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Farmer-led agroecology for biodiversity with climate change

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The increasing pace of climate change is an existential threat to farming continuity and biodiversity. Agricultural innovation is running too slowly but could be accelerated by a change in the agroecological narrative. A farmer-led agroecology prioritising farming continuity for biodiversity would speed up innovation and better serve science and society.

Climate change is an existential threat to farming

The goal of feeding 9 billion people by 2050, sustainably and equitably, is under threat from climate change that increases the frequency and severity of extreme weather events [1,2]. Modelling and observation suggest that the performance of common crops will decline, severely affecting livelihoods of farmers of arable land worldwide [1]. This is an existential threat that will cause significant numbers of farmers to abandon farming, adding to those who have already left. Without innovation of practices to mitigate the agronomic and socioeconomic challenges faced by farmers, climate change will have detrimental impacts on food security, biodiversity and ecosystem services, and the well-being of individuals and society [3,4]. The future of farmland biodiversity and ecosystem services are therefore inseparably linked to, and only assured by, the continuity of farming in the face of climate change.

Time is running out for farmland biodiversity and the environment

The pace of agricultural innovation needs to reflect the speed of climate change with some irreversible tipping points of climate change predicted within a decade. This is a short window of opportunity, especially as current targets for biodiversity conservation in farmland are not being met [5,6]. Innovation, or the adoption of novel, useful practices based upon existing or new methods, behaviours, and technologies [7], takes time, and many proposed management practices are not adopted due to low acceptability to farmers, wasting valuable effort. With many competing needs and wants, the time scales of agricultural innovation represent a 'wicked problem' that needs solving [8,9]. The pace of acceptable innovation in sustainable farming must be increased, and we contend that this will only happen through a reorientation to farmer-led agroecology.

Changing the narrative

In Western Europe, farming innovation has typically been addressed by the framing of key questions in policy, the commissioning of agroecological research to discover answers, and persuading farmers to adopt these via regulation, incentives, and communication [10] (Figure 1). Farmer-led agroecology changes the narrative to one that explicitly seeks to answer the agronomic and socioeconomic problems farmers have for the continuity of farming *and* also to meet societies' environmental needs. In principle, therefore, farmer-led innovations should be more acceptable and adopted more rapidly.

Farmer-led agroecology reorders the roles of scientists and farmers in the innovation process. Farmers lead in cocreating a narrative that assures the continuity of farming, and agroecologists follow to explore the scenarios for their complex economic,

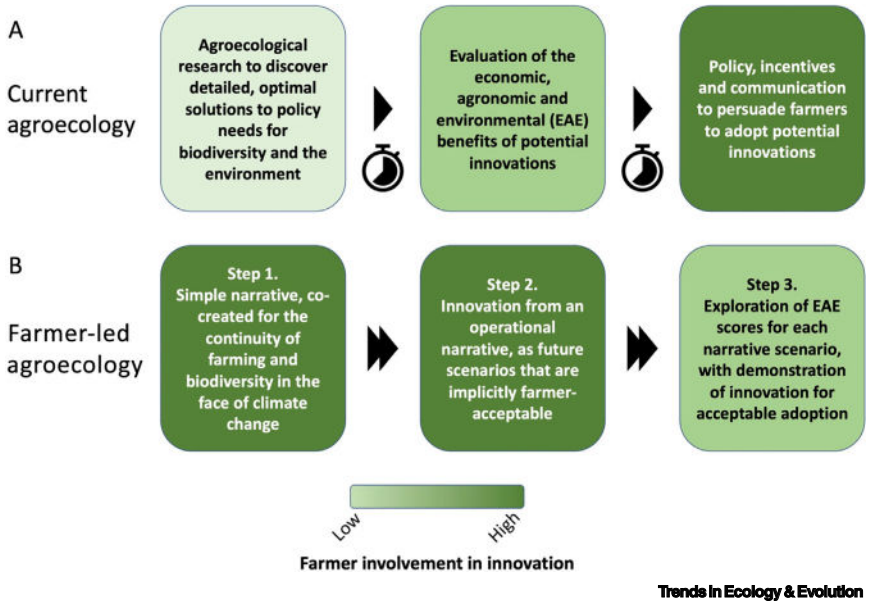

Figure 1. Schematic descriptions of the process of innovation for biodiversity and ecosystem services in agriculture. (A) The current agroecological approach. (B) The farmer-led agroecological approach proposed in this paper. The colour of the text boxes indicates the involvement and investment of time by farmers in the innovation process, illustrating the reordering of the farmer-led approach. The symbols represent the relative speed of passage between the steps in the process of innovation.

