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## PERSPECTIVE

# Learning from the future: mainstreaming disruptive solutions for the transition to sustainable food systems

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## 1. The edge of our known solution space

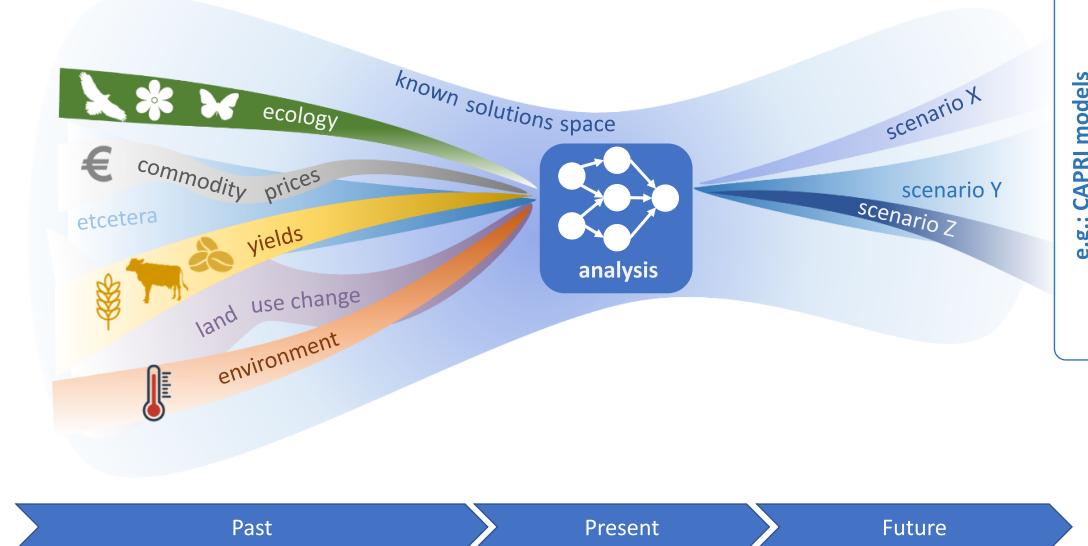
Keeping the food system within environmental limits (Springmann *et al* 2018), specifically reversing the food system-driven transgression of the planetary boundaries of land, water, biodiversity, nutrient loading, and climate change (Rockström *et al* 2020), requires novel approaches for envisaging and realizing radically progressive yet attainable futures. Scenario building, supported by quantitative models or qualitative scenario narratives, is useful to explore the tangible consequences of different courses of action in a pragmatic and useful way for food and climate policy, as exemplified by the CAPRI (Common Agricultural Policy Regionalised Impact) models (European Commission 2011) and explorations of future land use in the face of climate change (e.g. Gomes *et al* 2020). However, model-based scenarios are typically built, parameterized and calibrated using a limited number of drivers of change (e.g. population growth, commodity prices) (Raudsepp-Hearne *et al* 2020) and known relationships between those drivers (e.g. the trade-offs and synergies between the delivery of commodities and public goods) (Verburg *et al* 2008, De Vries *et al* 2013, O'Neill *et al* 2014, Gomes *et al* 2020) (figure 1). Elements of the global food system that are either more distal or inherently more difficult to model quantitatively (e.g. different forms of governance) are commonly considered out of scope or are assumed, explicitly or implicitly, to be constant. Such scenario analyses are therefore confined to new permutations and combinations of drivers and interventions within the *terra cognita* of the known solution space and as such cannot account for disruptive solutions that defy known relationships between model variables.

