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Enhancing the Effectiveness of CAP Greening as a Conservation Tool: a Plea for Regional Targeting Considering Landscape Constraints

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Abstract The EU Common Agricultural Policy (CAP) has tried to counteract negative impacts of intensive agriculture on biodiversity and associated ecosystem services mostly by means of voluntary agri-environment schemes (AES). More recently, direct payments to farmers have been linked to the application of greening measures derived from previous AES experiences. AES and greening measures (CAP greening hereafter) have become the main farmland conservation tools in Europe due to large budgets and extensive application. Effectiveness of greening measures (i.e. differences in biodiversity or ecosystem service measurements that can be attributed to the application of such measures) has not yet been evaluated thoroughly, whereas evaluations of AES effectiveness—although still not systematically incorporated into policy design—have lead to the conclusion that AES generally increase farmland biodiversity at the field scale with effect sizes that depend on the surrounding landscape. On the basis of knowledge gaps derived from available AES evaluations, we develop a five-stage hierarchical decision-making proposal to improve the effectiveness of CAP greening. Effectiveness is difficult to predict because non-linear relationships between diversity and land-use intensity at both field and landscape scales constrain and modulate it. Besides, relationships vary regionally and among target species, species groups and ecosystem services. Hence, regional targeting, landscape-scale thinking, and learning processes linked to systematic evaluations are key elements in any decision-making procedure aimed at improving this effectiveness. Ideas and guidelines developed here will help to develop regionally adapted measures aimed at overcoming constraints to CAP greening effectiveness and improving farmland conservation policies.

Keywords Agri-environment schemes · Common agricultural policy · Effectiveness constraints · Decision-making guidelines · Greening · Land-use intensity · Landscape complexity · Targeting

Introduction

Agriculture is a key driver of biodiversity change all over the world [1]. Conversion of natural land into cropland, intensification of existing farmland and abandonment of extensive agricultural uses have strong effects of biological diversity, which vary, however, with regional history of land use [2, 3]. In Europe, and also probably in other areas with a long history of agriculture, biodiversity protection depends more and more on maintaining biodiversity in human-dominated landscapes [4, 5••].

The main responses in Europe to the environmental problems associated with agriculture were the agri-environment schemes (AES hereafter) linked to Pillar II (aids to rural development) of the EU's Common Agricultural Policy (CAP). AES are voluntary contracts with interested farmers that involve the implementation of a set of management practices

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that are expected to benefit biodiversity or the environment and are usually applied at field or farm scales. This latter fact may limit its effectiveness if regional uptake is too low to fulfill the requirements of target groups (see below and [5••]). The CAP reform in 2014 tried to counteract this limitation by increasing environmental compliance for Pillar I (direct payments to all farmers given as production subsidies allocated per unit area of productive land), incorporating some management practices originally designed as AES into the practices obligatory for farmers to qualify for subsidies. Compulsory greening measures have generally not been incorporated, however, because of massive use of exemptions contemplated in the reformed CAP [6, 7••]. In spite of these limitations, AES and AES-derived greening measures (CAP greening hereafter) are prime conservation tools in Europe as they are applied in large parts of the territory (9–95 % of agricultural land depending on countries for AES, and 50 % for compulsory greening measures) and have budgets orders of magnitude higher than other conservation measures [5••, 7••].

The conservation potential of CAP greening has not been linked, however, to a systematic evaluation to improve its performance. No systematic data on the effects of compulsory greening measures are yet available [7••], and evaluation of AES' ecological effectiveness has generally not been routinely and rigorously incorporated into policy evaluations [5••]. Numerous local and regional evaluation studies [e.g. 8–10] emerged after Kleijn et al.'s [11] worrying results for Dutch farmland, and have now been summarized in distinct reviews and meta-analyses [5••, 12–14, 15•, 16]. These studies, however, are still strongly biased to a handful of countries, mostly in northern and central Europe. For instance, the 284 studies listed in the last meta-analysis available [5••] have been carried out in 12 countries, 84 % in Germany, UK, Sweden, the Netherlands and Switzerland (see also [12]). On this basis, general findings are that application of AES generally increases farmland biodiversity at field scales, but effect sizes depend on the structure and management of the surrounding landscape. The likely mechanistic causes of this landscape dependence of AES effectiveness were established in the seminal works by Tscharntke et al. [17] and Concepción et al. [18]. However, this knowledge, which is key to developing effective conservation measures, does not seem to have been properly incorporated in CAP reforms. In fact, AES effectiveness has not improved since 2007 as compared to previous assessments [5••].

