How may food systems evolve: looking ahead in an uncertain world

Contents

This paper was prepared by Professor Tim G. Benton, Research Director of Emerging Risks, and Director of Energy, Environment and Resources Programme at the Royal Institute of International Affairs, Chatham House as a stimulus paper to frame discussions on the role of genebanks in the future.

1. Introduction

To develop a strategy for the future of genebanks for the conservation of plant genetic resources for agriculture requires some discussion of future drivers that will shape both the food system (e.g. will dietary shifts in favour of better nutrition require greater emphasis on fruits and vegetables in future and less on current grain commodities?), and also the wider way that society might evolve (for example, will we continue current trends away from globalisation and stability, leading to greater focus on regional economies and more instability driven by geopolitics, inequality, insurgency and environmental breakdown)? Taking no consideration of the way the future may unroll risks making decisions that are dependent on today's thinking in today's world, which may be unfit for the future and also create a path-dependent process that locks in a lack of ability to change course if necessary. To make robust decisions for the future needs consideration of what plausible futures may exist.

Recent years have seen the undermining of the post-war architecture of international cooperation, the emergence of trade wars, disruption created by COVID-19 – itself an exemplar of disrupted ecologies likely arising from climate change – driving a new focus on local resilience, sustainability and nutrition. Together these suggest a plausible future that differs from one extrapolated from the trends evident at the turn of this century: One with more diverse agricultural systems, perhaps more localised and regionalised, with a focus that goes beyond simply increasing productivity of a small number of crops for a globalised market. In such a world, a network of regional gene banks, focussing on a very diverse range of culturally appropriate and historically consumer crop species, may be more appropriate than a single centralised global hub with a focus on existing commodity crops and their wild relatives, or indeed, a network of commodity-based genebanks.

This paper has the following structure: Section 2 introduces some of the historical drivers of the food system and why there is growing recognition of the need for it to change radically to promote greater resilience, sustainability and nutritional outputs. Section 3 examines some of the non-food drivers and events that may contribute to systemic change. Section 4 introduces scenarios as a method of strategizing under uncertainty, and presents the results of some recent scenario exercises. Section 5 concludes the paper.

2. A brief history of food systems

Investments in agricultural research and innovation underpinned rapid productivity growth and, in concert with both the development of global and liberalised trade, and the competitive pressures it creates, has stimulated the adoption of intensive and large scale agriculture across much of the world in recent decades. Increasingly large scale, intensive and productive agriculture has been the engine that has made food more available, and, on average cheaper decade-by-decade (Fig 1).

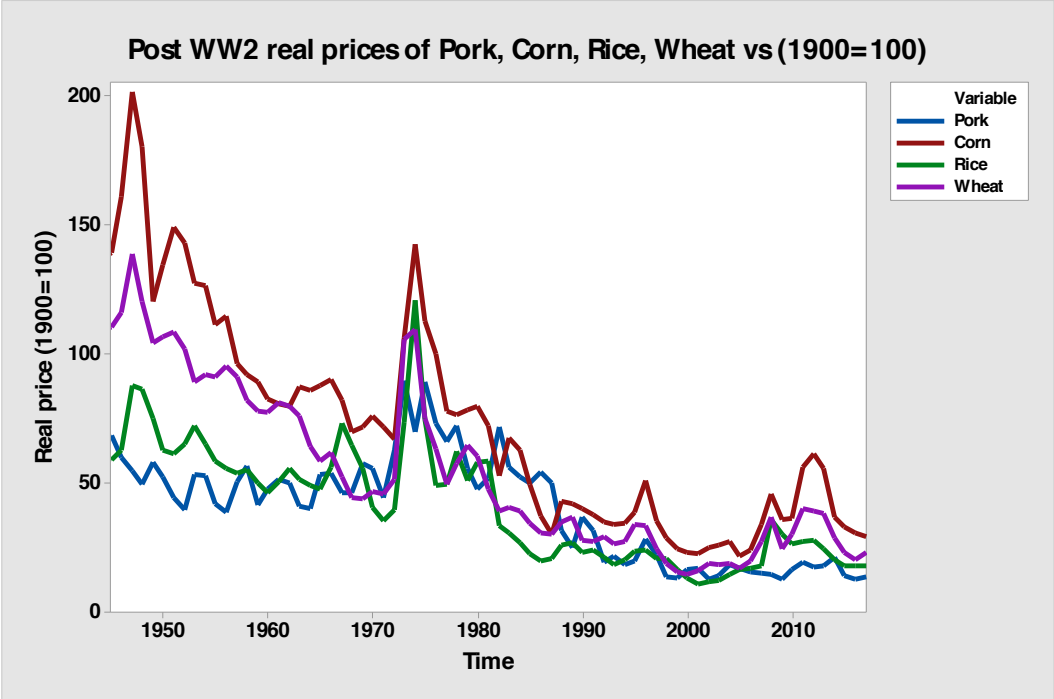

Fig 1. Real food prices since the Second World War for 4 agricultural commodities. The prices are indexed to 1900=100, and are part of a longer series. The sharp spike in the 1970s represents the global oil price crisis, but against that up to the first decade of the 21st century there have been global long term declines on average, such that commodities in the first decade of this century were ~20-30% of the price relative to the first decade post-war. Data available at: http://www.sfu.ca/~djacks/data/boombust/index.html and come from Jacks "From Boom to Bust: A Typology of Real Commodity Prices in the Long Run." NBER Working Paper 18874.