This leads us to one of the scientific paradoxes of our times: the contemporary and influential scenario analyses that call for new paradigms for the global food system are themselves locked into a past solution space. The implications of this stretch well beyond the academic domain, as demonstrated by the European Commission's recent critique of its own CAPRI model, lamenting its inability to explore the full impact of the new EU Farm-to-Fork policy proposals (European Commission 2021). There is clearly a need for complementary approaches that can expand the search horizon of our future solution space beyond already well-explored drivers. In this perspective paper, we put forward one such complementary approach, which we provocatively refer to as 'learning from the future': the assessment of operational farming systems and food systems that are early successful exemplars of sustainable futures that transcend the horizons of the currently known solution space (figure 2). By illuminating nascent methodologies that support the imagining, anticipating, and planning of desired equitable, resilient, and sustainable futures that explicitly include disruptive, hitherto unexplored solutions, we seek to enrich and contribute to the ongoing scientific discourse on food system transformations.

## 2. Learning from the past and learning from the future

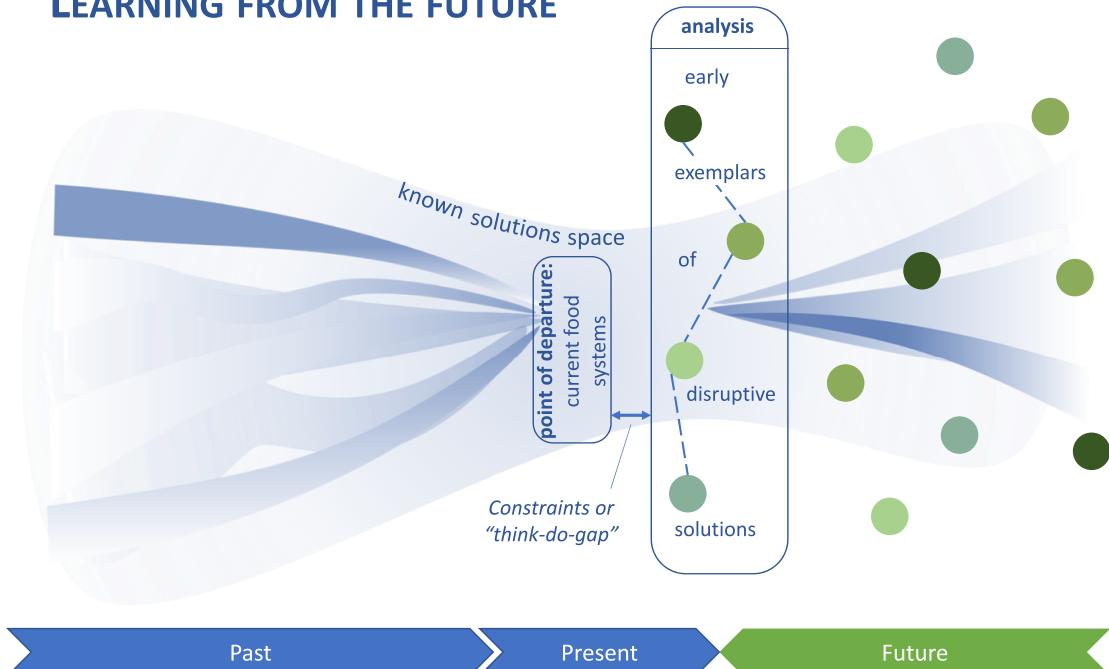
The identification of early exemplars of disruptive solutions complements current scenario modelling (based on 'learning from the past') by allowing us to disentangle and understand the reconfigured relationships between the agronomic, environmental, economic and entrepreneurial variables of these

## LEARNING FROM THE PAST



**Figure 1.** Learning from the past: scenario modelling commonly relies on relationships between drivers (five examples included for illustration: ecological and environmental drivers, commodity prices, yields, land use change dynamics) that have been observed in past and present food systems, to project realistic future scenarios (three examples included for illustration: scenarios X, Y, Z).

