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AGRICULTURE POLICY

EU agricultural reform fails on biodiversity

Extra steps by Member States are needed to protect farmed and grassland ecosystems

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In December 2013, the European Union (EU) enacted the reformed Common Agricultural Policy (CAP) for 2014–2020, allocating almost 40% of the EU's budget and influencing management of half of its terrestrial area. Many EU politicians are announcing the new CAP as "greener," but the new environmental prescriptions are so diluted that they are unlikely to benefit biodiversity. Individual Member States (MSs), however, can still use flexibility granted by the new CAP to design national plans to protect farmland habitats and species and to ensure long-term provision of ecosystem services.

POLICY

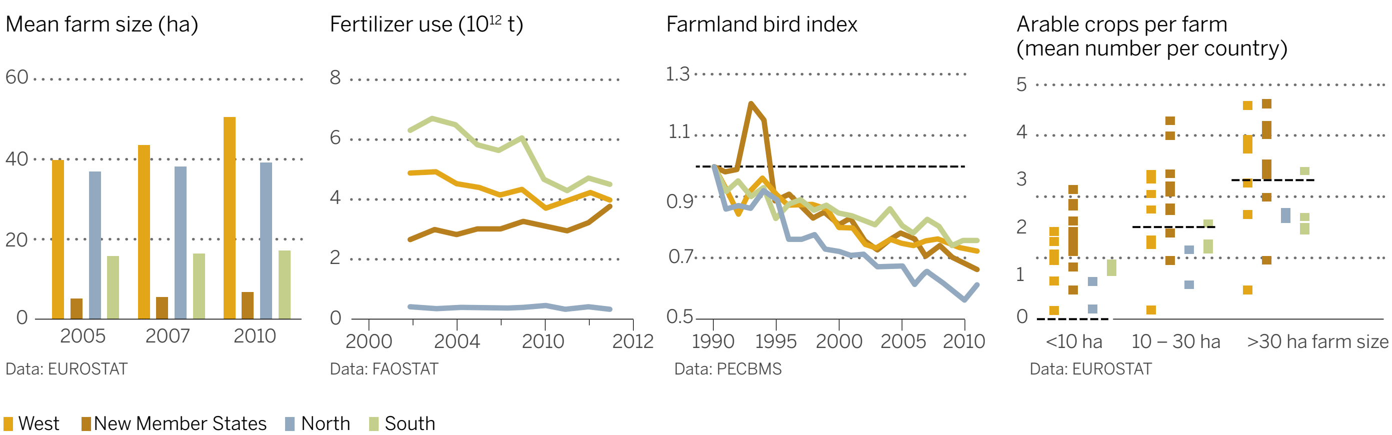
Agricultural expansion and intensification are important global drivers of biodiversity loss and ecosystem degradation (*1*). In Europe, habitats associated with agriculture, such as grasslands, heathlands, and peatlands, support threatened and declining species and provide important ecosystem services, yet have the worst conservation status among all ecosystems (*2*). Declines in species richness seem to have slowed for a few taxa in parts of northwestern Europe (*3*), albeit at a biodiversity-impoverished status quo.

Expansion of the EU and its common market continue driving agricultural intensification in Europe (*1*, *3*). Aided by CAP subsidies, the scale of agricultural operations is increasing throughout the EU [e.g., increasing holding size (see the chart)], with new MSs showing an increase in agrochemical inputs [e.g., fertilizers (see the chart)]. These processes, alongside peatland drainage and abandonment of seminatural grassland in less productive or accessible regions, lead to continuing decline of farmland biodiversity (*4*–*6*) (see the chart).

Certain problems relating to biodiversity decline are addressed through existing EU legislation and policies to protect the environment (e.g., directives on habitats, birds, water, nitrates, and sustainable use of pesticides), but the CAP has a much broader influence on ecosystems in the EU. With a total budget of €362.8 billion (U.S. $495.4 billion) for 2014–2020 (*7*), it provides finances, policy mechanisms, and control systems with higher environmental impact than all other policies and directives [supplementary materials (SM) part A]. Recognizing the role of the CAP for biodiversity, the EU Biodiversity Strategy for 2020 sets Target 3A to "maximise areas [...] covered by biodiversity-related measures under the CAP" (*8*). The CAP reform does not fulfill this target.

