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Future agricultures: The promise and pitfalls of a (re)turn to nature

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Abstract

This paper introduces the *Outlook on Agriculture* Special Issue on biomimicry and nature-based solutions. It provides a selective overview that will help frame and situate the collection, with a particular focus on agriculture and food production. The relationship between agriculture and nature is a central concern, and particularly how this relationship is framed by those promoting the idea that to overcome the multiple challenges it faces, agriculture must (re)turn to nature. The significance of different understandings of 'nature-based solutions', and the relative importance of biomimicry, are explored.

Keywords

Regenerative agriculture, sustainable intensification, biomimicry, nature-based solutions

Introduction

It is frequently asserted that agriculture across the globe is in crisis. Indeed, current narratives suggest that agriculture is confronted by multiple 'grand challenges', including soil degradation and declining soil health, biodiversity loss, water pollution, loss of eco-system services, climate change, and an imperative to drastically reduce greenhouse gas emissions. More broadly, rising demand for food, increasing food insecurity, declining food quality and relentless pressure on small-scale producers and rural livelihoods have all being tied to a 'broken food system'.

Proposed responses sit along a continuum from the incremental to the transformational, but can be broadly characterized as coalescing into two stylised groups. The first looks to more and better science and technology to improve existing systems. Framed under the broad heading of 'sustainable intensification' (Tilman et al., 2011; Pretty et al., 2011; Cassman and Grassini, 2020), the general assumption is that closing yield gaps through modernization and increased efficiency must be a core focus (for alternative views on sustainable intensification see e.g. Kuyper and Struik, 2014; Mahon et al., 2017; Struik and Kuyper, 2017). In addition to good agronomy, progress is sought through digital technology, precision farming, new models of genetic manipulation, robots, and ration-based control of livestock GHG emissions.

The second reflects a view that the future can only be assured by a more radical shift to 'alternative' agricultures involving technical, social and economic change. Underpinned by the science of ecology and systems thinking, and generally oriented to strengthening smaller scale producers and local food networks, proposals include organic farming (Muller et al., 2017), agroecology (Altieri, 1995), permaculture (Suh, 2014), climate-smart agriculture (Lipper et al., 2014), food sovereignty (Wittman, 2011) and others. In recent years efforts to develop and promote alternative agricultures have begun to coalesce around the language of 'agroecological principles' (HLPE, 2019) 'regeneration' and 'regenerative agriculture' (Sherwood and Uphoff, 2000; Al-Kaisi and Lal, 2021; cf. Giller et al., 2021). Reflecting their roots in an ecological perspective, many of these alternatives are framed explicitly or implicitly as a '(re)turn to nature'. While this is particularly the case with 'natural farming' (Fukuoka, 1978), 'natural systems agriculture' (Jackson, 2002), permaculture (Mollison and Holmgren, 1978) and agroforestry (Plieninger et al., 2020), it was also evident from the early days of the organic farming movement (Howard, 1943). In addition to looking to nature for inspiration and better ways to farm, at least for some proponents, the (re)turn to nature also has an important philosophical dimension, as it suggests a resetting of the relationship between humans and nature (on the 'relational' values of nature see Klain et al., 2017; Stålhammar and Thorén, 2019).

It is important to note that at least since the Renaissance period, as the idea of human-nature dualism became central to Western philosophy, there have been consecutive waves of interest in returning to nature (Dallmayr, 2011). The current wave, with its focus on learning from nature, goes

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way beyond agriculture (e.g. O'Hogain and Mccarton, 2019; Brears, 2020; Perez and Perini, 2018). From urban design and management, through climate change mitigation, there is now a large, cross-disciplinary literature built around a host of related terms and concepts. These include natural solutions, biomimicry, nature-inspired design, nature-positive agriculture, working with nature, bio-informed design, bioinspiration, ecosystem-based approaches, green infrastructure, and ecological engineering. Given that there are different understandings of nature, it should not be surprising that there is little agreement as to the precise meanings of many of these, and as we will see, this is also the case for what is perhaps the most widely used term, viz. 'nature-based solutions.'

