Applications

<table>
<thead>
<tr>
<th>Select Technologies/Approaches</th>
<th>Potential Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agrifood Waste Mitigation:</strong> Prevention, reduction, and reuse of waste</td>
<td>Treat wastewater, produce bioenergy, upcycle waste into food or feed</td>
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<tr>
<td>Pyrolysis, Anaerobic digestion, Insect bioconversion</td>
<td></td>
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<tr>
<td><strong>Alternative Proteins:</strong> Proteins from sources other than conventional animal agriculture</td>
<td></td>
</tr>
<tr>
<td>Plant-based proteins, Fermentation, Cell culture</td>
<td>Reduce environmental impact, enhance nutritional value</td>
</tr>
<tr>
<td><strong>Animal Technologies:</strong> Enhancements in livestock farming and aquaculture</td>
<td></td>
</tr>
<tr>
<td>Feed additives, Health monitoring, Vaccines, Genomics, Recirculating Aquaculture Systems</td>
<td>Improve animal health, increase food production, cut emissions</td>
</tr>
<tr>
<td><strong>Controlled Environment Agriculture:</strong> Crop cultivation in controlled settings</td>
<td></td>
</tr>
<tr>
<td>Vertical farms, Greenhouses, Container farms</td>
<td>Localise food production, enable urban farming, eliminate food deserts</td>
</tr>
<tr>
<td><strong>Crop Inputs:</strong> Technologies and products to optimise crop cultivation</td>
<td></td>
</tr>
<tr>
<td>Biofertilizers, Biopesticides, Biostimulants; Technologies enabling site-specific nutrient management</td>
<td>Increase crop yields, reduce biotic and abiotic stress, reduce chemical use</td>
</tr>
<tr>
<td><strong>Food Supply Chain Technologies:</strong> Improvements in food logistics</td>
<td></td>
</tr>
<tr>
<td>Online farmer marketplaces, Blockchain for traceability, Smart packaging</td>
<td>Ensure product safety, reduce waste, improve market access for smallholders</td>
</tr>
<tr>
<td><strong>Crop Improvement:</strong> Advanced breeding and genetic technologies to optimise crop yield and health</td>
<td></td>
</tr>
<tr>
<td>Gene editing techniques, e.g. CRISPR, GEiGS, TALEN</td>
<td>Fast-track new crop varieties with improved physiology that are highly tolerant to climate stress and pathogens</td>
</tr>
<tr>
<td><strong>Precision Agriculture:</strong> Advanced farming technologies</td>
<td></td>
</tr>
<tr>
<td>AI, Data analytics, Robotics, Sensors, IoT systems, Remote sensing</td>
<td>Enhance farm productivity, monitor soil and crop health, reduce losses</td>
</tr>
</tbody>
</table>

Source: This is an original table produced by the authors
2. WHY DO WE NEED NOVEL AGRIFOOD TECHNOLOGIES?

Given their relevance to increasing efficiency and sustainability in food production, novel agrifood technologies can be pivotal to advancing three interconnected objectives of sustainable development:

- Ensuring food security and ending hunger
- Preserving livelihoods and alleviating poverty among agricultural and food-producing communities
- Addressing climate change and other environmental impacts in food systems

Ensure food security & end hunger for food-producing communities

Ensuring that everyone in the world has access to enough nutritious food is a primary imperative for food systems.

A recent UN-led report⁸ reveals that over 250 million individuals experienced severe hunger in 2022, marking a significant increase of 65 million compared to the previous year. Addressing this trend will require the establishment of a sustainable, secure, and resilient food production system capable of nourishing a growing global population that is expected to hit 10 billion people by 2050.⁹

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Meeting rising demand and solving the existing problem of hunger is far from a simple case of expanding agricultural land. Converting land to agricultural use often involves destruction of natural environments, including deforestation. Moreover, the opportunity to add more agricultural land is limited; farming already takes up 45% of Earth’s habitable land, with much of the rest occupied by vital forests and scrub, as well as built-up areas.¹⁰ There is also disparity between nations in terms of the cultivable land and freshwater resources at their disposal; take, for instance, a highly urbanised city-state like Singapore,¹¹ or countries that are primarily desert and arid land, such as in the Sahara and Sahel regions.

Instead, increased productivity will need to come from improved practices and novel agrifood technologies that enable more efficient production with whatever land and other resources are locally available. This comes at a time when arable land and freshwater resources are declining in many geographies, like Asia.