In this paper, we critically review current knowledge on the factors that condition AES- and AES-based greening measures of the CAP. In particular, we focus on regional- and landscape-scale effects on the effectiveness of field- and farm-scale conservation measures and their theoretical and mechanistic basis. On these grounds, we generate guidelines for developing regionally adapted measures aimed at overcoming constraints to AES effectiveness. These guidelines can be arranged into a hierarchical decision-making proposal (Table 1, Fig. 1), ultimately aimed at improving the ecological effectiveness of farmland conservation policies. We define effectiveness as the difference in biodiversity or ecosystem service target measurements between conventionally farmed areas and areas that incorporate conservation measures, regardless of initial levels of these measurements.

Table 1 A hierarchical decision-making proposal for improving the effectiveness of conservation measures on farmland

1. Targeting conservation measures: Definition of conservation objectives, i.e., what we are aiming to preserve: populations of endangered species, species-rich communities, biodiversity-related ecosystem services [19].
2. Considering field- and landscape-scale requirements of targets: Establishment of field- and landscape-scale or habitat elements or traits required by targets (e.g. hedgerows, fallow land, uncultivated open areas, perennial crops, etc.) [20].
3. Considering landscape-scale constraints under a functional approach: Definition of the regional levels of landscape complexity, assessed using landscape metrics and threshold values derived from basic theory [14] or from empirical studies according to the regional context and the specific requirements of targets [10].
4. Adapting policy instruments to regional and target-adapted landscape constraints: Which instruments should be applied according to landscape complexity constraints [10, 18, 21]? Are they already available, or do we need newly developed tools?
   a) *Simple landscapes* ('cleared landscapes' sensu [19]): Increase landscape complexity by means of compulsory or coordinated measures to achieve high take-up by farmers before considering AES-driven extensification of local management.
   b) *Intermediate landscapes*: Extensification measures (AES) targeted at species, communities, or ecosystem services. Research on regional targets' habitat requirements in terms of minimum ecological contrasts needed will help enhance effectiveness, which should not be constrained by landscape thresholds in this intermediate part of the gradient.
   c) *Complex landscapes*: Maintenance of landscape complexity and farming practices, to avoid land-use abandonment or changes (e.g. afforestation, perennial crops) that may simplify landscapes. Development of compulsory or highly attractive measures (e.g. conservation agreements, direct subsidies to high-nature value farming systems, etc.) rather than voluntary or weakly compulsory extensification measures.
5. Systematic evaluation and learning process: Assessment of the ecological effectiveness of measures by means of paired or before-after-control-impact (BACI) designs should be established in parallel to scheme development [8, 19]. A good alternative when long-term maintenance of controls is difficult or impossible is the monitoring of as wide a range of farm types as possible (e.g. a random sample stratified by land cover), that will allow post-hoc testing of AES impacts [6]. Results of assessments should be then integrated into the design of subsequent reform rounds.