However, in recent years, there has emerged a growing recognition that "the cheaper food paradigm" has not simply provided the social good that is typically thought to arise from cheaper food but is increasingly creating social costs as "externalities" arising from the production and consumption of food. These externalities occur under the headings of health and environment.

Environmental externalities. Incentives based on production, global competition based on price, and long supply chains reducing transparency, encourage the externalisation of significant costs on the environment – including on soils[1], biodiversity[2], water[3] and climate, where agri-food emits as much as 30% of global greenhouse gases[4] and air quality (for example, a study in the US suggests local health costs can be about half the value of production[5]). On average, each global citizen used, 284g of pesticide active ingredient in 2015 (data from FAOSTAT), 9g of antimicrobials in 2010[6], and 15kg of nitrogen fertiliser[7].

Furthermore, as prices have been driven down by production growth and global competition, the economic incentive to avoid food waste has declined[8]: as productivity increases, waste increases faster, creating further pressure on the environment (from unnecessary production, and disposal of the waste, plus its packaging). There is increasing evidence that tackling climate change not only requires agricultural mitigation, through adopting "climate smart agriculture" but a fundamental change in the demand-side of the food system[9]. The Paris climate agreement, effectively codifying the level of "safe" climate change to well below 2 degrees[10], requires significant and rapid dietary change, coupled with largescale agricultural change to free up land for widespread deployment of land-based carbon storage.

Health system externalities. Some of the focus of the productivity agenda has been motivated by reducing global under-nutrition, and, to some extent this has been successful with a decreasing prevalence of underweight and stunting[11]. The flipside, however, is decreasing prices and increasing availability of a small handful of crops which underpin a globally increasingly homogenous diet, rich in calories but often lacking nutrition[12]. As a result, global malnutrition "in all its forms" is increasing due to the increasing prevalence of overweight and obesity, which has overtaken the global

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[1] Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E., & Sparks, D. L. (2015). Soil and human security in the 21st century. *Science*, *348*(6235).

[2] Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., Ferrier, S., ... & Burton, V. J. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science*, *353*(6296), 288-291.

[3] Dalin, C., Wada, Y., Kastner, T., & Puma, M. J. (2017). Groundwater depletion embedded in international food trade. *Nature*, *543*(7647), 700-704.

[4] Bajželj, B., Allwood, J. M., & Cullen, J. M. (2013). Designing climate change mitigation plans that add up. *Environmental science & technology*, *47*(14), 8062-8069.

[5] Paulot, F., & Jacob, D. J. (2014). Hidden cost of US agricultural exports: particulate matter from ammonia emissions. *Environmental science & technology*, *48*(2), 903-908.

[6] Van Boeckel, T. P., et al. (2015). Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, *112*(18), 5649-5654.

[7] Davis, K. F., et al. (2016). Meeting future food demand with current agricultural resources. *Global Environmental Change*, *39*, 125-132.

[8] Benton, T. G., & Bailey, R. (2019). The paradox of productivity: Agricultural productivity promotes food system inefficiency. *Global Sustainability*, *2*.

[9] Bajželj, B. et al. (2014). Importance of food-demand management for climate mitigation. *Nature Climate Change*, *4*(10), 924-929.; Springmann, M. et al. (2018). Options for keeping the food system within environmental limits. *Nature*, *562*(7728), 519-525.

[10] IPCC Special Report on 1.5 degrees. www.ipcc.ch/sr15

[11] RisC, N. C. D., & NCD Risk Factor Collaboration. (2016). The weight of the world: trends in adult body mass index in 200 countries since 1975: pooled analysis of 1,698 population-based measurement studies with 19.2 million participants. *Lancet*, *387*, 1377-1396.

[12] Khoury, C. K., et al. (2014). Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences*, *111*(11), 4001-4006.

prevalence of underweight[13]. Non-communicable diseases associated with an excess of calories include diabetes, dementia, cardiovascular disease and several cancers. Dietary-related ill-health is now recognised as the prime global determinant of mortality[14].