## LEARNING FROM THE FUTURE



**Figure 2.** Learning from the future: understanding and mainstreaming early exemplars of disruptive solutions. The circles represent early exemplars of disruptive solutions, projected against the background of the known solution space and scenarios of figure 1; some of the disruptive solutions lie outside the horizons of the currently known solution space of most scenario models. In this approach, the analysis (vertical box) focusses on the elucidation of the reconfigured relationships (dotted lines) between variables, shared in common by the early exemplars of disruptive solutions.

existing exemplars. In general, disruptive exemplars are farming and food systems that have reconfigured, and as such redefine, our understanding and management of at least one or more dimensions of sustainability, pertaining to natural resources,

ecological processes, biodiversity conservation, economics, equity or social justice. The characterization of disruptiveness does not require us to wait for the outcomes of retrospective analyses: exemplars can be identified as disruptive by virtue of the path

**Table 1.** Generalized characteristics of the approaches 'Learning from the past' and 'Learning from the future'.

	Learning from the past	Learning from the future
Solution space	Wide, but typically limited to new permutations of relationships observed in the past.	Unbounded and largely unstructured, includes both known and unknown solution spaces.
Common objectives	Supporting evidence-based decision making in complex managerial environments.	Elucidation and proof-of-concept of novel drivers and disruptive solutions to complex challenges.
Main applications	Typically forecasting: facilitates the specification on most likely scenarios and what-if analyses.	Typically includes backcasting: facilitates identification of systemic lock-ins and barriers to change within current farming/food systems.
Associated transition pathways	Typically continuous improvements added to current farming/food systems. Support systems for transition are commonly in place already.	Typically discontinuous redesign of (part of) farming/food systems. Transitions require bridging of multiple think-do-gaps.
Application domains	Known challenges: harnessing insights gained in the context of past knowledge environment (known solution space).	Unknown/emerging challenges: harnessing insights gained in challenging contexts where existing knowledge systems did not suffice.
Replicability/predictability	High: commonly based on substantial databases/numerous studies.	Low: commonly based on singular or few examples.
Audience	Farmers, policy makers, industry, scientists, society.	Farmers, policy makers, industry, scientists, society.

they follow in creating radically different operating models from the status quo (Christensen *et al* 2015). The extent to which a disruptive exemplar leads to scaling and widespread adoption is difficult to predict; this in itself is not a precondition for being disruptive. As such, the analysis of disruptive exemplars serves a wider purpose that goes beyond a mere retrospective exercise with limited relevance for understanding current and emerging societal dynamics (Hopster 2021).

One such exemplar is the agroecological symbiosis piloted in Finland, in which the generation of on-farm bioenergy from green manure is combined with precision fertilization, resulting in a concomitant increase in the production area of cash crops for human consumption (Koppelmäki *et al* 2019). As such, this novel production system has overcome the food-fuel competition for land that is implicitly assumed in, *inter alia*, the CAPRI scenario analyses by the European Commission that informed European biofuel policies (Blanco *et al* 2013). It has allowed for the generation of new models for food-fuel integration at farm scale (Koppelmäki *et al* 2019), regional scale (Koppelmäki *et al* 2021a) and up to national and international scales (Koppelmäki *et al* 2021b). The resulting scenarios for the cycling of biomass, nutrients and energy are complementary to existing scenarios (such as the CAPRI analyses) and serve to widen the search area for future farming systems beyond the horizons of the current solution space (Schulte *et al* 2021), as we have visualized in figure 2.

By reconstructing how these disruptive exemplars emerged over time, we may identify transition pathways towards alternative futures that lie outside the

currently known solutions space. This allows us to examine and delineate the financial, technical, knowledge and cultural gaps that must be bridged for scaling disruptive solutions. Collectively, these gaps have been referred to as the gap between scientific knowledge ('thinking solutions') and implementation ('doing solutions'), or 'think-do-gap' (O'Sullivan *et al* 2018). The explicit analysis of think-do-gaps facilitates the discovery of novel sets of drivers of the future (e.g. cultural diversity, trust, gender relations) that have thus far eluded past experiences and trends (Raudsepp-Hearne *et al* 2020). By building new ways of thinking about the future that also draw from imagination and creativity, this approach broadens the gamut of possible pathways and people's agency to shape desired futures (Wyborn *et al* 2020).