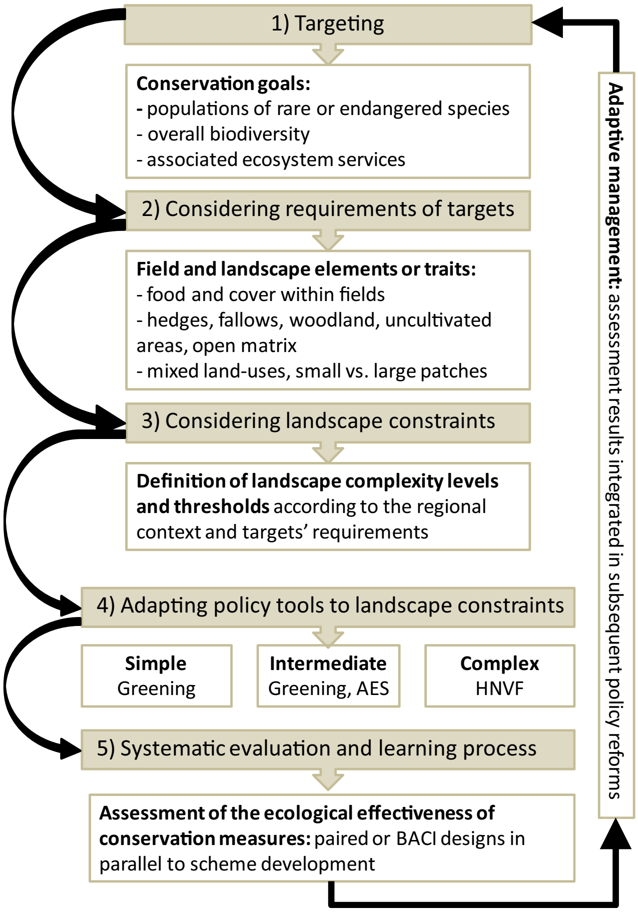

Fig. 1 Flowchart for a five-stage decision-making proposal aimed at improving the ecological effectiveness of CAP greening measures. Greening: compulsory (Pillar I) wide-entry measures aimed at providing basic green landscape infrastructure; *AES* agri-environment schemes, *HNVF* high-nature value farmland, *BACI* before-after-control-impact experimental designs. See also Table 1

A Five-Stage Decision-Making Proposal for Improving CAP Greening

Targeting Conservation Measures

It is hard to evaluate the effectiveness—and even more so, the efficiency—of any proposal if it has no explicit goals [8, 19]. Nevertheless, many assessments are still based on indirect or vaguely defined targets [e.g. 22], and this is also despite the fact that targeting has been proven to influence both effectiveness itself [12, 23] and its assessments [19].

A key first stage is, thus, defining the specific aims of each AES within the general goal of biodiversity conservation (Table 1, Fig. 1). Kleijn et al. [19] proposed that conservation of intrinsic biodiversity values (i.e. rare and endangered species) should be restricted to the extensive systems still maintaining these species. In these systems—typically occurring in many Mediterranean, Alpine and Eastern regions of Europe—conservation measures should include analyses of the responses of target species, beside a general assessment of changes in overall abundance and species richness [e.g. 24, 25]. Very few evaluations are available for this kind of system, however [5••]. On the other hand, conservation measures in intensive systems devoid of rare species may rather be aimed at the conservation of functional biodiversity (i.e. the maintenance of ecosystem services provided by biodiversity such as pollination or pest control [19]). The restoration of populations of species common before intensification but decreasing nowadays, when known (e.g. farmland birds), can also be a valid aim [5••]. Most available assessments, and the general ideas derived from their meta-analyses, have been carried out in these intensive systems [8]. Here, evaluations of effectiveness can be based on overall species richness and abundance metrics, assuming that ecosystem services are related to these simple community variables, or on surrogates of such functional diversity. Under these assumptions, it is valid to use species characteristics linked to specific functions (e.g. pollination, pest control), the number of functional groups, or species within a given functional group, instead of species identity, to calculate diversity [e.g. 26, 27]. For instance, Garibaldi et al. [28••] showed that farms with high richness of wild insects have higher levels of pollination. However, more research is still necessary to assess whether effective AES in terms of taxonomic or functional diversity are in fact effective in promoting ecosystem services.

Considering Field- and Landscape-Scale Requirements of Targets

Batáry et al. [5••] concluded their meta-analysis of properly designed AES assessments by stating that the main factors affecting the effectiveness of field-scale measures are land-use intensity and the ecological contrast created by AES, modulated by local and regional effects of the surrounding landscape, thus supporting the model proposed by Kleijn et al. [19]. Field-scale requirements (availability of food and cover; Table 1, Fig. 1) are usually addressed by means of measures applied within productive areas (on-field practices [5••, 28••]), such as reductions in pesticides, fertilizers or mowing operations. These measures aim at reducing land-use intensity within fields, and thus increase the ecological contrast with those fields that are farmed conventionally.