THE DILUTION OF AMBITION. When the European Commission launched the latest CAP reform in 2010, it outlined three main challenges: food security, environment and climate change, and maintaining the territorial balance and diversity of rural areas (*9*). To help address the second challenge, 30% of direct payments to farmers ("Pillar 1") were to become conditional on compliance with three "greening measures": establishing Ecological Focus Areas (EFAs) on 7% of farmed area, maintaining existing permanent grassland, and growing a minimum of three different crops on any farm with >3 ha of arable land. Yet after 3 years of negotiation (*10*), these measures now apply to roughly 50% of EU farmland, and most farmers are exempt from deploying them.

EFAs are now set at 5%, instead of 7%, and only on farms with >15 ha of arable land. Countries can reduce the requirement to 2.5% or lower in some regions (SM B). The area threshold exempts at least 88% of EU farms and over 48% of farmed area (table S1). Farms with permanent crops, grasslands, or pastures do not need EFAs. On the other hand, various land uses may qualify as EFAs, including nitrogen-fixing crops, catch crops, short-rotation coppice, and green cover. These land uses could help maintain soil and water quality



EU agriculture. (**Left**) Farm sizes are particularly large in Western and Northern Europe and have increased in Western Europe (+27%) and the new MSs (+30%) since 2005. (**Left middle**) Fertilizer use in new MSs has been increasing in the past decade (other types of agrichemical inputs show similar trends). (**Right middle**) The Farmland Bird Index (normalized to 1990 levels) declines throughout the EU. (**Right**) Average crop diversity in different MSs (symbols) compared with the minimum requirements set by the new CAP (horizontal lines). See SM for data sources and details.

but are not known to deliver benefits for biodiversity (*11*). In such a diluted form, and without specific management guidelines, EFAs will likely contribute little to biodiversity.

Permanent grasslands have decreased in cover by 6.4% between 1993 and 2011 in the EU and by 11.8% in new MSs (SM C). The new CAP aims to halt this decline, thereby reducing biodiversity loss and greenhouse gas emissions. But rather than maintaining all permanent grasslands, the reformed CAP allows a reduction of up to 5% in the net area of permanent grasslands at national or regional scales. Further degradation is permitted by the lack of habitat quality and management criteria. MSs are required to identify and protect ecologically valuable grassland within protected sites ("Natura 2000"), but outside these sites, farmers will continue receiving subsidies while converting low-input, extensively managed, species-rich grassland (*3*) to highly intensified, uniform, species-poor swards (*6*). The potential to maintain grassland biodiversity is further undermined by incomplete mapping, lack of differentiation among regions and grassland types, and a focus on net area without consideration of continuity and connectivity of existing seminatural grassland parcels.

The crop diversification measure obliges medium (10 to 30 ha) to large (>30 ha) farms to cultivate at least two or three crops, respectively (SM D). Farms with <10 ha of arable area (instead of 3 ha as originally proposed) are exempt, accounting for 92% of arable holdings in new MSs and 13% of arable area across the EU (table S4). Cultivating three crops on large, intensively managed farms is unlikely to enhance biodiversity (*11*). Moreover, in many MSs these targets are lower than current average crop diversity at the farm scale (see the chart). Combined with the absence of requirements regarding eligible crop types or rotation, this measure is unlikely to deliver benefits to biodiversity or soil quality, or to prevent further landscape homogenization.