Estimates of the total healthcare costs of malnutrition are patchy, but the FAO suggested in 2013 that health care costs associated with inadequate nutrition might exceed 5% global GDP[15]. This may be an underestimate as, in the US, the economic cost of diabetes, a disease strongly associated with obesity and affecting ~23m Americans, is estimated at $327bn in 2017, with direct healthcare costs of $9,600 per person[16]. By 2025, it is estimated that globally there will be over 700m people with diabetes, over 30x the number in the US[17]. Even if a global average cost of diabetes per capita was a quarter of that in the US, the total economic cost of diabetes would be approximately the same as global agricultural GDP (3.79%[18] in 2015). Given our current food system, malnutrition is both increasing, and increasingly expensive economically[19].

The recognition of the magnitude of environmental and health impacts ("the global syndemic of malnourishment and climate change" gives a strong argument, based on the concept of planetary health, for a systemic transformation of the food system[20].

Transforming the food system

Transforming the food system to deliver healthy and sustainable diets is likely to be necessary to balance health, food and climate security and tackle the syndemics. Furthermore, the UN's 17 Sustainable Development Goals (the SDGs) are challenging not only because each of the goals is challenging, but because they are inter-dependent: tackling the "Zero Hunger" challenge by producing more and cheaper food is likely to further undermine other goals (such as Goal 6, access to clean water, Goals 15 and 14, life on land and in water, and Goal 13, climate action).

Looking ahead to a population that is likely to be over 9.5bn in 2050, and may even reach nearly 12 bn towards the end of the century (although it could also shrink below today's population size)[21], there are very significant challenges on the horizon. If the current food system is reducing human and planetary health, doing the same thing more intensively is not sustainable. In fact, there is growing recognition that a systemic transformation of the food system is required, and that "business as usual is not an option". This recognition comes from the business community, academic academies, and the IPCC – as well as many environmental and civil society institutions.

If, in the long term, business as usual is not an option, what forces may cause it to change?

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[13] Swinburn, B. A., et al. (2019). The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *The Lancet*, *393*(10173), 791-846.

[14] Stanaway, J. D., et al. (2018). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, *392*(10159), 1923-1994.

[15] Food and Agriculture Organization of the United Nations. State of Food and Agriculture 2013: Food systems for better nutrition. 2013 Rome, Italy.

[16] American Diabetes Association. (2018). Economic costs of diabetes in the US in 2017. *Diabetes care*, *41*(5), 917-928.

[17] Zhou, Bin, et al. "Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4· 4 million participants." *The Lancet* 387.10027 (2016): 1513-1530.

[18] https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

[19] Swinburn, B. A., et al. (2019). The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *The Lancet*, *393*(10173), 791-846.

[20] Swinburn, B. A., et al. (2019). The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *The Lancet*, *393*(10173), 791-846.; Willett, Walter, et al. "Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems." *The Lancet* 393.10170 (2019): 447-492.

[21] Vollset, Stein Emil, et al. "Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study." *The Lancet* (2020).

3. Is the future "designed" by trends or events?

The world - globally, regionally and locally - is changing increasingly fast in many dimensions: social, economic, technical, environmentally[22]. We have growing populations, with, on average, more mobile, more connected, more wealthy people, but with greater inequality between the rich and poor. Collectively our developing economies are demanding more resources (e.g. food, water, energy, goods). Simultaneously with the planet being under pressure from increasing demand, there is increasing recognition of the finiteness of the environment's ability to buffer the environmental footprint of demand (e.g. emissions of greenhouse gases and other pollutants, including plastic waste; soil degradation; biodiversity loss). Arguably, we are now closing in on "planetary boundaries" beyond which earth-system processes may degrade, and furthermore in some places "local boundaries" are being crossed, with irreversible land degradation, for example. Around the world extreme weather is becoming more common, impacting people through floods and droughts and heatwaves. The indirect impacts of climate change are also being felt – for example, in the emergence and spread of pests and diseases, both affecting food production[23] and, potentially even, the emergence of SARS-CoV-2[24]

At the start of the 21st century, the future looked very different from our impression of how it might be from today's standpoint. International rule-based cooperation had led to unprecedented periods of stability and global integration, such that there was even discussion of a world without nation states as we know them[25]. However, over the last 20 years, growing radicalism, terror, the threat of terror, growth in inward-looking nationalism, driven by inequality growth and perceptions of immigration, awareness of the reality of climate change, and COVID-19 has now led us to a very different world. We are radically diverging from the direction of travel since the Second World War and the rise of the Bretton Woods' international architecture of cooperation which has underpinned the trend of increasing globalisation.

Not only is the world changing fast, but the changes are increasingly challenging from the perspectives of geo-politics, as well as environmental change. Together, both undermine, or potentially undermine, the stability of local, regional and global societies and their governance. Within this "changing and challenging world" context, some societal issues are becoming both more urgent (as time runs out to drive positive change) and more important (as the scale of the challenges grows). These factors set the context for the future of all economies in the decades ahead.