Nature-based solutions, natural farming, natural systems agriculture and biomimicry are most commonly used to reflect the (re)turn to nature in agriculture, food production and land management. The suggestion is that nature provides a kind of treasure trove of forgotten or yet to be discovered tools, ideas, models and lessons that can, and indeed must, be the basis of more sustainable future agricultures. The central idea is that agriculture must shift so that it is working 'with' not 'against' nature, while agricultural science must be more open to learning from nature.

There have been a number of recent reviews of nature-based solutions and biomimicry that to one degree or another touch on agriculture and food production (Seddon et al., 2020; Miralles-Wilhelm, 2021; Miralles-Wilhelm and Iseman, 2021), and Potschin-Young et al. (2016) provide useful background. Several special issues and conferences have also focused on natural systems agriculture and nature-based solutions for agriculture.[1] Some key individual papers include Ewel (1999); van Noordwijk and Ong (1999), Malézieux (2012); Denison and McGuire (2015) and Stojanovic (2019).

The special issue of *Outlook on Agriculture*, which this paper introduces, contributes to this literature by adding a multi-disciplinary and critical perspective. The aim of this introduction is to provide a selective overview that will help frame and situate the other 12 papers in the collection. What it does not attempt is a general review of the literature on the use of biomimicry or nature-based solutions in agriculture. The focus throughout the collection is on the (re) turn to nature in agricultural production, and particularly food production, as opposed the use of nature-based solutions for natural resource management more broadly, ecosystem services or climate change mitigation.

The paper proceeds as follows. The next section highlights three individuals – Albert Howard, Masanobu Fukuoka and Wes Jackson – who played important parts in initiating the current interest in agriculture's (re)turn to nature. Their views on humans' relationships with nature, and what could be gained through a (re)turn to nature are of particular interest. Following this, the relationship between nature and agriculture is briefly explored via the question 'What is natural about agriculture, or nature?'. Here the role of personal and perhaps idiosyncratic 'reference natures', and contested views of the structure, function and dynamics of natural systems, are highlighted. The next section identifies the ways that the term 'nature-based solutions' is used in relation to agriculture, and the relative emphasis put on biomimicry. Critically, when biomimicry is downplayed, there is considerable overlap between what are identified as nature-based solutions and what are well-established farming techniques. This apparent re-branding raises important questions. In contrast, including biomimicry in the understanding of nature-based, highlights a potentially wider set of solutions. The last section introduces the papers in the collection, a number of which tackle the biomimicry element of agriculturally-oriented, nature-based solutions.

A long march back to nature?

The idea that agriculture – and society more generally – would have much to gain by looking to and learning from nature has been a minor but persistent theme since at least the early decades of the 20th century (see e.g. Vogt, 2007). For example, Sir Albert Howard, a pioneer of organic farming, looked to the 'primitive forest' to discern the characteristics of 'nature's farming':

> 'The main characteristic of Nature's farming can therefore be summed up in a few words. Mother earth never attempts to farm without live stock; she always raises mixed crops; great pains are taken to preserve the soil and to prevent erosion; the mixed vegetable and animal wastes are converted into humus; there is no waste; the processes of growth and the processes of decay balance one another; ample provision is made to maintain large reserves of fertility; the greatest care is taken to store the rainfall; both plants and animals are left to protect themselves against disease.' (Howard, 1943: 14)

Based on his observations of 'man-made systems of agriculture' in Asia, Howard concluded that only 'balanced' agriculture, based on nature's ways, can stand the test of time. Howard's message could be no more clearly stated than in his introduction to the 1945 edition of Charles Darwin's *The Formation of Vegetable Mould*, in which he writes: 'Nature is the supreme farmer and gardener, and that the study of her ways will provide us with the one thing we need – sound and reliable direction'.

While Howard praised the balanced agriculture that he saw in 'the East', Masanobu Fukuoka also looked to nature to dramatically transform his own farm in Japan, and agriculture globally. His vision of 'natural farming' as articulated in '*The One Straw Revolution*' (Fukuoka, 1978), which has become a classic in the alternative agriculture corpus, is rooted in his observation that 'nature, left alone, is in perfect balance' (p.43). For Fukuoka, natural farming is based on four principles which 'comply with the natural order and lead to the replenishment of nature's richness' (p.47): no cultivation (ploughing or turning of the soil), no chemical fertilizer or prepared compost, no weeding by tillage or herbicide, and no dependence on chemicals. While these principles are sacrosanct, he acknowledged that 'natural farming takes a distinctive form in

accordance with the unique conditions of the area in which is it applied' (p.51).

