TECHNICAL BRIEF

MAY 2025

Next-generation crops

A 30-year horizon

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Key takeaways

- Earth is on a trajectory towards more than 2.5°C rise in average temperature by the end of the century, so food production faces new challenges, and mitigation requires not only emissions reductions but also carbon sequestration and capture, involving land-intensive technologies
- Climate change, nutrition, and the preferences of urban consumers will be strong drivers of future markets.
- Technology, notably in crop breeding, is moving rapidly, which creates an exciting array of options for the next 30 years to develop the next generation of crops to meet the immense challenges of climate change.
- New environments are emerging for future crops, such as transformation zones where climates are changing fast, desert farming, urban agriculture, mariculture, and an advancing northern arable frontier across Asia, Europe and North America.
- Opportunity crops to diversify diets and address environmental challenges include a wide range of under-utilised and early-expansion species for food, energy and forage.
- Diversification of farms and production methods is a priority and creates a need for crops that thrive in multi-species and specialist production systems such as mixed cropping, agroforestry, land rehabilitation, carbon farming, agrivoltaics, hydroponics, aquaponics and other circular economy systems.
- Microbial, chemosynthetic and cellular foods challenge the usual notion of a farm and may contribute an increasing proportion of our diets.
- Crop breeding can target specific desired traits for next-generation crops, from perennial versions of annual crops to enhanced microbial interactions or more nutritious food products.
- For success, several enablers and lock-ins will need attention, especially around rights and benefit-sharing over genetic materials and data.
- The brief ends with some suggestions on nearer-term actions that various protagonists may take forward to advance next-generation crops in the next 30 years.

Likely climate scenarios for crop production

Staying within the agreed safe 1.5°C boundary looks increasingly unlikely. National climate policies in place today will lead to a mean global temperature 2.5-2.9 °C above pre-industrial levels by 2100.[I] This is consistent with the Intergovernmental Panel on Climate Change (IPCC) Shared Socioeconomic Pathway 2 (SSP2), or 'middle of the road', scenario.[I] Effects on crop production (Table 1) will, of course, be complex and context-specific—and include some positive impacts among the broader set of negatives. Global warming in the 2.5-2.9 °C range will likely exceed critical climate tipping points and trigger acceleration of impacts and positive feedback loops (e.g. a certain level of deforestation in the Amazon is likely to trigger collapse of regional rainfall recycling and hence accelerate forest dieback).

Our small remaining carbon budget means that emissions reductions, sequestration and capture will all be needed to stay in a safe space Hence net zero for crop production entails: (a) displacing high-C footprint foods with lower C footprint foods (e.g. shifting cereals and soy from livestock feed to human food), (b) increasing efficiency in resource use and material waste, (c) decarbonizing energy use in agriculture and food supply chains (with implications for mechanisation), and (d) managing agricultural lands and landscapes to retain and absorb carbon.

As the global carbon budget is squeezed further, active carbon capture will become a bigger part of the solution space. The forefront option here, BECCS[IV], is land-intensive and competitive with food crop production. All these climate solutions have implications for—and provide opportunities for—crop breeding.

Table 1. Projected impacts of climate change on crop production systems under likely climate scenarios by 2100.

Climate change impact on crop production	Notes	Example
Changing ranges for crop suitability	Water availability and heat thresholds are key determinants	Many current cropping areas will become unsuitable for production, for example, in Sub Saharan Africa. But areas warm enough for cropping are projected to double by 2055 across China, Russia, Nordics, and Canada[2]
Greater within-year and between-year variability	Variability may be more important than climate trends in determining crop production	About 60% yield variation in major breadbaskets[3] and 30% food price hikes in Europe[II] due to climate variability
More extreme events	Disruption to food systems even when crop yields are not directly affected	Wildfires in North and South America, floods in Asian breadbaskets
Novel pests and diseases	Accelerated 'arms race' and new geographies; risk of global pandemics	China predicts a doubling of diseased crop area by 2100 due to temperature[III]
C fertilisation	For some crops and geographies positive impacts may outweigh negative	Sugarcane shows a net positive yield effect

[I] Continuation of historical trends, post-2050 plateau in global population, improvements in resource and energy-use intensity, uneven environmental benefits, slow progress towards sustainable development goals, increasing inequality.