In addition, numerous studies emphasize the need for halting agricultural intensification impacts at both local (field) and landscape scales [10, 14, 16, 19, 21, 29, 30•]. For instance, richness of wild insects and pollination levels have been found to increase most with off-field practices aimed at increasing landscape heterogeneity, such as wildflower planting or restoring semi-natural habitats [28••]. These measures improved other ecosystem services as well (e.g. pest control, soil erosion mitigation, as well as scenic and cultural values). Scheper et al. [15•] showed that sown flower strips were the most effective conservation measure for pollinators, and that their effectiveness was mostly driven by the ecological contrast in floral resources created by their application. On-field practices like reduced pesticide application and mechanical operations, however, have also been found to increase wildflower plant richness [28••]. The results of Clough et al. [31] in arable-dominated landscapes surrounding semi-natural grasslands also emphasize that landscape management measures tailored to pollinators and the wild plants that they pollinate are both required. Hence, AES design should include measures to cope with the ecological needs of target groups at landscape scales as well (e.g. [32–34]; Table 1, Fig. 1), especially for groups or species that require different resources over their life cycles, require mosaic-like rather than continuous habitats, or have large home ranges [19, 21, 24]. In fact, many AES incorporate management prescriptions potentially useful to create mosaics or uncultivated refuges for species that perceive landscapes at higher scales than fields or farms, such as conservation headlands, pulse crops or buffer strips [5••, 32]. Reaching landscape-scale goals may be difficult, however, as it would require some coordination between AES management on multiple different farms, unless average farms where measures are applied were large enough to influence the landscape structure. Likewise, some of these off-field practices have been incorporated as compulsory greening measures in the last CAP reform. Insufficient uptake levels, even for supposedly compulsory measures, may, however, severely limit their effectiveness [6, 7••].

Considering Landscape-Scale Constraints Under a Functional Approach

Even if properly designed to enhance both within- and around-field requirements of target species, conservation measures may still fail to deliver significant ecological benefits due to landscape-scale and regional processes limiting effectiveness [10, 17–19]. Effectiveness (i.e. the difference in the of biodiversity or ecosystem service target measurements between conventionally farmed areas and areas that incorporate conservation measures) is expected to reach its maximum at intermediate landscape complexity levels, a pattern known as the 'landscape-moderated effectiveness hypothesis' [19] or the 'intermediate landscape complexity hypothesis' [29]. This hypothesis has been derived from the theoretical nonlinear relationships between landscape complexity and field-scale species richness, which interact with local management effects [10, 18]. Species richness at field scales generally increases from simple to complex landscapes because more diverse resources and dispersal corridors allow more species to coexist. Nevertheless, a minimum amount of unfarmed habitat and corridors would be necessary to maintain the presence of many species inhabiting fields. At the other extreme, a saturation point of landscape complexity would be reached, from where no further increases in species richness are expected (Fig. 2a). Such saturation may be due to full occupancy of fields by species coming from the species-rich surrounding landscape, or to potential negative effects of unfarmed habitats on open-country organisms inhabiting farmland patches [17, 18]. In any case, effectiveness (measured by some metrics, such as species richness) is expected to become null in both the simpler and the more complex landscapes, so that landscape complexity constrains, rather than only moderates, AES effectiveness (Fig. 2b). This non-linear model has been proven to be true in European agricultural land, both by means of experimental studies [10] and through meta-analyses [5••, 16]. It is based on the need for a minimum amount of semi-natural habitat around fields to support species within fields (lower threshold) and on an equilibrium distribution of the whole regional species pool over fields in the other extreme of the gradient (upper threshold at high complexity levels [17, 18]). The model, although developed and tested for species richness, may be potentially applied to any ecological variable showing a sigmoidal relationship with landscape traits (i.e. minimum requirements and saturation points where no further increases are possible due to space or resource constraints). Obvious relevant candidates are abundance of groups or target species, and most ecosystem services provided by farmland, although no evidence that such variables follow such a sigmoidal pattern has yet been found. This lack of evidence seems to be due to the large amounts of high-quality data required to test these non-linear models (e.g. [10]), although precise constraints may differ in practice for measures that are more sensitive to environmental variation than species richness. Explicit modeling approaches rather than meta-analyses are required to test the general applicability of models including thresholds [35].

Constraints on biodiversity responses due to non-linear effects of landscape complexity may interact with non-linear effects of land-use intensity [9], also reflecting from ecological theory ('intermediate disturbance hypothesis', which predicts peak diversity at intermediate rather than at undisturbed or heavily disturbed fields [9, 12] (Fig. 2c). Because of these non-linear relationships between field-scale intensity and biodiversity, the ecological contrast between conventionally farmed fields and fields that incorporate conservation measures will have much larger effects in extensive than in intensive systems (Fig. 2d).