Fukuoka is at pains to distinguish the 'broad, Mahayana natural farming' (or 'transcendent' natural farming), which he lived and practiced, from what he termed 'narrow natural farming'. While the former 'arises of itself when a unity exists between man and nature [and] it conforms to nature as it [nature] is' (p.102), narrow natural farming, pursues 'the way of nature; it self-consciously *attempts* [emphasis in the original], by "organic" or other methods, to follow nature. Farming is used for achieving a given objective' (p.102).

Wes Jackson was another early champion of a (re)turn to nature. Framing the problem in terms of a 'split' between the ways that nature (polyculture of perennial crops) and man (monoculture of annual crops) 'cover the earth with vegetation', he argues 'it is the human agricultural system that had better grow toward the ways of nature' (Jackson, 1978: 6). For Jackson, this split emerged some 10,000 years ago, when humans embraced 'enterprise in food production [i.e. annual grain crops]' (p.11). In Jackson's view, serious soil loss makes it easy to argue that 'the way of nature is inherently better than the way of agricultural man in the developed world' (p.7).

> 'If we are serious about negotiating with nature while there is still time to heal its split with humanity, are we not being asked to put vegetation back on the ground and promise that we do not plow except for the occasional replanting? If that is nature's demand from the corn belt to the Rockies, will it require that we develop an agriculture based on the polyculture of herbaceous perennials which will yield us seeds not too unlike our cereals or legumes…' (p.8)

Jackson and his colleagues at the Land Institute looked to nature as their teacher (Jackson, 1978: 115), and he later suggested that 'a primary feature of NSA [natural systems agriculture] is to sufficiently mimic the natural structure to be granted the function of its components' (Jackson, 2002: 111).

Finally, it is worth noting that while the idea of natural farming is not central to the agroecology movement, Altieri (2002) acknowledges the importance of mimicking local ecosystems: 'At the heart of the agroecology strategy is the idea that an agroecosystem should mimic the functioning of local ecosystems thus exhibiting tight nutrient cycling, complex structure and enhanced biodiversity' (p.8). The critical but unexamined assumption here is that all local ecosystems exhibit tight nutrient cycling, complex structure and enhanced biodiversity (see e.g. Lenné and Wood, this volume).

What is natural about agriculture, or indeed nature?

Agriculture and farming are generally understood as uniquely human endeavours, that might be conceived as an intricate dance that involves 'piggy-backing' on natural processes on one hand, and 'intervening' to manipulate and modify them on the other.[2] In this sense, all forms of agriculture 'work with nature', and the affordances of local nature; just as all forms of agriculture are 'unnatural'.[3] The rhythm and tempo of this dance shifts over time in response to population growth, environmental change, technology and markets, as reflected in the different ways that farming is described – e.g. as tending, husbanding, managing, producing and exploiting. In contrast, notions like 'natural agriculture' and 'nature's farming' suggest that nature undertakes farming in the absence of human intervention, and thus provides a yardstick against which the naturalness of (human) agriculture systems and techniques can be judged.

At one level, these different views reflect long-running philosophical, ethical and religious debates about the relationship between humans and nature. These debates have been explored endlessly in other places, and will not be elaborated on here (for a discussion of why humans look to nature for norms of behaviour see Daston, 2019). At another level, they highlight assumptions about nature that are hard-wired into much of the discussion of more natural forms of agriculture. For example, that:

- Perennial plants are more natural than annuals.
- More diverse plant communities are more natural than less diverse communities.
- Tight nutrient cycling is more natural than open nutrient flows.
- Systems at equilibrium are more natural than systems in flux.

It would be reasonable to expect that assumptions like these reflect first, individuals' understandings of the 'laws' of nature or overarching ecological principles, and second, the particularities of the real or imagined 'reference natures' – humid tropical forest, Andean highlands, North American prairies and so on – that are foregrounded in the mind's eye of promoters of particular forms of natural agriculture.

