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农业景观异质性与生物多样性与生态系统服务的影响研究进展

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摘要: 农业景观是人类生活所需资料的最主要来源地, 农业景观及其提供的生物多样性和生态系统服务是影响人类福祉的最主要因素之一。系统梳理了景观异质性变化对生物多样性和生态系统服务影响的相关研究, 总结指出: (1) 农业景观格局变化会强烈的影响着区域生物多样性和生态系统服务, 但总体上更关注了空间异质性, 对于时间和功能异质性的研究仍需加强; (2) 尺度效应、大尺度上景观背景的差异、种间差异、营养级联效应等会对景观异质性和生物多样性、生态系统服务间的关系产生显著的、综合的、交互的影响效应。未来区域农业景观中如何通过景观构建和管理措施的施行来确保生物多样性与生态系统服务供给的持续稳定仍需进一步加强以下内容的研究: 景观异质性变化在时间上和功能上的影响效应及其阈值的探讨; 跨尺度、多因素、多物种类群与多生态系统服务的综合及其交互作用; 不同生物类群和不同生态系统服务间的权衡; 景观异质性提高与有效生境面积下降及其引起的生物随机丧失间的权衡等问题。

关键词: 景观异质性; 生物多样性; 生态系统服务; 尺度效应; 时滞效应; 种间差异; 营养级联效应

Impact of agricultural landscape heterogeneity on biodiversity and ecosystem services

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Abstract: Biodiversity and ecosystem services, a frontier and hotspot of international ecology and geography research, are key to realizing the healthy development of regional ecosystems. The well-being and survival of humanity depend upon the stability and sustainability of services provided by the agricultural landscape. This study systematically reviewed research on the effects of landscape heterogeneity on biodiversity and ecosystem services. We found that changes in the agricultural landscape pattern strongly impact regional biodiversity and ecosystem services. However, previous studies have focused more on spatial heterogeneity; research on the temporal and functional heterogeneity of landscapes still needs to be strengthened. In addition, the scale effects, differences in the large-scale landscape context, interspecific differences, and trophic cascade effects have significant, comprehensive, and interactive effects on the relationships between landscape heterogeneity and biodiversity and ecosystem services. In the future, research on how to ensure a stable and sustainable supply of

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biodiversity and ecosystem services through the methods of landscape reconstruction and agricultural landscape management at the regional scale should be further strengthened. Specifically, four potential limitations to further expansion must be addressed, including the effects of temporal and functional heterogeneity on biodiversity, ecosystem services and their thresholds at the landscape scale; the cross-scale, multi-factor, multi-species, and multi-scale integration and interactions; the trade-offs of different biological groups and different ecosystem services; and the trade-offs between improving landscape heterogeneity and decreasing the effective habitat area, as well as the loss of biodiversity caused by declining habitat area.

Key Words: landscape heterogeneity; biodiversity; ecosystem services; scale effects; time lag effects; interspecific difference; trophic cascade effects

生态系统服务(Ecosystem services)是指人类直接或间接从生态系统中得到的各种惠益^[1]。它的形成和维持是人类文明和社会经济持续发展的根基。在各种生态问题愈来愈严重的背景下,生态系统服务也已经成为当前国际地理学和生态学研究中最重要的前沿和热点问题之一^[2-4]。因为景观尺度上的研究能更有助于对生物多样性与生态系统服务(功能)的关系、生物多样性保护策略和生态系统服务维持等问题的解决^[5-6],尽管从景观尺度上探讨这些问题困难更大^[5],所以景观尺度是研究生态系统服务形成、维持和权衡的更佳尺度;同时生态系统服务只有在景观和区域等尺度上才能够得以充分地表达和为人类所感知,所以对生态系统服务形成和维持机制的研究以及管理措施的制订也应该从景观层次上进行探讨^[7-10]。