For example, one area of novel agrifood technologies innovation that can achieve this is controlled environment agriculture (CEA). These technologies optimise the use of resources such as space and water, enabling crop cultivation in urban areas or extreme climates such as deserts.

Another example is nitrogen-fixing crop inputs, which leverage the natural nitrogen drawdown ability of microscopic soil-based organisms to increase the efficiency of fertilisers.

Crop genetics technologies could also help to produce more food with the same or fewer resources. Wheat growers in Ethiopia experienced a growth in yields of up to 40% after planting varieties bred to be resistant to rust, a fungal disease.¹²

To identify more such innovative technologies, the UNDP Global Centre for Technology, Innovation and Sustainable Development launched Cultiv@te¹³ in 2019 with the support of Singapore’s Ministry of Sustainability and the Environment. This initiative aimed to bring innovation and technology to the places where they are needed the most, providing targeted mentorship, catalytic funding, and partnership support to help pilot and prototype a few of these promising solutions. This global innovation initiative successfully brought together 200 innovations from 50 countries, yielding valuable insights for the potential applications of novel agrifood technologies.

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¹⁰ Hannah Ritchie and Max Roser, “Half of the World’s Habitable Land is Used for Agriculture,” Our World in Data, February 16, 2024.
¹¹ See the later article in this series: UNDP, “Novel Agrifood Technologies for Sustainable Development,” accessed July 15, 2024.
¹² Kristalina Georgieva, Vitor Gaspar, and Ceyla Pazarbasioglu, “Poor and Vulnerable Countries Need Support to Adapt to Climate Change,” International Monetary Fund, March 23, 2022.
¹³ UNDP, “Cultiv@te,” accessed July 15, 2024.
Preserve livelihoods & alleviate poverty

Around a quarter of the global population is employed in the agricultural sector, either formally or informally. But this only scratches the surface. When considering the entire food industry – from farming and food processing to manufacturing operations and intricate logistics chains – the numbers are much higher, though difficult to pinpoint.

While public perceptions of modern agriculture often fixate on large-scale industrial farming, about a third of the world’s food is in fact grown by smallholder farmers working plots of two hectares or less. These smallholdings make up 84% of global farms; the families who work on them are among the world’s poorest people.

About 80% of the global population living in extreme poverty are in rural areas, with most making a livelihood from farming. Raising agricultural productivity in these areas is arguably the most impactful way of reducing extreme poverty.

Novel agrifood technologies could help to boost smallholder incomes by improving the efficiency and productivity of small-scale agriculture. This could also help to raise smallholder farms from a subsistence state to become profitable, livelihood-supporting businesses.

One example of such technology is online farmer marketplaces, which leverage internet connectivity to create links between farmers, suppliers, and consumers. Theoretically, these links grant smallholders access to a wider range of inputs and services at more competitive price points; while also opening additional markets for the offtake of their produce and providing a channel for the dissemination of timely agronomic advice via mobile apps.

An added potential benefit of these marketplace platforms is the data they generate. This could be used to offer appropriate financial products and services for smallholders, giving them more financial security and allowing them to expand their businesses.

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The sobering truth is that the same regions which are home to most of the world’s smallholder farmers are also expected to experience the worst of climate change’s devastating impacts in the coming years. Desertification, changing weather patterns, drought, floods, and rising sea levels will mean that these farmers must produce more food on increasingly limited land. This problem particularly affects smallholders in places like South Asia, Southeast Asia, and Africa, where arable land use is already close to capacity or even declining in some regions, with few possibilities to expand.

Crucially, food production is not only a casualty of climate change: it is also a cause, being a major emitter of greenhouse gases (GHGs).

Global food systems account for between one-quarter and one-third of total anthropogenic GHG emissions, according to different interpretations.¹⁷

Of total food systems GHG emissions, about half come from on-farm activities; a further third originates from pre- and post-production processes in the supply chain, with another one-fifth from land use changes.¹⁸

Regionally, on-farm emissions are highest in Oceania (71%), Asia (50%), and the Americas (43%). Land-use change is the primary contributor in Africa (44%).

Among all sectors, food systems contribute the most GHG emissions in Africa (59%) and the least in Asia (around 25%), with the latter primarily explained by massive increases in emissions in other sectors such as energy.


Beyond emissions, conventional agriculture can have other negative impacts on the environment and biodiversity. About 70% of global freshwater consumption can be attributed to agriculture.¹⁹ Over-application of crop inputs, such as fertilisers and pesticides, can degrade land and water resources adjacent to farms due to leaching and runoff. Livestock farm effluent can also pollute water bodies if not managed effectively.