The problem is that these assumptions ignore the fact that our understanding of nature remains partial, while available evidence around e.g. history, structure, function and dynamics can be hotly contested. Further, the reference natures that frame much of the discussion of agriculture's (re)turn to nature are large and diverse constructs, of which, we must suspect, any individual's point of reference reflects a relatively narrow slice (in Masanobu Fukuoka's case, his farm). Finally, they tend toward a 'rosy-eyed view' of nature that ignores the roles of floods, fire and drought, and the importance of dynamic succession. All of this suggests that assumptions like those listed above must be approached with great caution.

More prosaic perhaps, but equally important, are assumptions and claims about the unnaturalness of particular practices like soil cultivation. If ploughing is unnatural, does it then follow that cultivation:

- With a dibble stick is more natural than with a hand hoe?

- With a hand hoe is more natural than with a tractor-drawn implement?
- With a ripper is more natural than with a mouldboard plough?

It is worth noting the similarities with long-running debates around the naming, marketing and regulation of 'natural' foods (Lorient, 2016; Sainclivier, 1977; Boström and Klintman, 2003; Goodman, 2017). In the US, the use of the adjective natural to describe food products is not regulated by the government, and as a result, natural is largely a marketing device. Other countries including the UK and Canada regulate when foods can be labelled as natural. This may reflect different underlying approaches to regulation and food safety, but nevertheless, countries that desire to regulate face a serious challenge in defining what is or is not natural, or sufficiently natural to warrant the label and any price advantages it may bring. This challenge led Sanchez-Siles et al. (2019) to propose a 'food naturalness index' based on 15 attributes, with scores ranging from 'not at all natural' through to 'extremely natural'. If the notion of natural agriculture is to be more than transient marketing rhetoric, one has to wonder whether an 'agriculture naturalness index' (or 'agriculture regeneration index') might be somewhere on the horizon, and if so, on what attributes it might be based (see e.g. Lundgren et al., 2021). There are also parallels here with the challenge of quantifying seductive but complex, multi-dimensional concepts like soil health (Baveye, 2021; Lehmann et al., 2020).

Using nature, mimicking nature

If 'natural' is difficult to pin down, 'nature-based' is even more problematic. In what way or to what degree does something need to be 'based on nature' in order to be considered 'nature-based'? Should the incorporation of any particular aspect of nature (e.g. perenniality) be given more weight than others (e.g. species diversity) in determining what is or is not nature-based?

The literature generally draws on one of two approaches in defining nature-based solutions in agriculture. The first is work by IUCN, which defines nature-based solutions as 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (Cohen-Shacham et al., 2016: 5; also see IUCN, 2012). Importantly, with a focus on what they call 'active solutions', these authors note that this definition excludes 'interventions that are merely inspired by nature, such as biomimicry' (p.6). This suggests a purely anthropocentric, instrumental use of one or more elements of nature – nature provides tools, but not inspiration or models. The second source is work by the European Commission, which defines nature-based solutions as 'actions inspired by, supported by or copied from nature' (European Commission, 2015: 24). While broadly similar, compared to IUCN, this definition puts greater emphasis on biomimicry (i.e. 'copying from nature' and nature as a source of inspiration).

Recent reports published jointly by FAO and The Nature Conservancy cite the IUCN definition but leave the door open to biomimicry (Miralles-Wilhelm, 2021; Miralles-Wilhelm and Iseman, 2021). For example, in his review of nature-based solutions in 'agricultural landscapes that contribute to reducing negative trade-offs between sustainable production and conservation objectives' (p.7), Miralles-Wilhelm (2021), suggests that they:

> 'can mimic natural processes and build on land restoration and operational water-land management concepts that aim to simultaneously improve vegetation and water availability and quality, and raise agricultural productivity […] can involve conserving or rehabilitating natural ecosystems and/or the enhancement or the creation of natural processes in modified or artificial ecosystems' and in agricultural landscapes, 'can be applied for soil health, soil moisture, carbon mitigation (through soil and forestry), downstream water quality protections, biodiversity benefits as well as agricultural production and supply chains to achieve net-zero environmental impacts while achieving food and water security, and meet climate goals' (p.7).