生物多样性是人类赖以生存的最重要的物质来源,也是生态系统功能形成和制约生态系统服务发挥的最关键因素之一^[11-16]。而随着人类活动的进一步加强,造成了地球上生物多样性的持续迅速丧失^[17]。其中由于农业用地扩张和集约化加剧引起的景观格局简化、景观破碎化、自然、半自然生境丧失等被认为是引起生物多样性快速下降的最主要原因之一^[18-20]。当前,在全球人口激增、粮食需求日益增加的背景下,为保障粮食供给,土地利用集约化程度日益增强,化肥、农药等大量施用,非农生境持续丧失,与之相伴的是农业景观中景观异质性的下降、生物多样性的持续丧失和生态系统服务的剧烈波动^[21-24],并使生态系统服务面临的威胁进一步增加^[25],而这种状况在发展中国家尤为严重^[26]。同时,作为地球陆地表面上最重要的一类景观和全球粮食供给的最主要来源,农业景观在维持生物多样性和生态系统服务中具有举足轻重的作用^[26-27]。

景观异质性(Landscape heterogeneity)是指景观及其属性的变异程度,它是景观生态学形成的基础与核心内容,也一直是景观生态学研究的最重要方向和内容^[28-29],它是许多基本生态过程和物理环境过程在空间和时间尺度连续系统上共同作用的产物,包括景观要素组成的多样性和景观要素空间格局及空间构型(configuration)的复杂性及其所产生的景观功能的多样性^[30]。景观异质性对于生物多样性的维持意义重大,而地球动物(包括人类和其他动物)都需要两种以上景观要素的事实也证实了异质性的重要性^[31]。

本文围绕农业景观异质性对生物多样性的影响、生物多样性与生态系统服务(功能)的关系、农业景观异质性对生物多样性与生态系统服务(功能)的影响效应等,对国内外相关研究进行系统整理,分别从不同景观异质性特征(空间异质性、时间异质性、功能异质性等)、尺度效应、景观背景及种间关系和种间作用等方面进行分析,探讨景观生态学研究在生物多样性保护和生态系统服务研究中的作用,以及该方向尚存在缺陷和不足的地方,以期服务于相关学科的发展(图1)。

1 生物多样性与生态系统服务的关系

随着人类福祉的提高,人类对众多生态系统服务(包括供给、支持、调节和文化服务等)的利用和需求都在持续增加和扩张,但全球尺度上除粮食生产供给之外的其他生态系统服务在过去50年中均呈持续下降的态势^[32]。如何维持生态系统服务的持续稳定供给成为影响人类福祉的最重要因素之一,生态系统服务的可持续利用也必将成为生态系统服务研究的重点内容^[33]。而生物多样性被认为是影响生态系统服务的最关键因素之一,Mace等认为生物多样性在生态系统中扮演了3个角色:生态系统过程的调节器(Regulator),最终

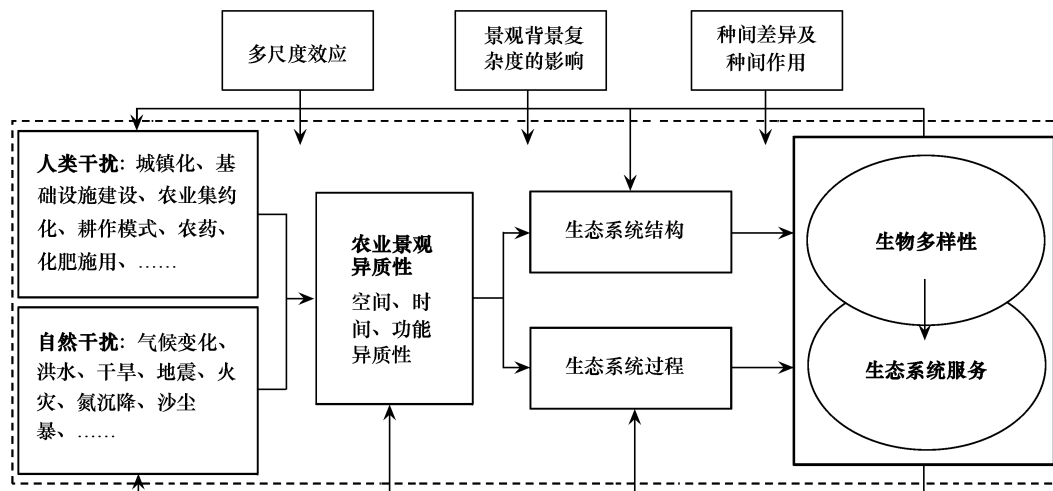


图 1 农业景观异质性与生物多样性与生态系统服务的影响

Fig.1 Impact of agricultural landscape heterogeneity on biodiversity and ecosystem services