[II] Paul Behrens, University of Oxford, personal communication

[III] Wang et al 2022 cited in Raza & Bebber (2022)[4]

[IV] Bioenergy with carbon capture and storage – i.e. growing large-scale biomass for fuel and directly capturing emissions from power stations into long-term underground storage

Drivers of future food markets

Future food demand is not simply an extrapolation of recent trends; diets change rapidly from one generation to the next. Looking ahead to the coming decades, urbanisation and convenience will probably remain a strong driver, with people in cities seeking convenience, so ready-made meals will be a growth sector. These will most likely involve processed foods that are compatible with climate adaptation (longer shelf life, fewer seasonal ingredients) but less so with nutritional advice. Another key driver will be nutrition—not only accelerating demand for protein, but also plant oils and fats (the fastest growing food group) and—in a possible future with a broadened perspective on nutrition-dietary fibre.[V] Even in the absence of public policy, climate change will drive food markets through price signals, as we already see for food prices in general and most strongly for climate-sensitive crops like coffee.

Crop breeding in flux: learning from the last 30 years for the next 30 years

Crop breeding has undergone a technological revolution in the past 30 years. Major advances in genomics (characterising genomes), phenomics (characterising the expression of genomes), and precision breeding (use of molecular tools like genome editing) have involved innovations in information (e.g. big data, AI), lab (e.g. sequencers, CRISPR[VI]) and field (e.g. robotics, citizen science). These tools used in combination radically improve the ability of crop breeding to respond to climate change, in terms of both speed (halving, or better, the time that new varieties can get to market), and scope (making breeding simultaneously for multiple traits much easier and facilitating wider use of adaptive genetic variation).

However, the effects of these breakthroughs have not had nearly as widespread an impact on global crop production as predicted at the turn of the century, at the initial cusp of change.[5] Market value in the seed industry is dominated by a small number of crops (maize, soy, cotton) and geographies (North America ~35%), and market concentration has increased over the last decade. The big three are Bayer with 23% global seed sales, Syngenta 18%, and Corteva 17%.[VII] The long tail of medium (e.g. BASF, Vilmorin, Limagrain, KWS, LongPing, East-West), small and public sector breeding programs cover a much wider range of countries, crops and customers, but their adoption of innovative technologies has been uneven. Market value is poorly correlated with seed volumes; most seed grown by farmers comes through lower-value routes with less Research and Development (R&D). Public sector breeding is weakly funded.

Alongside the technological revolution has been a shift in the goals of crop breeding, as climate change effects have moved from future to real, and constraints on inputs have grown. In effect, crop production is moving from the goal of maximizing yield per hectare towards more nuanced bundles of benefits per unit of multiple inputs (Figure 1).