Kleijn et al. [19] considered that the combination of both non-linear effects will still produce landscape moderation, i.e., higher effectiveness at intermediate landscapes and lower, but not zero effectiveness at the simpler and more complex landscapes. Effectiveness at simpler landscapes will, hence, be enhanced by means of measures providing high ecological contrasts at field scales, somewhat compensating for the negative effects of landscape-scale intensity on local diversity

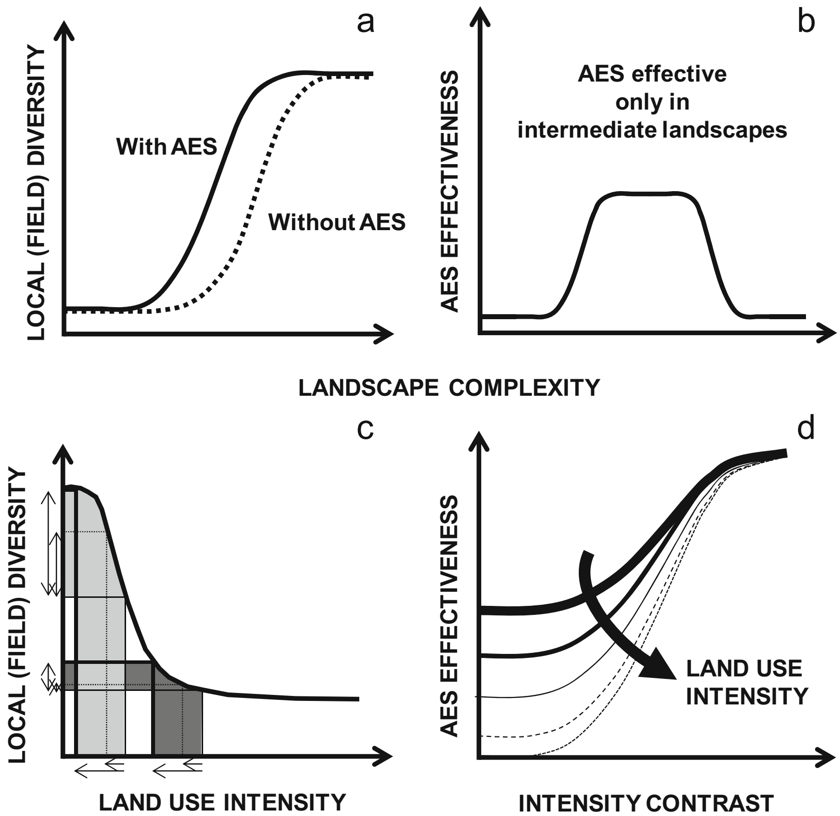

Fig. 2 Conceptual models depicting the consequences of non-linear relationships between landscape complexity (**a** and **b**) and land-use intensity (**c** and **d**) and field-scale biodiversity for the potential ecological effectiveness of agri-environment schemes (AES). Arrows near axes in **c** indicate the decrease in intensity achieved by the application of AES (X-axis) and the consequences of these intensity changes on field-scale biodiversity (Y-axis), in systems with low (*light grey*) and high (*dark grey*) overall levels of land-use intensity. Note that in the case of landscape complexity (**a** and **b**), the X-axes are the same, whereas for land-use intensity (**c** and **d**), the X-axes are different and in **d** indicate the intensity contrast (i.e. the reduction in land-use intensity accomplished by the application of AES) along hypothetical situations of increasing overall levels of land-use intensity, indicated by decreasing line width and dashing. After [9] and [18]