The role of events in shaping the future

The large-scale trends associated with driving appreciable change, whether through attitudinal, behavioural, economic or environmental mechanisms, are known as "mega-trends". The trends identified as "mega" depend to an extent on the context and institution describing them. For example, *PwC* describe five: urbanisation, climate change and resource security, shifting global power, demographic and social change, and technology[26], whereas the UN adds poverty and inequality, shocks and crises (as well as development finance) to their list[27].

Humans are typically very linear thinkers and tend to look at trends from the past and project them forwards into the future, and we often fall into the trap of thinking that the future is defined by what has happened in the past. However, as 2020 has already shown, the future is not a simple linear

[22] Steffen, W., et al. "The trajectory of the Anthropocene: the great acceleration." *The Anthropocene Review* 2.1 (2015): 81-98.
[23] http://www.ipsnews.net/2017/01/zambias-armyworm-outbreak-is-climate-change-to-blame/
[24] https://news.un.org/en/story/2020/07/1067711
[25] Sassen, Saskia. "Towards post-national and denationalized citizenship." *Handbook of citizenship studies* (2002): 277-292.
[26] https://www.pwc.co.uk/issues/megatrends.html
[27] http://www.undp.org/content/undp/en/home/librarypage/sustainable-development-goals/global-trends--challenges-and-opportunities-in-the-implementatio.html

extrapolation of trends, unfolding in a constant and gradual way. Instead, "events happen" as the saying goes, and sometimes these events are both highly impactful and disruptive.

Such events can arise for two main reasons. Firstly, "black swan" events are rare, but with very high impact; perhaps both unexpected and unprecedented. COVID-19 is arguably such an event. Secondly, a single event (a hazard) or multiple hazards, can occur, and together they create chains of interacting effects that cascade across borders[28]. For example, the food price shocks of 2007/8 and 2009/10 created ripple effects that impacted across the world and arose from relatively minor climate events interacting with other policy areas (biofuel policy), and a lack of transparency of stocks, leading to an over-amplification of market dynamics. In extremis, "risk cascades" and black swan events can create "systemic risks" (Andy Challinor et al., 2018; Homer-Dixon et al., 2015), and create the conditions, that re-shape economies.

As time goes on, our economic systems are growing in fragility (Homer-Dixon et al., 2015). To illustrate, take food security – a secure supply of food to feed a country – which typically comes from the combination of local supply and regional and global trade. The latter has become more important with growing market integration across borders, which creates increasing reliance on imports and exports for economic functioning. Agriculture depends on water, land, supply of labour and typically also chemicals and energy. Increasingly, agriculture is also reliant on more advanced technologies like satellite navigation in precision agriculture and transport networks. The drive for economic efficiency also leads to a greater reliance on just-in-time supplies. Food security therefore relies on a range of sectors, infrastructure, complex logistics, finance, and so on, domestically, regionally and globally to work in concert in order to supply a nation's requirements. This co-dependency across sectors, and just-in-time supply, means that any shock (which could be a climate change impact, a change in energy policy, a geo-political disruption) can propagate around the world. Proportionally, the impacts of such events can be felt most strongly by those with the lowest incomes[29] .

Perhaps most importantly, the co-dependency (across space and sectors) means that there are a very large number of combinations of potential shocks, places they could happen, and pathways they could propagate through to create a high impact. Thus, whilst we often think of individual "black swans", the number of potential ways that risk cascades can impact on any given country is very large, and so we should regard events like the global financial crises, food price spikes, insurgency, pest and disease outbreaks, extreme climate events, and crises deriving from movement of people to be "the new normal". Each event may be a rare "one-off", but in any given period, we should expect something big to happen.

Our linear thinking pre-disposes us to think of the future in terms of "business as usual" scenarios. But, as outlined, the world is highly non-linear, stochastic and complex. Given enough shocks, our locked-in, resilient-to-change "business as usual" may be reconfigured into a "new normal".

Quoting from United States *Global Strategic Trends 2035*[30] (p65):

Examining the trends…. makes vivid that the world will become more volatile in the years ahead. States, institutions, and societies will be under pressure from above and below the level of the nation-state to adapt to systemic challenges—and to act sooner rather than later. From above, climate change, technology standards and protocols, and transnational terrorism will require multilateral cooperation.

[28] Challinor, A. J., Adger, W. N., Benton, T. G., Conway, D., Joshi, M., & Frame, D. (2018). Transmission of climate risks across sectors and borders. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2121), 20170301.

[29] Bekkers, E., Brockmeier, M., Francois, J., & Yang, F. (2017). Local food prices and international price transmission. *World Development*, *96*, 216-230.

[30] https://www.dni.gov/files/documents/nic/GT-Full-Report.pdf

From below, the inability of government to meet the expectations of their citizens, inequality, and identity politics will increase the risk of instability.