In addition to a list of forest and conservation interventions,[4] Miralles-Wilhelm (2021) identifies a number of agriculturally-oriented nature-based solutions:

- **Avoided grassland conversion** (Protected areas establishment and improved enforcement to prevent the conversion of grasslands to tilled croplands; improved land tenure; intensification of existing croplands)
- **Biochar** (Extension programs to build capacity on biochar management; improved land tenure; certification systems; incentives programs)
- **Cropland nutrient management** (Certification programs that seek to maintain water quality by reducing excessive fertilizer; water quality/pollution mitigation; credit trading programs; removal of regulations creating perverse incentives to apply excessive fertilizer; improved manure management)
- **Conservation agriculture** (Cultivation of additional cover crops in fallow periods; shift to reduced-tillage or zero-tillage systems and other conservation agriculture practices may enhance soil carbon benefits of cover crops)
- **Trees in croplands** (Regulations and certification programs that promote the integration of trees into agricultural lands; agroforestry certification systems; increasing the number of trees in croplands with windbreaks, alley cropping, and farmer-managed natural regeneration)
- **Grazing, optimal intensity** (Decrease in stocking rates in areas that are overgrazed and an increase in stocking rates in areas that are undergrazed, but with the net result of increased forage offtake and livestock production)
- **Grazing, legumes in pastures** (Sowing legumes in existing planted pastures)

- **Grazing, improved food** (Inclusion of energy-dense feeds (e.g. cereal grains) in the ration, with the greatest potential in production systems that utilize little or no grain to feed animals)
- **Grazing, animal management** (Use of improved livestock breeds, and increased reproductive performance, health, and liveweight gain)
- **Improved rice cultivation** (Adopting water management techniques such as alternate wetting and drying and midseason drainage; residue incorporation; fertilizer management)

From an agronomic perspective, many of these interventions have been known for decades and have proved to be useful in particular contexts. Indeed, most are within the canon of good agricultural practice (GAP), although perhaps not used as widely as they might be. What is new is that the descriptions of some interventions on this list make an explicit link between technical actions and economic, social or political innovations like certification schemes and protected areas. But with or without these links, the re-branding of well-established agricultural techniques as 'nature-based solutions' raises important questions about motivation and underlying theories of change (these same questions would also be relevant in any analysis of the earlier re-branding of long-standing established farmer practices as GAP).

Perhaps the most widely promoted examples that are said to be inspired by, rooted in or mimicking nature include perennial grains (e.g. Glover et al., 2010; Snapp et al., 2019), some models of agroforestry (Ewel, 1999), some models of short rotation grazing (Savory, 1988) and conservation agriculture (Kassam et al., 2009). It is suggested that the 'lessons' from nature that these draw upon include the critical importance of perenniality (perennial grains and agroforestry), minimal soil disturbance (conservation agriculture), biodiversity (agroforestry and perennial grains) and plant-animal interaction (short-duration grazing).

But as noted above, for each of these one must ask, 'What nature is being referenced, and whose reading of that nature does the intervention reflect?' and 'What biological or ecological mechanism does the intervention rely on?' Finally, it is again worth considering the extent of inspiration or mimicry that might warrant the label 'nature-based'.

None of this is to suggest that agriculture research should not be looking to, learning from and/or mimicking nature as it seeks to address productivity, sustainability and quality challenges. Nor is it to suggest that agriculture of all types should not be managed by ecological principles (Weiner, 2017), whose application might lead to more sustainable forms of production, and in some cases, even to enhanced ecosystem function (Perfecto and Vandermeer, 2015). Rather, the question is from what basis, and how this is done. The penchant for framing debates in terms of existential threats, combined with the organizational and individual imperatives – shared by researchers and advocates across the spectrum, from mainstream to alternative – to stay ahead of the game, access financial resources, and build brands, must not be allowed to overshadow the importance of evidence-based analysis rooted in plant physiology, ecology, soil ecology, agronomy, economics, policy studies and the like.