[15•, 16, 19]. Landscape moderation would, however, turn into landscape constraint in the simpler and more complex landscapes if upper and lower thresholds of landscape complexity on field-scale diversity are taken into account (Fig. 2). In both simpler and complex landscapes, complexity will constrain AES effectiveness to zero irrespective of ecological contrast. Increasing contrast will only increase maximum effectiveness between complexity thresholds at intermediate landscape complexity levels, either symmetrically, if there is no interaction between landscape complexity and field-scale intensity (Fig. 3a, b), or biased towards more complex landscapes, if increased landscape complexity is correlated with decreased land-use intensity at the field scale (Fig. 3c, d; [36]). Consequently, increased landscape complexity, besides favoring biodiversity [10, 21, 30•], will also enhance the effectiveness of measures aimed at reducing within-field land-use intensity, but only within landscape complexity thresholds [10, 18]. Overall, the combination of two key non-linear relationships between land-intensity at landscape and field scales generates highly variable expectations for AES effectiveness, a fact that may explain the highly unpredictable, mixed results of most effectiveness evaluations [5••, 8]. A further consequence of non-linearity is that the range of intensities of the system under analysis may uncover only part of the full intensity gradient, and this may bias results of intensity effectiveness evaluations [10, 18]. This fact requires explicit modeling approaches to test the general applicability of the model, as meta-analysis results may be biased by this property of non-linear relationships.

Field-scale land-use intensity can be estimated by means of several alternative mechanisms [e.g. 10, 37], all clearly linked to ecological mechanisms influencing local abundance or diversity (e.g. resource availability or disturbance regime) and usually tightly correlated [9]. Landscape complexity, however, is much more elusive to measure [19]. Complexity, as defined by Concepción et al. [18], refers to the amount and distribution of distinct landscape elements in relation to three main landscape gradients of functional significance for organisms inhabiting agricultural landscapes: field traits (size, shape, boundaries), landscape composition [of land uses,

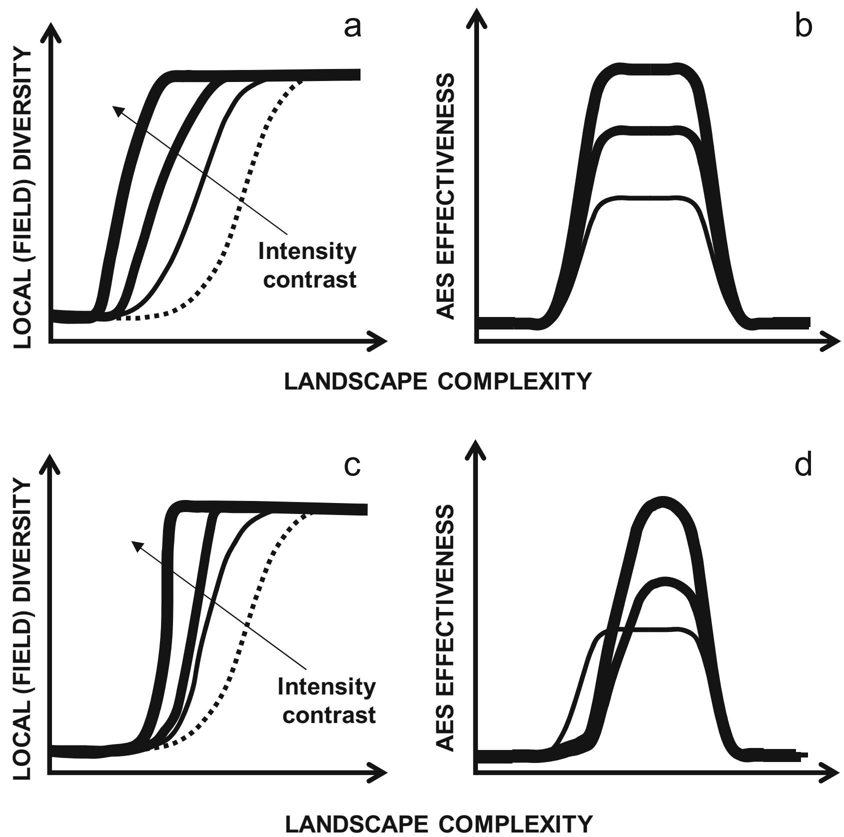

Fig. 3 Hypothetical combination of the effects of landscape complexity and AES-driven intensity contrast on the effectiveness of AES along gradients of landscape complexity, based on models shown in Fig. 2. The models **a** and **b** assume constant effects of ecological contrasts along gradients (i.e. no interaction among effects of landscape complexity and land-use intensity on field-scale biodiversity), whereas the models **c** and **d** try to incorporate non-linear effects of land-use intensity by assuming decreasing intensity, and, hence, increasing effectiveness for the same contrast, with increasing landscape complexity. Subsequently, maximum AES effectiveness would be reached at higher levels of landscape complexity when considering such potential interactions between landscape complexity and field-scale land-use intensity (*c* and *d*). Dashing in **a** and **c** and the thin line in **b** and **d** correspond to panels **a** and **b** in Fig. 2, and increased line widths indicate increased intensity contrast (reduction in land-use intensity accomplished by the application of AES)