4. Thinking about an uncertain future: strategizing under uncertainty

As described above, the future is highly uncertain. High-impact, large-scale events are likely to grow in frequency as the world changes, becomes more interconnected, is put under greater pressure through demand and consumption growth, and is challenged by environmental-change related events arising from increasingly extreme weather, or new pests and diseases.

All this means its future is far from predictable. This unpredictability is summed up with the acronym "TUNA": Turbulent, Uncertain, Novel, Ambiguous[31]. The future is turbulent because of its systemic fragility and non-linearity, meaning events can lead to escalating impacts[32]; uncertain because these are often highly unpredictable and – from a climate perspective, unknown; novel because technological, social and environmental change create unprecedented situations; and ambiguous because every problem or solution is wicked – with both "winners" and "losers".

The megatrends are also typically increasing the uncertainty through undermining broad sustainability. For example, economic and population growth drive consumption growth, which drives climate change that then undermines the potential for the trends to continue. In the long term, therefore, continuation of the "business as usual" global megatrends is not an option. The section above highlights that our fragile complex socio-economic-environmental systems may increasingly be subject to shocks. Such shocks, like COVID-19, may be disruptive enough that they also unshackle "business as usual lock-in" and disruptively provide opportunities for rapid change. Given this, what might the future look like?

Scenarios are a route to aid decision making under uncertainty[33], when past trends cannot necessarily be extrapolated into the future with confidence, and where the future is likely to be shaped by drivers or events which may plausibly lead to very different outcomes. Scenarios can inform today's thinking about strategic decisions through exploring different possible futures. They examine a range of plausible futures, not to forecast what they may be like, but to provide a mechanism for thinking through the challenges that might be encountered and the opportunities that might arise. Scenarios are most useful when there is uncertainty about some of the factors that may significantly shape the future and when a range of outcomes may be plausible (even if some are more plausible than others). Decisions need to be taken today against the backdrop of future uncertainty, and many will play out over times scales during which things may change radically. Thus, scenarios can be a tool to examine blind spots and broaden perspectives: they are less about "betting on a future" and more about stress-testing plans to see – if the world diverged from existing trends – whether decisions made in the near future would remain "fit for purpose". Can our plans be robust to alternative futures? Given how TUNA the current world is looking, scenario thinking is more important than ever before.

A number of scenarios analyses have been published recently for food systems (see compilation at https://www.foresight4food.net/). Whilst scenarios may take a variety of forms, a common approach is to use participatory processes to identify the two most important drivers which will shape the future, but about which there is great uncertainty about what form they will take. A recent report taking this

[31] Ramírez, R., & Wilkinson, A. (2016). *Strategic reframing: The Oxford scenario planning approach*: Oxford University Press

[32] Homer-Dixon, T., Walker, B., Biggs, R., Crépin, A.-S., Folke, C., Lambin, E. F., . . . Troell, M. (2015). Synchronous failure: the emerging causal architecture of global crisis. *Ecology and Society, 20*(3). doi:10.5751/ES-07681-200306

[33] Courtney, H., Kirkland, J., & Viguerie, P. (1997). Strategy under uncertainty. *Harvard business review, 75*(6), 67-79

approach and asking "what will global food systems be like in 2050?" was published by The World Economic Forum in 2017[34].

Summarising the WEF scenarios

The WEF's two key axes were chosen because they are inherently unknown in terms of how they may develop but are very strong determinants of the way local food systems may be shaped.

The two key axes of uncertainty were:

(1) Dietary shifts

Away from food systems with high externalised costs on health and environment, that have focussed on growing calorie-rich but nutrient-poor diets, **to food systems that provide more healthy diets in a sustainable way**. The drivers for such shifts include:

- climate mitigation,
- the costs of malnutrition and associated non-communicable diseases (whether from the perspective of (a) improving personal health, (b) business productivity and economic growth[35], or (c) the social costs of poor public health),
- impacts on health from intensive production (e.g. the rise of anti-microbial resistance from intensive livestock production, urban air quality being impacted by intensive agriculture and volatilization of nitrogenous fertiliser),
- or broader elements of environmental sustainability (e.g. reduction in plastic waste, reduction in land degradation, arresting the loss of biodiversity, reduction in food waste, societal demand for less pesticide use in agriculture).

Other exercises that consider the shift to healthy and/or sustainable diets include Agrimonde[36], the EU JRC's food systems' foresight study[37] and the Shared Socio-economic Pathway 1 for the IPCC[38]. Whilst the term "healthy diets" is not exactly synonymous with "sustainable diets" there is a significant overlap between the two as (a) healthier diets have fewer calories through reduced average consumption, and (b) healthier diets are more based on plant-produced foods, and less reliant on meat, with its high environmental footprint[39]. Hence, given the alignment between diets that are healthy and sustainable, and the costs of diets that are neither, the two are increasingly addressed together.