agronomic, and environmental (EAE) effects. The narrative links what is 'likely to happen' under climate change to the economic, agronomic, and environmental outcomes that farmers and society want. The role for agroecologists in farmer-led agroecology is to work with farmers towards (i) creating a simple narrative for the continuity of farming in the face of climate change, (ii) operationalising the narrative so that farmers can imagine and innovate new management as a set of scenarios, and (iii) exploring the scenarios of innovation to identify those that are EAE acceptable. These are steps in the process of farmer-led agroecology to facilitate the continuity of agriculture and the delivery of the biodiversity and ecosystem services with climate change (Figure 1), which we illustrate using a case study for the innovation of arable rotations [11,12].

Farmer-led innovation will improve acceptability and adoption to achieve societal aims

Step 1. Creating a simple narrative for the continuity of farming

A farmer-led agroecological narrative prioritises farming continuity for biodiversity and the environment. To cocreate a narrative, it is necessary to go through a discursive, participatory evaluation of agricultural management to identify what contributes to the continuity of farming and how this impacts the environment. This might lead to an expectation that climate change will affect future crop performance [1]. In Europe, as in much of the rest of the world, crops are grown in rotations that are part of the basic toolkit of arable management [11,12]. So, one type of innovation is changed future rotations for farming continuity and environmental outcomes. Changes to rotations would also drive additional, important changes in management options, such as irrigation or intercropping. Considering the wicked complexity of all these options simultaneously would render the task of farmer-led innovation intractable by overburdening farmers with detail, thereby limiting the types of new management conceived and unwittingly causing conflict [13].

The goal of step 1 is to deliver a simple narrative for the key effect around which farmers can imagine and innovate new managements in step 2. Examples of narratives might consider land use diversification, investment in machinery, or even new technology such as robotics for precision farming [10]. For our case study (Box 1), we wanted to develop novel rotations for farmers to continue to farm profitably with climate change while assuring biodiversity and ecosystem services [11]. Discussion in our case study identified that all arable farmers in Europe use rotations, but not all

Box 1. Innovating future rotations using farmer-led agroecology

Step 1 delivers a simple narrative that enables farmers to imagine and innovate management, such as 'climate change will lead to changed crop rotations and consequent changes in biodiversity and ecosystem services.' The Future Rotations Explorer tool [11] is used in step 2 to visualise the narrative metric of crop yield change for a climate change scenario of average CO_2 increase to 2030 or 2050 (Figure I). The visualisation allows farmers to examine the expectations of climate change on these crops in terms they understand, yield change, and to assemble crops into novel rotations that optimise yield change (Figure II). Farmers thereby innovate new rotations, which become the farmer-led scenarios of step 3. Based on this Supporting (carbon sequestration, biodiversity, etc.), Regulating (organic matter content, weeds, natural enemies, etc.), Provisioning (yield), and Cultural (landscape aesthetics) services linked to the rotations [15] can be explored and demonstrated to farmers, and rotations can be selected to meet wider societal needs. These principles may be applied to any farming innovation.