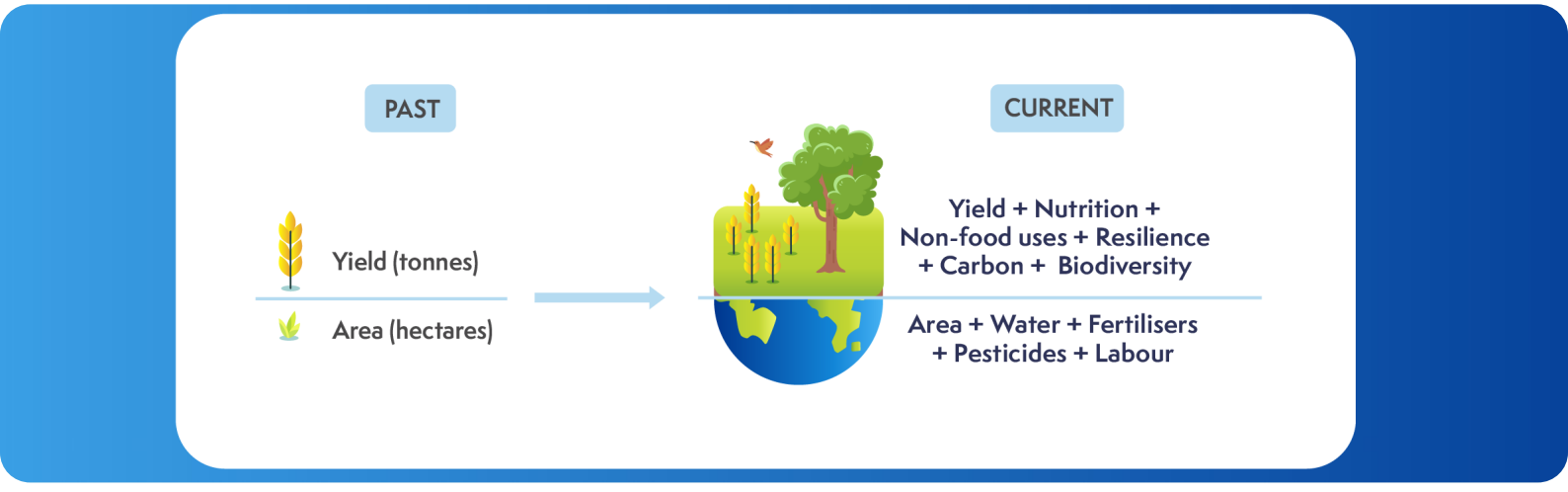


Figure 1. Crop production goals have shifted from maximizing yield per hectare to optimizing bundles of benefits and inputs.

This shift yields a much more holistic appraisal of the benefits of agriculture and the role of crop breeding together with agronomy in delivering these benefits. Again, uptake of this new thinking is patchy, largely due to policy and market signals (e.g. absence of price on water or carbon, or price premiums for nutritional quality).

Options for actions towards next-generation crops

This longer section of the brief provides an overview of options for the next 30 years to develop the next generation of crops, in light of the climatic, market and crop breeding contexts outlined above. The options are summarised in Table 2, giving an informed guess at the relative potential of each option to make a difference in how the food and land use sectors mitigate and adapt to climate change, as well as the role of crop breeding in getting us there. Each option has a little more discussion in the text following the table.

These options are at many different stages of development, from being well established commercially but still with much promising space for innovation (e.g. urban agriculture) through to the blue-skies discovery stage (e.g. much of the research on plant physiology and symbiotic associations). Importantly, while these options can all make contributions to environmental sustainability, none can solve climate change alone. They can only have an impact within a wider set of actions that prioritise reducing emissions from fossil fuels.

1. Emerging environments

Ever-increasing pressures on land use—due to climate change, land degradation and competing demands for urban expansion, energy and industry—puts a spotlight on how the farm landscape will change, even challenging the notion of what a farm might be.

Transformation zones: Much climate change research has focused on how farmers and consumers might adapt as current crop growing areas become unproductive with climate change, with contraction of suitable growing areas for many crops. As climate change drives large areas of arable land to become less suitable for current cropping systems, we can anticipate major transformations that involve switches in both the crops grown and the management systems used. Several large-scale examples are already documented, including the replacement of cereals with tree crops and the re-siting of irrigation systems.[6]

Northern frontier: As well as the negative impacts of climate change on crop production, we can anticipate emerging production areas. Particularly notable is the vast opening up of the boreal region to cereal production, with attendant opportunities (year-round opening of the Northern Sea Route for shipping) and problems (accelerated release of carbon from thawing peatlands). Since crops are bred for specific geographies, both transformation zones and expansion zones like the northern frontier will create strong demand for localised crop breeding solutions.

Desert farming: Desert farming is one of the fastest developing areas of agriculture. These systems mainly supply high-value fruits, vegetables and herbs to local urban markets from either outdoor irrigated or indoor hydroponic systems, for example, in adapted shipping containers. Since the water supply is often from seawater, and high rates of evapotranspiration lead to saline soils, salinity

[V] Global Burden of Disease studies find that consumption of unrefined versus refined cereals accounts for the largest portion of health outcomes from diets, relative to e.g. meat, saturated fats, fruit and vegetables

[VI] A cost-effective gene editing technology (Clustered Regularly Interspaced Short Palindromic Repeats)

[VII] Syngenta has been 100% owned by ChemChina since 2017. Bayer acquired Monsanto in 2018. Corteva was formed by a merger of Dow and DuPont's agricultural divisions in 2019 and owns the Pioneer brand.