(2) **Shifts in the momentum for globalised trade towards more regional or local food systems**.

The last five years' geopolitical trends have impacted on the globalisation agenda to the point where "deglobalisation" is being discussed, at least in some quarters. This arises from changes in the last few years that undermine the post-war architecture of international cooperation, in association with the rise of inward-looking and protectionist policies driven by increasing global inequality, including migration. These new trends have made a future of ever more liberal trade look uncertain – as barriers

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[34] World Economic Forum (2017). *Shaping the Future of Global Food Systems: A Scenarios Analysis* Retrieved from Geneva, Switzerland:

[35] https://www.chathamhouse.org/publication/business-case-investment-nutrition-wellesley-et-al

[36] http://institut.inra.fr/en/Objectives/Informing-public-policy/Foresight/All-the-news/Agrimonde-Terra-foresight-study

[37] https://ec.europa.eu/jrc/sites/jrcsh/files/jrc-study-tomorrow-healthly-society.pdf

[38] O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., . . . Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change, 42*, 169-180

[39] Aleksandrowicz, L., Green, R., Joy, E. J. M., Smith, P., & Haines, A. (2016). The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. *Plos One, 11*(11), 16. Nelson, M. E., Hamm, M. W., Hu, F. B., Abrams, S. A., & Griffin, T. S. (2016). Alignment of Healthy Dietary Patterns and Environmental Sustainability: A Systematic Review. *Advances in Nutrition: An International Review Journal, 7*(6), 1005-1025.

are erected distorting markets, and trade disputes escalate in number; with the Trump Administration actively orchestrating the undermining of the WTO.

COVID-19, other forms of disruption from climate change and environmental breakdown, alongside geopolitical instability, can also undermine supply chain resilience, leading to a perceived need for more local sourcing from a local security – or resilience - perspective. Attitudinal change (such as the belief that local food is in some sense "better") might also drive such a change.

The WEF Scenarios exercise is not alone in considering the future of globalisation: the EU JRC's food safety foresight study[40], and its scoping study the EC's Food [41], as well as the IPCC's Shared Socio-economic pathways (e.g. SSP3) all consider more regionalised economies[42]. The US and UK governments publish security-facing "Global Strategic Trends" reports; the most recent editions both utilise scenarios which consider radical change to the international architecture of trade and cooperation[43] as plausible futures. Other reports have highlighted the balance of risks, benefits and costs of trade, including the UK's climate change risk assessment[44] and the EU JRC's 2030 foresight report on food[45].

These two key axes define four plausible alternative futures for food systems, each of which has different implications for what the future food system may be like: what food is grown, where it is grown, how it is grown, and how is it used.

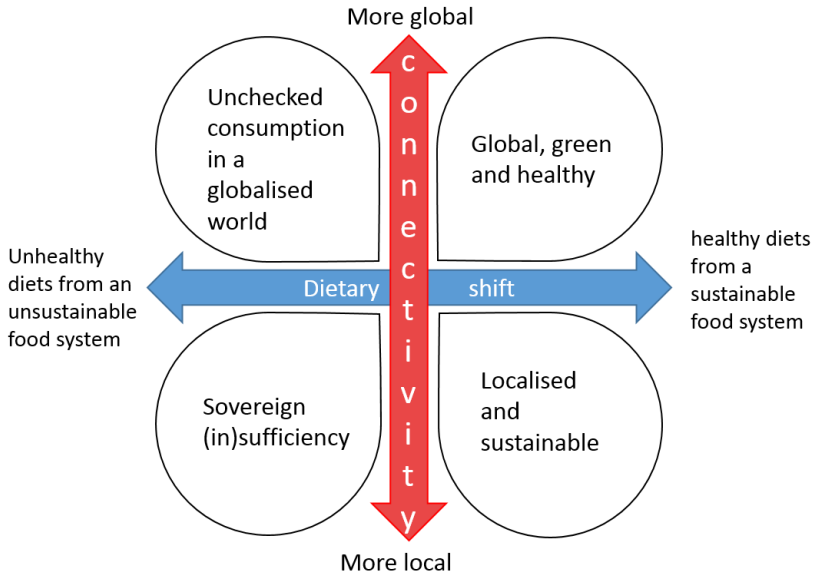

Fig 2 Four plausible alternative futures for food systems, based on axes of global-local connectivity, and degree of dietary shifts.