Beyond those compulsory measures, the new CAP gives insufficient attention and financial support to sustainable farming in marginal, small-scale, and biodiversity-rich farms. Measures deployed within the framework of the Rural Development Regulation (Pillar 2), especially agri-environment-climate schemes (AESs) that farmers could take up voluntarily, can improve habitat quality and maintain biodiversity when they are well-designed, targeted, and financed (*12*). Yet funding for Pillar 2 will decrease in absolute terms by 18% from 2013 to 2020 [from €13.9 to 11.4 billion (~U.S. $19) annually, in 2011 prices] compared to a 13% reduction in Pillar 1 budget (*7*). Although the proportion of Pillar 2 funding earmarked for environmental measures has increased from 25% in the previous CAP period to 30% now, the budget needs to cover other activities, including climate change mitigation, organic farming, and so-called climate and environment investment measures—with potential for both positive and negative impacts on biodiversity (SM E).

MSs have the flexibility to move some budgets from Pillar 1 to 2 ("modulation") but also vice versa ("reverse modulation"). The latter is already occurring in some MSs (SM E). Moreover, MSs still have to match Pillar 2 payments with national cofunding. Although the requirements for national cofunding were reduced in certain cases compared with the previous funding period, MSs may still lack the budgets required to unlock these resources or may prefer to allocate Pillar 2 funds to measures that are less beneficial for biodiversity. Too few developments in the new Pillar 2 regulations focus on improving cost-effectiveness in terms of uptake and biodiversity outcomes. One important advancement in some MSs, however, is encouraging farmers to act jointly toward achieving landscape-scale targets (see SM E).

Many EU politicians are announcing the new CAP as "greener," but the new environmental prescriptions are so diluted that they are unlikely to benefit biodiversity.

Recommended immediate actions by Member States

1. Maintain or enhance the AES budget in Pillar 2 through budget modulation, prioritizing context-specific measures shown to support biodiversity and ecosystem services. Set clear and measurable targets that are coherent with the EU Biodiversity Strategy.
2. Use AESs to allow specific target groups (e.g., small holdings in marginal areas, young farmers, cooperating farmer groups) to profit from environmentally friendly practices or jointly provide landscape-scale benefits.
3. Ensure that eligible land uses for EFAs prioritize elements that benefit biodiversity and ecosystem services, including management prescriptions when necessary.
4. Complete identification and mapping of grasslands, with differentiation into types, qualities, and required management.
5. Allocate sufficient funding and effort within the Farm Advisory System to deliver ecological expertise to farmers as required.
6. Institute comprehensive provisions for monitoring biodiversity outcomes to evaluate the effectiveness of the agricultural policy against the targets set in the EU.

Agricultural intensification clearly provides some short-term economic gains for farmers and the food industry. But these have to be weighed against the loss of public goods, such as climate stability (*13*), landscape quality, and biodiversity (*13*, *14*) with associated environmental, health, and societal costs that are largely externalized from the farming economy. The EU acknowledges the importance of biodiversity through its 2020 biodiversity targets, as well as by endorsing the Aichi targets of the Convention on Biological Diversity, including strategic targets on sustainable agricultural production and consumption (goal 1, targets 4 and 7) and elimination of incentives harmful to biodiversity (target 3) (SM F). These strategic goals, developed from the evidence for the various costs of losing biodiversity and ecosystem services (*15*), would be undermined if MSs adopt the minimum requirements as set by the reformed CAP.

THE WAY FORWARD. The EU has lost an opportunity to design better guidelines to improve agricultural sustainability. Yet the increased devolution of responsibilities to individual MSs offers flexibility for promoting biodiversity and farmland ecosystems. We provide six recommendations for immediate action by MSs within the CAP implementation (see box) (SM G). In addition, we identify five actions for the EU to consider in its deliberations over the next CAP reform (details in SM H): (i) publish an evidence-based assessment of the CAP's impacts on farmland habitats, species, and ecosystem services, drawing on national-level monitoring as a base for improvements; (ii) increase the EU-wide AES budget, direct it to more effective incentives, and shift to outcome—rather than area-based targets; (iii) improve EFA effectiveness by reducing exemptions, refin-

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ing management criteria for qualification, and expanding their total area, building on country-level evidence and experience (recommendations 3 and 6 to MSs); (iv) develop longer-term perspectives for more effective and comprehensive protection and restoration of grasslands and peatland; (v) reevaluate the usefulness of the crop diversity measure.