Table 2. Strategic options for next-generation crop systems and their relative potential to support climate change mitigation, adaptation, and nature-positive outcomes, as well as the role of crop breeding. Options are scored qualitatively (o to +++) to indicate estimated potential based on climatic, market, and breeding contexts.

Options for next-generation crops		Direct nature+ potential *	System-level nature+ potential **	Adaptation potential ***	Role of crop breeding in driving solutions
Emerging environments	Transformation zones	+	+	+++	++
	Northern frontier	+	++	+++	++
	Desert farming	+	+	+	++
	Urban farming	+	+	++	++
	Mariculture	++	++	+	+++
Opportunity crops	Food crops	+	++	+++	+++
	Energy crops	++	+++	-	++
	Forage crops	++	++	++	++
Diversified farms	Mixed cropping systems	++	++	+++	++
	Agroforestry	++	++	+++	++
	Land rehab & management	++	+++	++	++
	Carbon farming	++	+++	+	++
	Agrivoltaics	+	++	+	++
	Hydroponics	+	+	++	++
	Aquaponics	+	+	++	++
	Aeroponics	+	+	++	++
	Circular economy	+	+++	+++	+
Farm-free foods	Wild foods	+	+	+	O
	Microbial foods	O	+++	+++	+
	Cellular crops	O	+	+	+++
	Chemosynthetic foods	O	+++	+++	O
Targeted traits	Plant physiology	++	+	++	+++
	Perennial cereals	++	++	++	+++
	Symbiotic associations	++	++	+++	+++
	Enhanced nutrition	O	+	+	+++
	Processing and storage	O	++	+++	+++

* potential to make a significant contribution to climate change mitigation and biodiversity within agricultural systems

** potential to deliver gains in full factor productivity that, through reduced land use and material savings, in turn generate globally signifcant climate change mitigation and environmental benefits

*** potential to enhance food availability, affordability and nutritional value at a global level under climate change

tolerance is a key trait for crop breeding. The ambitions of the last 30 years to achieve self-sufficiency in cereals have been dropped by most desert countries due to the high costs but may re-emerge as climate change creates greater pressures for food sovereignty in the next 30 years.

Urban agriculture: Over the past half century, countries like South Korea have experienced what they call the 'white revolution'—a vast expansion of urban and peri-urban agriculture in controlled environments such as glasshouses and polytunnels. Both urbanisation and climate change will drive waves of global expansion and innovation in the next 30 years, with many space-saving solutions, like vertical farming, and circular economy systems such as the many 'ponics' (see below). Like desert farming, these will most likely focus on higher-value products, such as fresh fruits and vegetables, rather than large-scale supplies of cereals, pulses and oilseeds.

Mariculture: Algae have been talked up as an auspicious climate solution that can deliver bioenergy, livestock feed additives and speciality high-nutrition human foods with a minimal land footprint. Seaweed can also clean up coastal nitrogen pollution. However, despite this promise and growing demand, the global seaweed market is currently in decline due to the drag that disease is putting on production. Breeding is sorely needed, but the under-developed structure of the industry means that there is currently little private sector incentive to invest in R&D.

2. Opportunity crops

Agricultural land is currently dominated by pasture and the 'big four' food crops (wheat, maize, rice, and soy) that provide both food for humans and feed for livestock. There is great potential for this to change in the next few decades–towards a more diverse set of food crops and also supplies into the booming bioeconomy sector, particularly energy crops.

Food crops: With basic food security under threat under climate change, retaining the global focus of private and public sector breeding on the big cereals and pulses is a no-brainer. Nonetheless, thousands of species are under-utilized and promising in terms of nutrition, market value and climate resilience. Since breeding programs need a decent investment to be effective, choosing the handful of best-bet candidate crops is a challenge. A recent international expert exercise by the VACS[VIII] program identified pigeon pea, bambara groundnut, taro, sesame, finger millet, okra, amaranth, grass pea, tef, and cucurbits as a top ten 'opportunity crops' (dropping the older 'orphan crop' language). Other major opportunity crops will be those providing feedstocks and raw materials for alternative protein products; high-protein crops such as pulses and pseudocereals (e.g. quinoa, amaranth, buckwheat) are likely to gain in importance globally.