[40] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/delivering-eu-food-safety-and-nutrition-2050-future-challenges-and-policy-preparedness
[41] https://ec.europa.eu/food/sites/food/files/safety/docs/final_report_scoping_study_en.pdf
[42] O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., . . . Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change, 42*, 169-180
[43] *Global Trends: Paradox of Progress*. Retrieved from https://www.dni.gov/files/documents/nic/GT-Full-Report.pdf; (2018). *Global Strategic Trends: The Future Starts Today*. Retrieved from London: https://www.gov.uk/government/publications/global-strategic-trends
[44] Challinor, A., et al. (2016). UK Climate Change Risk Assessment Evidence Report: Chapter 7, International Dimensions.
[45] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC94867/lbna27252enn.pdf

Scenario 1: Unchecked consumption in a globalised world

This is the "business as usual future". More people on the planet, demanding more processed food largely based on a small handful of globally traded commodity crops, and more livestock consumption made possible from intensive feed production. The downward pressure on prices, within this scenario's conventional business model, causes a concentration in few crops grown at scale in breadbasket regions, global homogenisation of diets and makes it economically rational to waste food and over-consume calorie-dense products. This drives obesity and ill-health. In a world where meeting demand is the primary driver, "sustainable intensification" is the mantra, and long supply-chains the norm. Given intensive and efficient farming at large scales, and few crops, and demand growth, overall emissions increase, driving climate change. This impacts on yields in many places, and, at the same time, increases land competition – as more land is required for negative emissions technologies (such as afforestation) to mitigate climate change. So ever greater yields are sought from the same area of cropland, with high-tech, super-intensive cropping systems, intensive livestock production (with lots of concentrated feed). To intensify, and to build climate resilience, requires the broad adoption of biotechnology as well. Smallholder agriculture is increasingly amalgamated into larger land areas to provide yields and allow interconnection to global markets.

Scenario 2: Sovereign (in)sufficiency

This is a world where nations look more locally or even inwards. Sovereign states have "taken back control" from global markets and regained the "sovereignty" they sacrificed to the "the single worst trade deal" ever negotiated[46], brokered within the international architecture of cooperation (the UN, WTO and other bodies), as well as multinational corporations. The ingrained notion that food should be cheaper forms the dividend for protectionist policies, and the lack of political or social desire for a "nanny state" telling people what to eat, shapes the way the system works. With a greater need for self-sufficiency, and a loss of the agricultural efficiency that comes from comparative advantage and global trade networks, there is no scope for meeting demand from dietary breadth – so countries base diets on the handful of commodity crops which they can specialise in. These restricted crops are processed into food that can be consumed with pleasure, without regard to nutrition. Agriculture is super-intensive, but with little international cooperation, there is no drive for land-based mitigation so the agricultural footprint expands, and farming becomes more intensive, more extensive and drives more climate change. Nation states that differ in their endowments (land, water, soils, climate) and needs (population) become increasingly unequal. Endowment-poor, but highly populated, countries increasingly project power and grab land; endowment-poor nations with low population size struggle, and human migration increases. Both these undermine the national security of endowment-rich countries.

Scenario 3: Global, green and healthy

This is a world where globalised cooperation works, and supply chains are long (and climate agreements are cooperatively ratcheted-up). Commodity-crop agriculture remains the predominant mode of agriculture at scale, with nutrition added through biofortification during the processing that adds other pleasurable attributes technologically, but with fewer calories than the added sugar and fats in the scenarios above. Governments promote preventative health care, so people eat less and this reduces land-use pressure, and because climate mitigation happens more aggressively there are fewer climate impacts and less need for the extensive deployment of land-based negative emissions technologies, further easing the pressure on land. Intensification is important as land remains limited, but not to the extent of the scenarios above, because government incentivises lower waste (partly through shifting subsidies making food pricier, partly through waste taxes and food-carbon taxes). The shifting subsidies,

[46] Donald Trump, May 22nd, 2018 https://www.cfr.org/blog/trumps-china-deal-worst-ever

and changing social norms, result in small-scale but intensive horticulture (including lots of urban and vertical farming) for high-value, nutritious crops, grown in the urban environment and peri-urban fringe. Large scale horticulture is increasingly adopted by technologically advanced, arid, states – where pest pressure is low and there are technological solutions to provide water (desalination, "smart" irrigation).

Scenario 4: Localised and sustainable

This final scenario presents more of a world of circular food systems, diversified to provide healthy diets in more isolated regional food systems. Agriculture is more locally diverse, with more complex rotations, with mixed farming for nutrient cycling (including waste streams for local livestock and aquaculture). Because this system is more localised, the advantages of global competition maximising comparative advantage mean that the food system has to have efficiency built-in, rather than a focus on increasing only agricultural efficiency. Agriculture policy is driven by nutritional needs not economic growth considerations. Health costs are avoided, through emphasis on "preventative health care", and, along with circularity, agriculture is more diversified and landscapes more heterogeneous. Food prices reflect the resources required to grow them, so environmental externalities are internalised. Because agriculture is more diverse, but food is less abundant, the value added by processing is relatively expensive, so people increasingly shift towards home preparation of food. The increased efficiency of the food system (people fed healthily per hectare) reduces food system emissions, globally mitigating climate risks. As with Scenario 2, more localised systems will exacerbate between-country inequality, which may lead to aggressive land-grabbing, or mergers or alignments of countries into larger local blocks (creating regionalised food systems, e.g. further EU integration). Additionally, food systems reflect more local climates/soil/water conditions, creating both greater seasonality of diets, and local specificity built on locally-adapted produce.