Since disruptive exemplars offer novel suggestions of ways forward, they may introduce trade-offs with other benefits or lead to other unforeseen problems as disruptive exemplars grow in scale or inspire disruptions in novel environments. For example, we find that many of the disruptive farming systems are associated with complex managerial and knowledge requirements. This demand for significant inputs of knowledge and labour creates a barrier (or think-do-gap) for immediate widespread adoption (e.g. Koppelmäki *et al* 2021a). The unintended outcomes of scaling disruptive solutions may be negated through an iterative application of the two approaches: the study of disruptive exemplars can invoke the formulation of new models, which may subsequently be used to explore plausible scaling scenarios within the new, and expanded, solution space. In table 1, we elaborate on the complementarity of the two approaches.

**Table 2.** Three initiatives illustrate their approach to learning from the future, including how disruptive exemplars are identified and societal transformation achieved via scaling up, scaling out, and scaling deep.

Initiative	Disruptive exemplars	Identification of disruptive exemplars	Approach to 'learning from the future'	Societal transformation
Global Network of Lighthouse Farms	Lighthouse farms/farming communities	Expert assessment and local stakeholder validation for identification of exemplars that offer radical new interpretation of at least one dimension of sustainability.	Analysis of common ingredients of success (e.g. food-fuel integration across scales, Koppelmäki <i>et al</i> 2019, 2021a, 2021b). Influencing policy-making and major funding schemes (e.g. Veerman <i>et al</i> 2020).	Scaling up
Agroecological Lighthouses	Agroecological lighthouses	Farms that outperform other farms in a region based on indicators such as soil quality and crop health.	Farm demonstration modules; farmers' knowledge exchange (e.g. Nicholls <i>et al</i> 2004, McGreevy <i>et al</i> 2021)	Scaling out
Seeds of Good Anthropocenes	Bright spots	Landscapes and communities that perform much better than expected (e.g. statistical deviation from mean).	Elucidate possible management and policy strategies that allowed bright spots to emerge (e.g. de Vries 2005, Frei <i>et al</i> 2018)	Scaling deep
	Seeds	International participatory process to identify social-ecological bright spots that could benefit both environmental conditions and human well-being.	Participatory scenario exercises (e.g. Sharpe <i>et al</i> 2016, Pereira <i>et al</i> 2018, Falardeau <i>et al</i> 2019, Raudsepp-Hearne <i>et al</i> 2020)	

### 3. Glimpses of sustainable futures

Three initiatives—the Global Network of Lighthouse Farms, Agroecological Lighthouses, and Seeds of Good Anthropocenes—illustrate how 'learning from the future' can be applied and scaled to support societal transformation via different pathways: by changing institutions, rules and policies (scaling up); supporting replication of disruptive exemplars (scaling out); and changing narratives, values and ideas (scaling deep) (table 2; Moore *et al* 2015). These initiatives have developed independently and bring together disruptive exemplars known to the authors.

Other recent examples of disruptive agronomic innovations include strip-cropping, which overcomes the trade-offs between crop diversity and crop yields (Ditzler *et al* 2021), or technology-driven innovations such as the use of LED lights to control both crop physiology and pest behaviour (Lazzarin *et al* 2021), vertical farming, algae production, entomophagy and plant-based meats (see e.g. Smith 2013, Semov and Sweet 2021 for early and contemporary exemplars, respectively, of the societal discourse on the need for, and scaling of, disruptive solutions).