Energy crops: Bioenergy accounts for 7% of our global energy budget today and is expected to rise to at least 20% by 2050. BECCS technologies for carbon dioxide removals will drive up demand for bioenergy. Herbaceous energy crops (as opposed to woody feedstocks from forestry) are either converted into fuels or directly burned to generate energy. Key species are perennial grasses like silver grass (miscanthus), switchgrass and elephant

[VIII] Vision for Adapted Crops and Soils – an international multi-stakeholder program previously led by the US State Department

grass for biomass burning, and maize, palm oil, sugarcane, cottonseed and soy for biofuels. One of the challenges for plant breeding will be how best to manage the competition between food and energy production on land, for example, by breeding energy crops that perform well on degraded lands.

Forage crops: Pasture for livestock covers double the area of arable crops globally. Adjusting animal feed is a critical part of the solution space for climate change. Thus breeding of forages—to be less methanogenic, more productive, more resilient and so on—will continue to grow in importance in the coming decades.

3. Diversified farms

A major area for crop breeding in the next 30 years will be equipping plants for emerging agronomic systems, often involving multiple species.

Mixed cropping systems, agroforestry and land rehabilitation: Recent crop improvement has made good progress on resource-use efficiency. But crop breeding has missed a trick in understanding how novel crop varieties can best perform within different management regimes and multi-species settings. For example, the conservation agriculture community notes that crop breeding has poorly targeted this management system, despite it occupying ~200 million hectares (15%) of global farmland. The same is true for *agroforestry* and other mixed farming systems commonly practised by farmers. There are major opportunities to breed crops for (a) mixed cropping systems e.g. agroforestry, alley cropping, within-season rotations, (b) management systems compatible with environmental stewardship e.g. low-impact mechanised harvesting and regeneration of degraded lands. Close collaboration and joint research with farmers will be key to success.[IX]

Carbon farming: Turning crop and grazing systems into net carbon sinks would be a game-changer for climate change mitigation. But experience shows that farmers need multiple value streams to make carbon farming pay.[X] Important innovations include the microbial research outlined above, but also research on breeding for *deep-rooting crops*[XI] and *perennial cereals* [XII] A broader 'bundled benefit' approach to modern farming[XIII18] could pay off, with context-appropriate mixes of food, feed, energy feedstocks, fibre, industrial uses, environmental services, and clean-up/rehab tech.[XIV] Crop breeding is beginning to take this multi-benefit approach to measuring genetic gain.

Agrivoltaics: Growing crops beneath solar panels is a neat way to combine energy production with a harvest. There have been early successes, largely with vegetables, but even maize can be cultivated in this way. Crops can be bred for lower height, *shade tolerance* and so on, but perhaps the key frontier for R&D is to develop solar panels that separate the light spectrum so that the wavelengths used in photosynthesis can pass through.[8]

Hydro, aero and aquaponics: Indoor cultivation systems are developing and scaling rapidly and are likely to be a leading supplier of urban foods in 2050 and beyond. The proliferation of names is a sign of the rate of innovation. Hydroponics–soilless growth using liquid nutrient mediums along with substrates like rockwool or coir–has led to aeroponics (mist nutrient medium) and fogponics (fine mist). Aquaponics combines aquaculture and hydroponics so that plants are fed with the effluent from fish or shellfish production. Variations on aquaponics

[IX] For example, in Australia, primary producers in farming, forestry and fisheries pay a 0.5% levy to commodity-specific Research and Development Corporations and through these they drive the agricultural research agenda of universities and other research organisations.

include sandponics (using a sand substrate which has important filtering capacities), vermiponics (building in worms, which help with compost production), flocponics (similarly building in a bacterial system), maraponics and haloponics (both saltwater systems). These are rich areas for plant breeding.[9]

Circular economy: A nascent area for crop improvement is breeding for the full circular economyso that a crop has a set of genetic traits that consider how all the plant's parts will be used as food, fuel and fibre or recycled back into a farm's land and nutrient management system.