including crop types and (semi-)natural habitats], and landscape connectivity [boundaries of (semi-)natural vegetation]. This functional approach implies that complexity will depend on how organisms perceive their immediate surroundings and how large are the spatial and temporal scales at which they perceive the landscape [38]. Most likely, organisms of different size, dispersal ability and life-span will perceive the same landscape at different scales, so that it may appear complex for large organisms with a long life-span and high dispersal abilities (e.g. large vertebrates) and simple for small and/or sessile organisms (e.g. plants or ground-dwelling arthropods [18]).

Landscape perception may also vary within groups according to habitat requirements or geographical origin [e.g. 24, 34]. In fact, recent reviews on how landscape traits may influence organisms' distributions in agricultural landscapes emphasize that landscape variables used to measure landscape composition, structure, connectivity and, ultimately, complexity [18] should be selected according to species' requirements and scales of perception, to reflect the functional consequences of landscapes for organisms [20]. Following this approach, characteristics of regional pools of target species are expected to influence threshold values of landscape complexity on the effectiveness of CAP greening measures. Consideration of regional influences on effectiveness becomes even more compelling when considering multiple taxa, farmland and crop types [10, 14, 30•], as well as response variables other than species richness and abundance, such as species composition, population trends, and functional and ecological traits [16, 19, 25, 30•, 31]. If prescriptions are not matched to perception and requirements of local species pools, conservation measures may be ineffective even if they have proven effective in other sites or landscapes (Table 1, Fig. 1).

A way of dealing with non-linear relationships is to divide them into categories based on threshold points. For instance, Batáry et al. [14] and Kleijn et al. [19] differentiated cleared (i.e. extremely simple) from simple and complex landscapes in their reviews and meta-analyses of the landscape moderation hypothesis using a threshold value of 20 % cover of natural vegetation (mostly woody) in the landscape. This value was inspired by Andrén's [39] highly influential paper on the effects of habitat fragmentation on animal communities, which was, in turn, derived from percolation theory as the threshold value for cover of the original habitat under which isolation of remaining habitat patches increases exponentially [39]. This theoretical setting will be useful, and, in fact, it was, for analyzing responses of forest and woodland organisms to changes in landscape complexity, assuming that complexity is correlated with the amount of woody vegetation in the landscape. This assumption may, however, fail to predict equivalent threshold values differentiating the simple and complex landscapes of Concepción et al.'s [18] model (Fig. 2). Such a complexity threshold will not be predicted to arise for forest organisms, since an increased proportion of woody habitat in the landscape will only favor them (i.e. no evident saturation point would be reached). However, following the same approach, a threshold for organisms linked to the open matrix will arise when cover of the original uncultivated woody habitat will reach 80 % of the landscape. This will mean that the proportion of open habitats, either cultivated or not, will be below a 20 % threshold of connectivity. At least for birds, farmland communities are dominated by ecotonic and forest species in most of Europe [e.g. 40], but by open-land, steppic species in the southwest and southeast [24, 41]. Measures aimed at increasing complexity in north and central European farmland usually are (rightly) based on the recovery of natural woody vegetation [e.g. 42], but these same measures are known to be harmful in other regions [43–45], since they do not contemplate the landscape-scale requirements of their regional species pools. These results have not yet influenced meta-analyses, probably because data for these regions are still scarce as compared to the rest of Europe [5••], but must be taken into account for further improvement of the effectiveness of CAP greening in terms of increased target diversity and/or ecosystem services.

Adapting Policy Instruments to Regional Landscape Constraints

Non-linearity of key factors influencing farmland biodiversity and particularities of regional species pools and target traits make effectiveness of CAP greening measures hard to predict. Differences in landscape complexity perception among target groups further increase both unpredictability and the design of AES aimed at enhancing multi-group diversity. For this reason, ex ante evaluations of potential effectiveness [e.g. 22, 32] are unlikely to be reliable except at a quite crude level. Guidelines for adapting policy instruments to this reality should then consider the key factors driving major changes in expected effectiveness: target-defined requirements and landscape constraints (Table 1, Fig. 1).