Our recommendations should encourage MSs and the EU to start moving toward more sustainable agriculture, securing food provision alongside biodiversity and ecosystem services for current and future generations. ■

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EVOLUTION

Energy at life's origin

Analysis of the bioenergetics of primitive organisms suggests that life began at hydrothermal vents

By **William F. Martin**[1], **Filipa L. Sousa**[1] *and* **Nick Lane**[2]

Energy-releasing chemical reactions are at the core of the living process of all organisms. These bioenergetic reactions have myriad substrates and products, but their main by-product today is adenosine triphosphate (ATP), life's primary currency of metabolic energy. Bioenergetic reactions have been running in a sequence of uninterrupted continuity since the first prokaryotes arose on Earth more than 3.5 billion years ago, long before there was oxygen to breathe (*1*). Under what conditions did these bioenergetic processes first evolve?

Many ingenious ideas about energy at life's origins have nothing in common with modern life. It is conceivable that early life harnessed energy from volcanic pyrite synthesis (*2*), zinc sulfide–based photosynthesis (*3*), ultraviolet radiation, or lightning, yet none of these processes powers known microbial life forms. For biologists, the origin of energy-harnessing mechanisms used by real microbes is the issue. Recent studies point to parallels between the energy-harnessing systems of ancient microbes and the geochemistry of alkaline hydrothermal vents (see the figure), suggesting that natural ion gradients in such vents ignited life's ongoing chemical reaction.

How did the first cells harness energy? Because life arose in a world without molecular oxygen, some anaerobes are likely to be ancient, and anaerobic environments should harbor primitive bioenergetic reactions (*4*, *5*). Ancient anaerobic niches deep in Earth's crust often contain acetogens (bacteria) and methanogens (archaea), groups that biologists have long thought to be ancient (*4*). However, anaerobic environments harbor very little energy to harness (*6*, *7*). In the anaerobic environments of submarine hydrothermal vents, geochemically generated H_2 is the main source of chemical energy.

In addition to being strict anaerobes, acetogens and methanogens live from H_2, using the simplest and arguably most ancient forms of energy metabolism (*8*). Both synthesize ATP by reducing CO_2 with electrons from H_2 to make acetate and methane, respectively. They use a chemical mechanism called flavin-based electron bifurcation (*6*) to generate highly reactive ferredoxins—small, ancient iron-sulfur proteins (*5*) that are as central to their energy conservation as is ATP (*6*). The shared backbone of their energy metabolism is the acetyl–coenzyme A pathway, the most primitive CO_2-fixing pathway (*8*) and the one typical of subsurface microbes (*9*). Metabolism in these anaerobes is furthermore replete with reactions catalyzed by transition metals such as iron, nickel, molybdenum, or tungsten, another ancient trait (*2*, *5*–*8*).

... the primordial ATPase could have harnessed geochemically generated gradients at an alkaline hydrothermal vent.

All known life forms, including methanogens and acetogens, use two basic mechanisms to tap environmentally available energy and harness it as ATP. The first is substrate-level phosphorylation, in which highly reactive phosphate-containing compounds phosphorylate adenosine diphosphate (ADP) to make ATP (*6*, *10*). The energy conserved in ATP is released in a subsequent reaction that does chemical work for the cell or allows more sluggish reactions to go forward. The highly reactive phosphate compounds are generated during conversions of carbon compounds. Their synthesis is driven by environmental sources of chemical energy such as H_2 plus CO_2 that are harnessed during conversion to more thermodynamically stable compounds such as methane and acetate.

The second mechanism that cells use to harness energy involves ion gradients and is called chemiosmotic coupling. Here, an energy-releasing reaction is coupled to the pumping of ions across a membrane from inside the cell to the outside. The most common ions used for this purpose are protons,

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