4. Farm-free foods

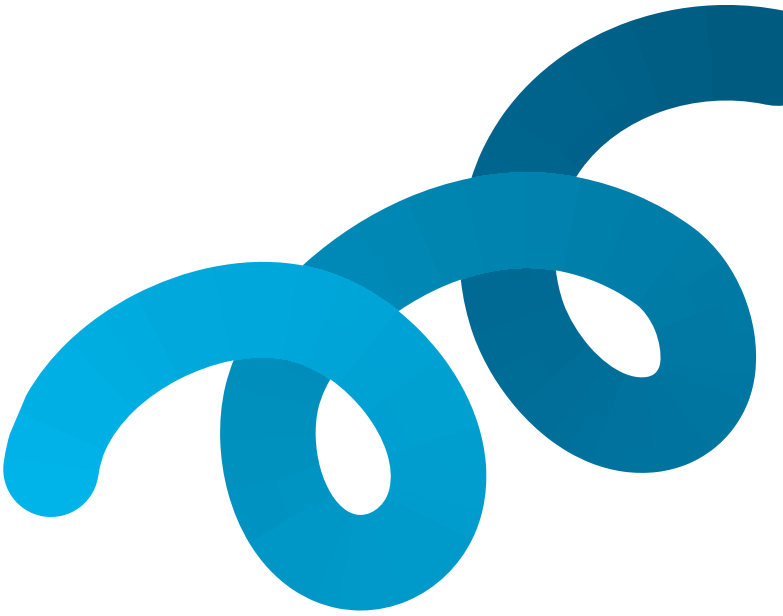
Moving beyond the usual notion of a crop as a multicellular plant cultivated by people, there are next-generation opportunities for food that do not depend on traditional agricultural systems.

Wild foods: Other than fisheries, there has been very little research on the future of wild foods under climate change,[10] but it is certainly conceivable that much larger-scale protection of natural lands could be combined with economic levels of wild food gathering.

Microbial foods: Microbial foods are produced from fermentation of feedstocks, such as byproducts from the food industry and agriculture, followed by different levels of processing to create liquid or solid foods, powders and so on.[11] We have made fermented foods for millennia. Interest is on the rise now for both health and environmental reasons, and there is substantial future potential.

Cellular crops: This is a similar notion to cultured meat—by culturing plant cells on a feed substrate, it may be possible to grow the desired fruit, seed or tuber alone without the leaves, stem or roots. In essence, photosynthesis and nutrient capture are outsourced. This technology is likely only to be viable for very high-value products such as flavourings, scents and medicines.

Chemosynthetic foods: Macronutrients–proteins, fats and carbohydrates–can all be chemically synthesised from feedstocks such as oil industry byproducts, municipal waste and even carbon dioxide from the air. Substituting synthetic oil for palm oil would deliver significant environmental benefits, for example, and costs may soon be competitive.[12] Consumer acceptance of chemical foods would be a key barrier to overcome, but the benefit-cost ratios means that these technologies deserve more attention.



[X] As described in Vermeulen et al. (2019)[7]: Investments in soil organic carbon only create value for farmers when they combine several of the following five elements: (1) enhanced productivity, (2) improved risk management (e.g. resilience to drought), (3) superior market access (e.g. certified value chains), (4) financial returns to carbon assets, and (5) government support (e.g. environmental subsidies)

[XI] Such as Penn State University and the, University of Copenhagen

[XII] Such as Land Institute, AgriFood Canada and several US universities

[XIII] I.e. a multi-benefit 'nothing goes to waste and value accrues with time' approach that is already common in modern forestry and traditional farming

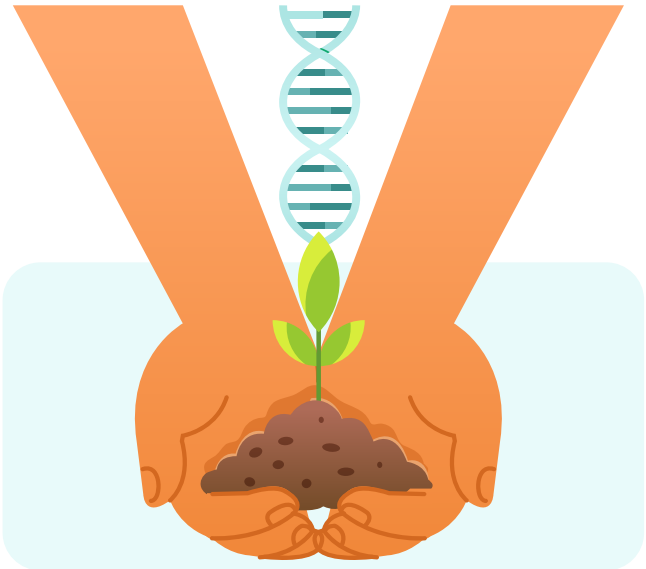
[XIV] For example, alfalfa is a crop that can remove cadmium and other toxic metals from the soil and trials are underway in Trinidad & Tobago and other countries to test its potential in rehabilitation of contaminated agricultural lands