Once the regional stage is set, criteria for the application of available, or newly developed, policy instruments should be guided by target-defined landscape constraints. In simpler/cleared agricultural landscapes, compulsory measures aimed at recovering complexity levels should be the top priority. Note that 'cleared' would mean 'with low cover of natural vegetation' if targets are woodland or ecotonic organisms, but 'with low cover of open fields' if targets are linked to open land or steppes. Landscape extensification measures could be implemented in these landscapes by means of compulsory greening measures [7••, 46] or wide entry-level schemes (i.e. measures accessible to many farmers with a few simple prescriptions [47]). Landscapes with intermediate levels of complexity, either current or achieved by means of compulsory measures, are the ones in which to apply AES-based extensification measures, designed according to the targeted species, communities or ecosystem services on the basis of their requirements in terms of minimum ecological contrasts needed. In complex landscapes with high biodiversity levels, extensification measures would be ineffective for further increasing field-scale diversity ([10, 18]; Figs. 2, 3). Here, measures that support farmers to maintain already existing extensive land-use practices should be implemented through, for example, subsidized high–nature value farmland (HNVF) programs [48], or regional-scale conservation agreements [e.g. 49]. The goal here should be to prevent abandonment or change to financially more attractive land uses, such as afforestation or perennial crops, which may reduce landscape complexity at least for open-land farmland organisms [e.g. 43, 50].

Systematic Evaluation and Learning Process

Interactions between complex and varying organism responses to changes in land use, and the policies developed to preserve them by influencing land-use change, add further levels of uncertainty to the task of improving the conservation goals of CAP reforms. This goal may even approach the category of wicked problems, that is, problems difficult or impossible to solve because of incomplete, contradictory and changing requirements that are often difficult to recognize [51, 52]. Apart from trying to disentangle problem complexity by indentifying the main goals and key points generating wickedness [52], a way of improving effectiveness is to systematically incorporate feeding-up results of evaluations into the successive reform rounds of CAP greening following principles of adaptive learning processes (Table 1, Fig. 1; [53, 54]). Systematic, direct evaluations have been claimed from the first seminal papers that showed large variance in AES effectiveness [8, 12], even proposing robust evaluation designs based on well-known paired or BACI (before-after-control-impact) experimental designs [8, 19]. Unfortunately, knowledge accumulated through non-systematic evaluations carried out in a handful of countries does not seem to have generated more effective measures yet [5••], a fact that may be partly due to the long duration of schemes (5–10 years; [5••]). Feedback from these studies, as well as systematic evaluations for the systems, regions and targets still barely covered in the literature, are urgently needed to ensure that common European agriculture and the policies supporting it meet their goal to be wildlife-friendly.

Conclusions

Measures aiming at enhancing and maintaining the complexity of agricultural landscapes will not only favor biodiversity, but also enhance the effectiveness of measures aimed at reducing within-field land-use intensity over most of the length of many landscape gradients ([10, 21, 30•]; Fig. 3). Landscape-scale thinking is, thus, essential to improve conservation in farmland, and specific management recommendations should be formulated regionally due to non-linear effects of landscape- and field-scale land-use intensity that vary among target species, groups and ecosystem services.

It is urgent to incorporate all these ideas arising from recent research into CAP greening efforts, since effectiveness has not been improved after the 2007 CAP reforms [5••] and lack of improvement was not due to relevant gaps in knowledge, as the relevant research and subsequent recommendations were available well before. Moreover, the reformed CAP for 2014–2020 is unlikely to perform better, as potential effects of the incorporation of compulsory AES-like measures to compensate for low take-up of voluntary AES is counteracted by low regional targeting and a high number of exemptions and reduced requirements that are permitted for the application of many environmental prescriptions [7••]. Accordingly, the current CAP is likely to continue driving agricultural intensification, as well as abandonment of less productive land. Guidelines developed here may help to explicitly incorporate current knowledge on how and why agricultural land-use intensity gradients modulate and constrain biodiversity and ecosystem services at field and landscape scales. Now, it is just time to apply this knowledge to policy design and evaluation.

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Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Human and Animal Rights and Informed Consent This article contains no studies with human or animal subjects performed by the authors.

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