Whilst we have focussed on one scenario exercise among many – and at a global level - it is instructive to note that a recent set of scenarios were constructed with stakeholders in countries in Southern and Eastern Africa. The "axes of uncertainty" – the ones that frame the 2x2 matrix of scenarios – were different in each country, but the list of axes discussed overlapped greatly. Axes are selected based on the criteria that they are the two most important drivers, but difficult to predict what values they will take. In each country, climate risk was selected as one of the two axes, and one other axis was selected. In sum the list was:

- Climate risks (disruptions to agriculture, trade and economies) (small to large)
- Land tenure and reform (little versus radical) (South Africa);
- Technology innovation and adoption (weak versus strong) (Tanzania)
- Market access and functioning from local to global (weak versus strong) (Zambia)
- Policy alignment across agriculture, nutrition, environment trade and infrastructure ministries to deliver food systems outcomes vs policy incoherence arising from policy silos (e.g. export-driven agriculture policy that undermines food security)(Malawi)

5. Utilising the scenarios for stress-testing decisions

Discussed above are two conceptual frames. First: the world is increasingly TUNA: turbulent, ambiguous, novel and ambiguous. Mega-trends that have shaped the world as we know it today are changing (e.g. economic and political power shifting from West to East, the multilateral cooperative world driving increasing globalisation coming under strain from competition between states and inequality). In addition, the growing fragility of the globalised world means disruptions are becoming more common: COVID-19, agricultural pests and diseases, climate shocks, people movement and so on. This frame suggests the world of the future is less likely to be a predictable extrapolation of the past, as it might have been considered a decade or two ago.

The second frame is that of the existence of a range of plausible futures; which might be shaped by new drivers that are likely to be important but are not currently predictable: changes in diets, changes in the 'polarity' of the world (e.g. the rise of China as a dominant power, or a more multipolar world with emerging powers vying for influence), climate risks, deglobalisation and access to markets and technology, structural changes around the access to and tenure of land, and more sophisticated policy frameworks tackling challenges systemically. Such a range of alternative, plausible, futures suggests a range of key questions for decision makers, which are discussed below.

If business as usual is unlikely: what will the future look like?

Given that the emerging drivers of the global and regional economies differ from the past, and yet the future is increasingly uncertain, how is it best to think about designing today's policies? Decisions made today, based on looking backwards, may become less fit for purpose as the future diverges from the past. Whilst scenarios are not a means of predicting the future, the challenge of thinking about alternative futures, is a route to challenging simple extrapolation of the past that may not be fit for purpose.

If "black swan" events are likely to happen, will that shift us towards a different future?

Today's economies often seem impossible to change, because there is so much invested personal, political and financial capital in today's way of running things (as well as planning for the future). Lower income countries are invested in replicating pathways to development that have allowed higher-income countries to achieve their economic success. However, as COVID-19 has shown, "business as usual" thinking about development can be undermined by events. Whilst disruptions can be painful, they also change the degree that the system is locked-in to its current trajectory. In some circumstances, such events can drive structural change sufficient to change the direction of travel. Recognition that such events occur, and will occur more frequently, reduces the degree that decision makers are locked-in, or constrained, towards believing the future is a simple linear development of the past.

Will today's decisions play out well if the future changes?

For example, what happens if today's policies are geared around increasing access to international markets if the world is entering a phase of "deglobalisation"? Scenario exercises help imagine different futures to ensure that today's decisions do not lock the system into a pathway that is increasingly difficult to achieve. They therefore help develop robust, future-proofing, of decisions given the uncertainty of the future.

Conclusions

To address how best to develop a strategy for conservation of plant genetic resources for agriculture and food systems into the distant future requires making assumptions – implicitly or explicitly – about what the role of genebanks will be. This in turn requires some in-depth analysis of the plausible futures for how food systems, economic development and societal values and functioning will evolve, to ensure robust decision making and to avoid planning on future developments that are not fit for purpose if the world changes. Will the world encourage much greater diversity of crops, fruits and vegetables, or will it focus on fewer and fewer commodities, which are engineered using de novo techniques (synthetic biology) or from gene transfer from other organisms? Will the world be unipolar (China?), multipolar (East vs West, North vs South) or a competitive hegemony, and how will that effect the movement of crop diversity across borders? Will trade be increasingly driven by profit, or will resilience and self-sufficiency in order to maximise security reduce the importance of long supply chains? If the world is stable and global, a centralised model may work better than regionalised networks of banks and vice versa.