5. Targeted traits

These crop breeding efforts focus on improving the performance of crops in terms of yield, nutrient use efficiency, nutritional value, flavour and other attributes by targeting specific genetic traits. This is a space in which discovery research can provide potentially game-changing innovation.

Plant physiology: Crop breeding has had notable recent successes with specific traits for *climate resilience, such as drought and salinity tolerance* . Work on disease resistance continues to be critical in the face of rapid pathogen dynamics. New work is emerging to increase growth rates and productivity, for example, by *increasing rates of nutrient binding* or '*supercharging' photosynthesis*, which involves targeting the physiological process by which captured energy is converted into glucose bonds (since the process by which plants capture light energy is already almost 100% efficient).

Perennial cereals: Perennialism has major advantages for soil health, biodiversity and carbon storage. Research on perennial cereals has been underway for more than half a century. The two key research directions are establishing perennialism in existing domestic varieties and domesticating wild perennial species. While there has been much progress, we are nowhere near commercial production due to problems with maintaining yield levels or maintaining the perennial traits.[13] However, there may be major breakthroughs in the next 30 years.



Symbiotic associations: R&D on manipulation of the soil microbiome should be an explosive growth area in the coming decades. The applications of *enhanced crop symbiotic associations* with *fungi and bacteria are huge* –such as weaning crops off artificial fertilizers, achieving a profitable yield on poor soils, or rehabilitating degraded lands. Many lines of promising research on innovations are underway, including *N-fixing cereals*[XV] and *enhanced bacteria*.[XVI]

Enhanced nutrition, processing and storage: Nutritional value comes both from increasing the density of macro—and micro-nutrients in crops and from increasing the diversity of crops in the diet. On the former, iron and zinc biofortification[XVII] have become standard traits in wheat and bean varieties. Gene editing (GE) has already demonstrated value in raising the content of specific nutrients such as oleic acids in soy, and in delaying rancidity in wholegrains, a major contributor to human health. Another opportunity is indirect human health benefits through breeding of fish and livestock feed with higher nutritional value.

Enablers and lock-ins that need attention

As mentioned above, the promise of the 21st century molecular crop breeding revolution is not yet reaping the anticipated benefits. Understanding and addressing barriers and lock-ins must be a core ingredient of any scaling effort. Here are five areas for attention.

Flows of materials, data and technologies: Intellectual property (IP) and benefit-sharing are extremely sensitive issues in crop breeding and the global seed industry. Previously, the focus has been on the transfer of genetic materials among countries and between the private and public sectors, but now, genomic data is equally contested, dominating negotiations at the Convention on Biological Diversity (CBD) Conference of the Parties (COP) IP protection over (GE technologies is a key hindrance for breeding programs in low-income countries (the technologies themselves are inexpensive to run). Progress can be made, e.g. the emerging China-led

[XV] Such as the University of Cambridge and MIT
[XVI] Such as Pivot Bio, Gingko Bioworks
[XVII] I.e. genes that enhance uptake of these elements from the soil

Genome2Phenome global program is giving close attention to protocols for sharing materials, data and technologies; and Corteva is actively enabling licensing of patented GE technologies. Serious attention from policymakers and multilateral processes is needed here.

Consumer safety and acceptance: The low rate of commercialisation of GE products is not surprising—experience with GMOs has taught us the importance of sensitivity and care in developing and marketing innovative crops. Public policy can be characterised as 'one step forward, two steps back'.[XVIII] This is an area where a multi-stakeholder effort could make a difference.