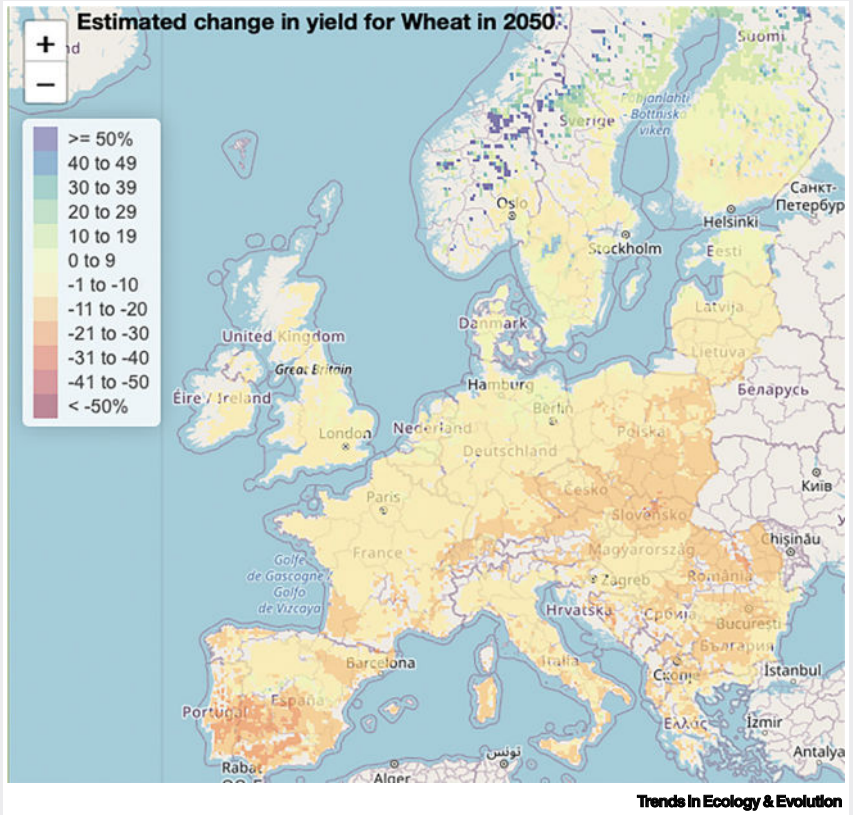

Figure I. Predicted wheat yield change across Europe to 2050 (https://connect-apps.ceh.ac.uk/prear-future-rotations-explorer/)