It is in this light that the papers in this special issue of *Outlook on Agriculture* offer a much-needed critical perspective on the (re)turn to nature in agriculture, with the objective of highlighting both promises and pitfalls, and suggesting potential lines for future research.

Papers in the special issue

Jillian Lenné and **David Wood** critically examine what they term the 'paradigm of in-field diversity', which suggests that monocultures, the source of most global food production, are ecologically dysfunctional and highly vulnerable to diseases and pests. They highlight evidence that natural monodominant vegetation is common in nature, and that the ancestral species of major cereals including wheat, barley and rice grew in monocultures maintained by disturbances such as fire or flood. They argue that monoculture agriculture, particularly for cereals, is a proven natural model for future food production.

Robert Loomis casts a critical eye over efforts to develop productive perennial grain polycultures. From an ecological perspective, he focuses on trade-offs, stability, risk and management, and calls into question the value of the concept of 'prairie polyculture'. He argues that as of 2005, there was little evidence that polycultures of perennial grains could produce sufficient food to serve as alternatives to the (then) current production systems.

Kenneth Cassman and **David Connor** provide historical background to the paper by Robert Loomis and then evaluate progress over the last 16 years in developing productive perennial grain crops capable of replacing annual grains. They see little evidence that yields of Intermediate Wheatgrass or perennial wheats have improved to the point they are viable alternatives. They conclude that perennial grains will require substantial further investment over several decades to achieve the gains in yield potential and persistence required for them to become more than a niche crop for upscale health food markets in wealthy countries.

Bart Gremmen brings a philosophical lens to the question of whether regenerative agriculture is a prime example of biomimicry or only a very important way to use nature in agriculture. Based on two definitions of mimesis, he distinguishes between a 'strong' concept of biomimicry that emphasizes natural principles and copying natural models, and a 'weak' concept, that emphasizes inspiration by nature and creative invention. These concepts are used to analyse regenerative agriculture, but as both are found wanting, he proposes a new concept of biomimicry based on a new definition of mimesis. He argues that the conceptualization of biomimicry helps to operationalize regenerative agriculture as a biomimetic technology.

R. Ford Denison accepts that natural ecosystems are a rich source of ideas for improving agriculture, but argues that simply attempting to mimic natural ecosystems is unlikely to yield optimal ecosystem design in agriculture. He asks: 'how can we recognize those aspects of nature that agriculture might benefit from copying?' Two approaches – 'copy-what-works' and 'tested-by-time' – are explored using a variety of examples. A key insight is that mere persistence is no substitute for good performance. He concludes that while natural ecosystems may have demonstrated sustainability, they are not necessarily a good model for agricultural ecosystems because they have not been subject to competitive testing or the massive nutrient removals in harvested products that current human populations require.

Joanne Thiessen Martens considers ecosystem restoration in relation to the prairie region of Canada, and posits a requirement for two intertwined transition processes: worldview reorientation and restoration of ecosystem functioning. The object should be to design and implement agricultural landscapes that mimic key features of natural ecosystems while maintaining a mix of land uses. She argues that human ingenuity and thoughtful integration of traditional and scientific knowledge are needed to support synergetic relationships within and among farm fields and other landscape features. Integrating social goals into the design of agricultural landscapes can spawn creative solutions, but will require a shift toward a more open and collaborative approach, especially regarding the use of privately-owned land.

Angelinus Franke and **Elmarie Kotzé** describe the historical background of grazing and rangeland degradation in southern Africa, the principles of high-density grazing, and the problems it aims to address. While this type of grazing management is promoted as a way to mimic how grasslands are utilized by wildlife in natural situations, they ask whether high-density grazing can be regarded as representative of natural ecosystems, and whether they can be seen as more representative of natural ecosystems than other grazing management systems. Finally, they suggest that the supposed relationship between nature and high-density grazing may have led to an overselling of high-density grazing and it being embraced by policymakers and development agencies without sufficient empirical evidence.