Technology traps and frivolous niches: A primary reason for slow adoption of new breeding tools is that applications can be very specific to crops or traits, and frequently the application only emerges after traditional breeding methods have provided a solution. As a result, gene editing easily falls into the trap of being a hammer looking for a nail-creating elegant solutions for relatively trivial innovations such as non-browning bananas and high-GABA tomatoes. Ramping up access to technologies among a broader set of scientists globally would help.

Resilience rationality: Some investors in agricultural development are switching focus from productivity to resilience as the key goal. But 'resilience' is an abstract term with multiple interpretations, and a singular focus on adapting specific crop species to failing environments may serve vested interests rather than positive outcomes for farmers and food security. There is an opportunity for much clearer gameplans or playbooks on the when/what/how of adaptation versus diversification to other crops, agricultural systems or non-ag livelihoods.[XIX]

Wider context of geopolitical shifts: National food security and food cultures are provocative topics in any country. A food future that involves international shifts in production areas, greater reliance on trade to deal with production volatility, plus changes in types or provenances of food, will collide headlong with national food sovereignty imperatives and self-identity. We have seen how governments react to food shortages and consumer price rises with export bans and large-scale procurement above international market prices, inadvertently feeding the price spiral. In the future, we may also see a reinforced dependence of tropical countries on China, Russia, Europe and North America for the supply of staples. Migration, food riots and war may well be shaped by future crop production.

Who and what next? Actions to enable next-generation crops

Looking across the opportunities, enablers and lock-ins, some key options for near–and medium-term action emerge for different groups of protagonists —with the aim of enabling the development of future crops that deliver on global goals for climate and environment. The table on the next page summarizes these for each group of actors.

[XVIII] For example, Kenya is see-sawing on biotech policy – in 2022 the government overturned a 10-year ban on GM and also released guidelines to support GE, so that in 2023-24 a limited set of biotech research projects launched, then in 2025 the appeal court blocked all GM research and imports.

[XIX] For example, The Nature Conservancy and ClimateAi have released these types of tools at the global level, but there is much scope for more local and context-specific guidance.

[XX] For example, active sharing of gene editing tools with public breeding programs including via the $25M joint venture between Corteva Catalyst and Pairwise Fulcrum Platform.

Actions to enable next generation crops

Policy makers and regulators

- Put real effort into providing a strong and practical policy framework for international transfer of genetic materials and data, and associated benefit-sharing, with a focus on affordable, fair and safe access for low-income country partners.
- Invest in information-sharing with citizens on biotech to enable wider knowledge and evidence-informed debate.

Upstream research programs

- Continue and, if possible, ramp up discovery research in key areas such as soil ecosystems and symbioses.
- Improve downstream partnerships so that testing of new technologies in real user contexts happens sooner and better.

Public sector and PPP breeding programs

Set breeding goals and priorities by using explicit holistic frameworks that consider:

- The full range of benefits and inputs (not just yields per hectare).
- Diversified farms.
- Long-range futures that may involve different crops and foods.

Tech start-ups

- Put real effort into providing a strong and practical policy framework for international transfer of genetic materials and data, and associated benefit-sharing, with a focus on affordable, fair and safe access for low-income country partners.
- Invest in information-sharing with citizens on biotech to enable wider knowledge and evidence-informed debate.

Medium and large established seed companies

- Get involved in PPPs, provide pre-competitive advice, training and tools to public sector and PPP breeding programs.[xx]
- Develop concrete climate strategies with SMART metrics.

Farmer and producer organisations

- Invest in, and shape, research agendas on future crops.
- Establish channels to enable early adopters to experiment with and demonstrate new tech in real farms and production systems.

Environment and development NGOs

- Continue to hold governments and private sector to account on ESG outcomes from biotech.
- Take a systems-level view of costs and benefits rather than any overly simplistic single-issue approach.

Investors for social and environmental returns

- Prioritize investments by identifying more likely winners through e.g. a structured Delphi process with a small handful of trusted experts.
- Invest in the enablers as well as the tech sides of innovation.

Thought-shapers and facilitators

Working closely with end-users and their needs, provide 'honest broker' services around issues such as interrogating claims on environmental impacts and scalability of new tech, supporting rational decision-making on both resilience and mitigation, and prioritizing among competing options for investment.

Citations

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