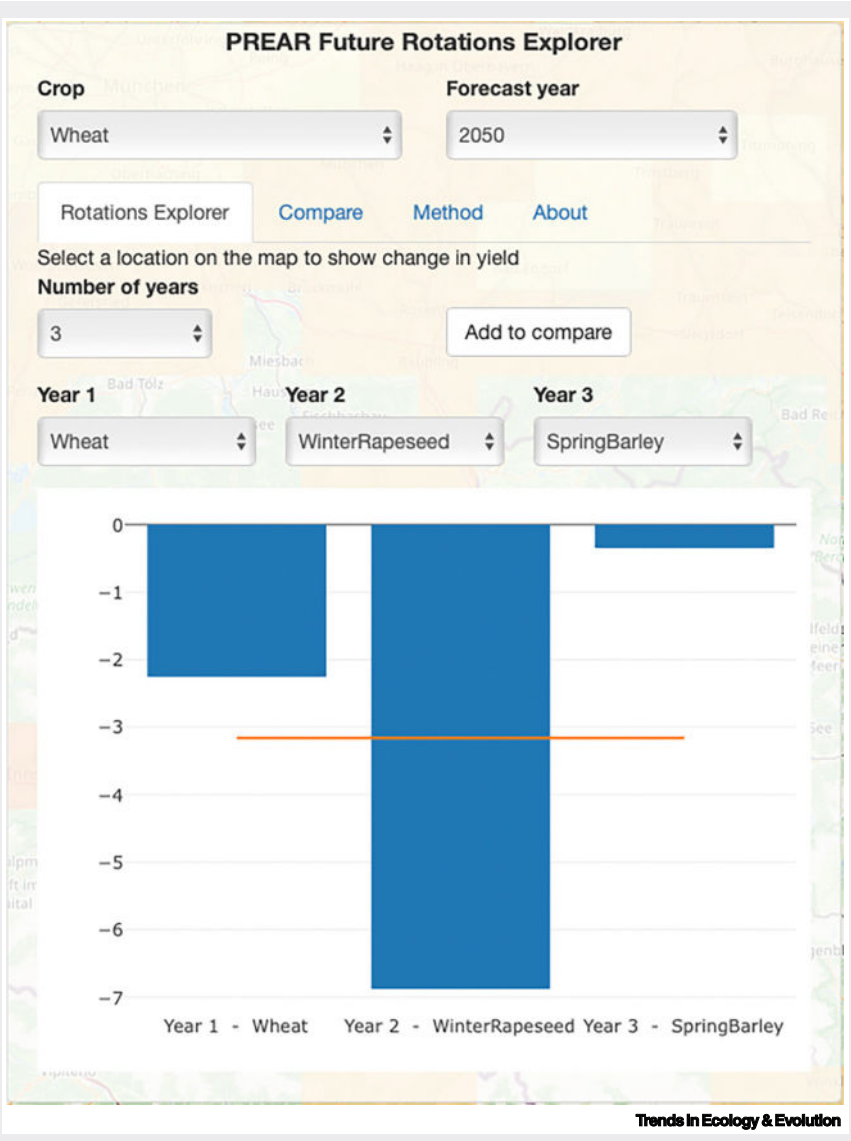

Figure II. Crop and overall yield change for a proposed rotation to 2050, for a particular locality, which shows an overall yield decline of 3.2%.

those farmers use irrigation or intercrops. This insight meant that the innovation of profitable rotations was the key, simple effect for the case study, suggesting the farmer-led narrative that we expect climate change to lead to changed rotational crop sequences that will, in turn, lead to changed biodiversity and ecosystem services. The lower-weighted and complex effects, such as irrigation or intercropping, were postponed to scenario exploration in step 3.

Step 2. Innovating, using an operational narrative

Climate change scenarios are often presented as extreme events, using metrics such as the frequency of high temperatures, droughting, and flooding. We have found that this climate change presentation is not operational for farmers, because the metrics cannot be used to plan their crop management [12]. Extreme occurrences are also interpreted pessimistically, limiting the types of new management combinations that farmers can conceive [12], potentially as their perception of risk varies.

The narrative created in step 1 becomes operational in the sense that it helps farmers to innovate once the climate change metrics are 'translated' into metrics that farmers can use to imagine new management. As an example, we have found that web-based tools, built for the step 1 narrative, have high operational value for innovation because they translate climate change scenarios into narrative metrics for farmers (Box 1). This has two clear benefits: First, farmers examine the expectations of climate change through visualisation; second, it allows farmers to innovate for their farm locality.

These metrics and knowledge impart urgency to the innovation for climate change adaptation. Importantly, farmers only propose innovative management that in principle makes agronomic sense, so the farmer-led innovations are farmer-acceptable and can be treated as scenarios of future management that allow exploration of adaptation in farming to climate change in step 3.

Step 3. Exploring the innovations as agroecological scenarios

At this point, agroecologists use their interdisciplinary skills in modelling, experimentation, and statistical analysis. The scenarios of innovative management can be expected to lead to modification of additional multiple management options and agronomic, socioeconomic, and environmental outcomes that we can model, predict, and evaluate experimentally (Box 1). Each scenario can therefore be given scores against EAE criteria to indicate what would likely happen

if that management were adopted. In our case study, some of the new rotations may already be used elsewhere, so their validation could be demonstrated to farmers, perhaps via Citizen Science or Agricultural Living Labs. Existing social science methods could be used to evaluate the EAE scores and select those farmer-acceptable innovations that also meet wider societal needs and in turn inform policymaking. If done correctly, this simple narrative and exploration approach would produce potential innovations that are optimistic and, as far as is possible, transparent and honest.

A future, farmer-led agroecology

Our rotational case study from Western Europe is just one possible example of a narrative. Farmer-led agroecology is, we believe, applicable to farming systems and management worldwide. Moreover, the farmer-led narrative may have better traction with the wider agricultural and processing industry because they also use similar narrative metrics, supporting the planning of green, circular economies with shorter and more sustainable supply chains [14].

The farmer-led agroecology we propose springs from a fear that the innovation of new management techniques is happening too slowly to assure the future conservation of biodiversity and delivery of ecosystem services in farmland. This makes it an exciting yet scary time in agroecology. Farmer-led approaches to innovation offer enormous opportunities to develop novel research in concert with farmers, fusing the best of socioeconomics, agronomy, and ecology to farmer knowledge to reduce the wickedness of the problem of innovation in agricultural systems. It also holds the exciting possibility that agroecological research will become more immediately useful, and used, better serving the needs of science and society.

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Declaration of interests

The authors have no interests to declare.

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