Mirjam Pulleman et al., examine the origins of popular ideas that have inspired nature-based approaches to improving biological soil functions, as well as the potential of these approaches to address key global challenges related to agriculture. Using three examples, they demonstrate how ecological theories have inspired agricultural practices or commercial products based on mimicry of soil biology in natural ecosystems. However, claims that these 'nature-based' practices stimulate soil biodiversity and/or beneficial soil organisms to enhance soil health cannot be generalized and require careful consideration of limitations and possible trade-offs. They also argue that dichotomies and pitfalls associated with the use of nature as a normative framework, or metaphor, for sustainable soil management can be counterproductive given the urgency to achieve solutions that sustain food production and natural resources.

David Powlson et al., ask whether it is possible to restore soil that continues in arable agriculture to pre-clearance soil organic carbon (SOC) levels through modified management practices. Evidence from Europe, Africa, North America and South America suggests that with only a few exceptions, under arable cropping SOC is typically 30–60% of pre-clearance values. They conclude that while for reasons of sustainability and soil health it is important to maintain SOC as high as practically possible in arable soils, it is unrealistic to expect to maintain pre-clearance values. To maintain global SOC stocks it is equally important to reduce current rates of land clearance and sustainably produce necessary food on existing agricultural land.

Wopke van der Werf and **Felix Bianchi** focus on the common assumption that increasing diversity in agricultural systems will diminish pest problems. Drawing together multiple strands of evidence they assess what diversification of crop systems might mean for pest control, and the prospects of reduced pesticide agriculture based on natural mechanisms. They suggest that the literature supports two general observations: natural pest suppression is less reliable than the use of pesticides, and there may be trade-offs between natural pest suppression and yield; and, the effects of diversification are contextual. This leads them to conclude that nature-based pest control solutions come with both benefits and costs, and if they are to be used widely for the sake of a healthier environment, society must compensate farmers for the pest-related losses they will likely incur.

Meine van Noordwijk et al., introduce the notion of 'mimetrics' – metrics of hydrological mimicry that reflect similarity in ecological structure and/or functions between managed and natural ecosystems. They argue that such metrics are essential in light of political commitments to reduce agriculture's impact on nature. Existing metrics, like water footprint, often ignore full hydrological impacts. To address this, the authors explore principles, criteria and indicators for understanding human impacts on water cycles via modified evapotranspiration, effects on streamflow, atmospheric fluxes and precipitation. A number of proposed mimetrics are illustrated for a set of pantropical watersheds. These mimetrics suggest hydrological mimicry options for forest-derived land use patterns through intermediate densities of trees with diversity in rooting depth and water use, interacting with soils, crops and livestock.

Lidia Cabral and **James Sumberg** profile some key individuals who have promoted nature-based and natural systems agriculture. They focus on the 'narratives with epic elements' that have been constructed around these personalities, and how these have helped gain legitimacy and influence for the individuals themselves, their ideas, and their organizations. Similar processes and dynamics can be seen in more mainstream agricultural research. As the struggle over the future of agriculture is increasingly played out in corporate boardrooms, through public relations agencies and on social media, it is critically important to understand how narratives with epic elements emerge,

and are used to influence the debate about the future of agriculture and the potential contribution of nature-based solutions.

Notes

1. See, for example: *Agroforestry Systems* 45(1–3), 1999; *Renewable Agriculture and Food Systems* 20(1), 2005; *Crop and Pasture Science* 65(10), 2014; *Australian Journal of Agricultural Research* 52(2), 2001. Important conferences were held Williams, Western Australia in 1997 ('Agriculture as a Mimic of Natural Ecosystems'), and in Lund, Sweden in 2019 ('Is the Future of Agriculture Perennial?').
2. I am grateful to Dominic Glover for suggesting the image of a dance. Also see Glover (2018).
3. Even agroecology works with 'unnatural' systems: in many cases crops are grown outside their area of origin, so ecologically these crops are exotics and the agricultural systems are novel ecosystems (i.e. not developed through or tested by evolution).
4. Avoided forest conversion; reforestation; natural forest management (i.e. management of naturally regenerated forests); maintaining riverine ecosystems as natural flood defences; improved plantations; fire management; avoided woodfuel harvest; avoided coastal wetland impacts; peatland restoration; avoided peatland impacts; coastal wetland restoration; peatland restoration.

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