#### 3.1. Scaling up

The Global Network of Lighthouse Farms ([www.lighthousefarmnetwork.com](http://www.lighthousefarmnetwork.com)) serves as a global outdoor laboratory on future farming systems by

bringing together existing 'successful exemplars of disruptively innovative farming systems (i.e. lighthouse farms) that are proving to be economically, environmentally and socially sustainable and as such already rising to the multiple challenges of a shared future that is food secure, nutritious, sustainable and resilient.' Each of these lighthouse farms has already uniquely redefined at least one dimension of sustainability. While individual lighthouse farms may be continuously evolving and as of yet be imperfect, as a network they have unveiled the diversity of context-specific solutions available, which allows for the study of the common ingredients that these reconfigured systems share. The Global Network of Lighthouse Farms is scaling up the redesign of future farming systems by influencing policy-making and major funding schemes. For example, 'lighthouse farms' feature strongly in the recommendations of the European Commission's Mission Board on Soil Health and Food, which was created to co-inform the formulation of Horizon Europe, the 7 year Research Funding Programme of the European Union with a budget of 94.4 billion euro. The Mission seeks to go beyond 'the traditional linear vision of research' by setting up networks of 'lighthouses' to showcase farms that are 'exemplary in terms of providing sustainably produced, healthy food, feed or fibre as well as ecosystem services linking rural and urban communities' (Veerman *et al* 2020).

### 3.2. Scaling out

The second example, Agroecological Lighthouses, exemplifies ‘learning from the future’ by using similarly existing disruptive exemplars to illuminate pathways for amplifying agroecological transformation from the farm to the territorial scale (Nicholls and Altieri 2018, McGreevy *et al* 2021). Agroecological lighthouses have already overcome the multiple challenges of translating agroecological principles into practical strategies for soil, water, and biodiversity management to enhance production and resilience (see Wezel *et al* 2009 for a review of the use of the term agroecology in science and practice). These agroecological farms outperform other farms based on indicators such as soil quality and crop health (Nicholls *et al* 2004). As a network, Agroecological Lighthouses have allowed for the discovery of key ingredients that take agroecology to scale (Mier y Terán Giménez Cacho *et al* 2018). For example, farmer-to-farmer knowledge transfers have proven to be an effective avenue to scale out to the broader rural communities and have indeed resulted in the reconfiguration of entire territories (McGreevy *et al* 2021).

### 3.3. Scaling deep

The third initiative, Seeds of Good Anthropocenes (<https://goodanthropocenes.net>), focusses on effecting change by building radically novel narratives of desirable futures based on existing bright spots and ‘seeds’. Bright spots are places that are performing substantially better than the norm (de Vries 2005, Frei *et al* 2018), while seeds may be social initiatives, new technologies, economic tools, or social-ecological projects that appear to be contributing to the creation of a future that is just, prosperous, and sustainable. Seeds are drawn from a diversity of practices, worldviews, values and regions that can accelerate transformative change beyond incremental improvements (Bennett *et al* 2016). A key way in which Seeds of Good Anthropocenes incentivize systems change is by changing narratives, beliefs, and ideas—a form of scaling deep (Moore *et al* 2015).

## 4. Conclusion

Within the context of the ongoing scientific and societal debate on the need to transform the global food system, ‘Learning from the future’ provides a novel complementary approach for thinking radically different yet realistically about the future. Identifying and studying disruptive exemplars (e.g. lighthouse farms and seeds) offers a viable approach for investigating how our world could intentionally follow transformative pathways, within a context of biotic, abiotic and economic shocks. While scenarios are useful in examining contrasts among alternative sets of assumptions about how the world changes through time, they are often based on highly

simplified worldviews dominated by just a few driving forces (Bennett *et al* 2016). Extrapolating current trends into the future runs the risk of resulting in scenarios that are very similar to the status quo. Learning from future successes complements this approach by considering disruptive systems into radically different future scenarios. Disruptive exemplars provide the research and extension infrastructure to facilitate the mainstreaming of disruptive solutions, while also showing inspirational visions and illuminating multiple pathways to achieve a series of desirable futures.

## Data availability statement

No new data were created or analysed in this study.

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