Technological innovation has a significant part to play in both reducing the environmental impacts of agriculture, as well as making the industry more resilient to the effects of climate change.

Alternative protein technologies can provide a complementary source of protein, offering an opportunity to reduce our reliance on livestock agriculture over time. Farther downstream, novel packaging that keeps food fresher for longer could reduce food waste and the resultant emissions from decomposition in landfills.

Methane emissions is another area in which novel agrifood technologies could have significant impact.

From paddy-based rice cultivation and livestock farming to food waste, food systems are a major contributor to total methane emissions. Relevant technology-enabled solutions include methods of planting and harvesting rice that could substantially reduce emissions, as well as genetic interventions that allow rice to be grown in different conditions.²⁰ Another approach might involve feed additive technologies that inhibit production of methane in animals’ digestive systems; trials suggest some of these products can slash livestock-related methane emissions by more than 80%.²¹

Technology also plays a key role in verifying sustainable food systems. In line with the EU’s upcoming 2025 import requirements, which will prohibit products linked to deforestation, georeferencing and high-resolution satellite image analysis can help detect deforestation, prove compliance with the EU Deforestation Regulation, and reduce the risk of fraudulent activity. For example, an initiative led by UNDP, the Costa Rican Coffee Institute (ICAFE), and CoopeTarrazú has successfully georeferenced its producers’ farms to complete the due diligence process for deforestation-free coffee, aligning with EU requirements.²²

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¹⁹ Tariq Khokhar, “Globally, 70% of Freshwater is Used for Agriculture,” World Bank, March 22, 2017.
²⁰ Paul Teng and Jose Maria Luis Montesclaros, “Is Rice Production Becoming a Wicked Problem?” NTS Insight no. IN23-03 (Singapore: RSIS Centre for Non-Traditional Security Studies (NTS Centre), Nanyang Technological University, October 2023.
3. HOW CAN WE DRIVE ADOPTION OF NOVEL AGRIFOOD TECHNOLOGIES IN A DEVELOPMENT CONTEXT?

We’ve seen how novel agrifood technologies have the potential to address specific development problems. However, to date, much of the investment and innovation in novel agrifood technologies has been concentrated in higher income countries with highly developed and industrialised food and agriculture sectors.

As shown in Figure 1, Europe and North America combined account for more than 75% of both the amount of money being invested, and the number of investment deals being made, in novel agrifood technologies.

**Figure 1: Regional share of total novel agrifood technologies investment 2018-2023**

NB: Inner ring reflects total share of deals. Outer ring reflects total share of dollars invested.
Source: Cleantech Group
These regions benefit from robust venture capital and private equity ecosystems, significant public sector investment, a supportive regulatory and policy environment, and the presence of large agribusiness corporations that facilitate further investment, pilot projects, and partnerships.

This concentration of funding and support means that many promising innovations in novel agrifood technologies have yet to be optimised for lower- and middle-income countries where they could have a significant impact on socio-economic development.

The disparity in global investment is evident: while higher income countries allocate approximately 3.25% of their agricultural GDP to R&D, lower- and middle-income countries invest only about 0.52%. Particularly low levels of investment are seen in African and South Asian countries, with Africa experiencing a declining trend in agricultural R&D spending.²³

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To bridge this gap and foster adoption of novel agrifood technologies in lower- and middle-income countries, several policy, governance, and investment strategies could be considered:

- Redirecting some existing agriculture and food industry subsidies, and other financial support, towards stimulating academic and public sector R&D, while simplifying access to private sector R&D.²⁴
- Encouraging local private sector R&D by promoting competition and market participation from foreign firms and investors, revising restrictive regulations, and strengthening intellectual property rights.²⁵
- Creating global systems that facilitate knowledge-sharing and technology-sharing around novel agrifood technologies between higher income, and lower- and middle-income, economies.²⁶
- Putting support structures in place that help smallholders to adopt and utilise novel agrifood technologies effectively.²⁷
- Investing in basic, fundamental agricultural and technology infrastructure where necessary (e.g. roads, rail, bridges, storage capacity, telecoms, and internet connectivity) to provide the optimal environment for adoption of novel agrifood technologies.²⁸

These non-exhaustive recommendations can help leverage novel agrifood technologies to enhance agricultural productivity and support a broader ecosystem that drives sustainable development. In upcoming articles in this series, we will examine select novel agrifood technologies and, through case studies and insight from experts, assess how they might best be adapted and implemented in a development context.

²⁴ Ibid.
²⁵ Ibid.
²⁶ Ibid.
²⁸ Ibid.
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