的生态系统服务 (Final ecosystem service) 和生态系统的产品 (Goods), 即生物多样性一方面在生态系统服务中是一种重要的调节器和调节载体, 同时其本身也是重要的生态系统服务^[14]。而生物多样性的丧失将产生一系列的负面效应, 并引起多种生态系统服务的下降^[12], 因此谈及生态系统服务的产生、供给、维持和影响因素时是无法绕开生物多样性的。生物多样性保护的早期, 人们关注的是如何减缓生物多样性丧失的速度, 尤其是一些稀有种 (rare species) 的绝灭。随着“生物多样性公约 2010” (Convention on Biological Diversity's (CBD's) 2010) 目标的失败 (尽管人类做出了很多的努力来保护生物多样性, 但全球生物多样性丧失的速度并未能够减慢), 新的 CBD's 2020 目标认为生物多样性必须与人类福祉相结合, 重视基于生态系统服务的生物多样性保护, 同时只有充分考虑生态系统过程的时空变化才能更有效的保护生物多样性^[34-35]。同时, 越来越多的研究发现, 生物多样性保护尤其是政策的制定和施行也必须从景观的层次进行, 根据区域内不同尺度上景观结构的不同以及目标生物的差异采取针对性的保护策略^[8]。

关于生物多样性丧失对生态系统功能和服务的影响, 绝大多数的研究认为二者呈正相关关系 (即生物多样性的下降会引起生态系统功能 (服务) 的降低), 尽管有少量的研究认为在自然生态系统中这种状况或许不一定存在^[12,36], 但随着研究尺度的增大, 最新的研究进一步证实了生物多样性保护的重要性: 要维持自然系统中的生态系统服务 (传粉) 的供给必须有大量的物种多样性作为支撑, 且随着尺度的扩大, 更多的物种都变得更为重要^[6]。而通过在景观尺度上进行多样化作物的种植、构建花草带、树篱等方式在提高区域的景观异质性的同时, 提高了物种 beta 多样性, 保育了更多的传粉者, 从而有利于传粉服务的提供^[37]。

2 景观异质性研究

景观异质性是景观生态学的核心, 目前景观异质性研究主要侧重 3 个方面: 空间异质性、时间异质性和功能异质性^[38], 景观异质性是联系生态系统生态学和景观生态学的桥梁, 是生态系统过程和基本功能以及景观功能的基础和驱动力^[28,39], 早期关于景观异质性的研究主要集中在对景观异质性成因、景观格局指数的变化等方面^[40-42], 后来人们开始更多的关注景观异质性及其变化而引起的生态效应, 并取得了大量的研究成果。研究结果认为, 景观异质性会直接影响生态系统的多种属性, 如植物的传播、动物的运动、种群的维持、物种间的相互作用、生态系统的动态和基本功能等^[30, 43-47]。更多的研究证实从景观水平上探讨农业生产、非农生物多样性保护、生态系统服务维持是区域可持续农业景观构建的核心内容和基础^[7-8,30,48]。

3 农业景观异质性与生物多样性和生态系统服务的影响

农业景观是农田、草地、耕地、林地、树篱和道路等的镶嵌体, 表现为物种生存于其中的各类破碎化栖息地

的空间网格^[49],也可以认为农业景观是任何形式的农业活动在具体地域空间上的落实^[50]。在农业景观中,景观格局常常表现为农田、村落和自然、半自然生境相间的小尺度镶嵌体,由于自然和人类干扰的影响,农业景观格局的变化通过影响生物多样性与生态系统结构和功能而影响区域生态系统服务的形成及其表达与维持。研究发现,在农业景观中,景观异质性的变化会对农业区域内生物多样性产生重要影响,有时会比农业耕作方式的影响更为强烈和重要^[7, 51-54]。而景观的简化和异质性下降则很可能会引起物种多样性和生态系统服务的下降^[55]。

3.1 空间异质性

景观空间异质性是景观中的斑块类型、组合方式以及属性在空间上的变异程度,它包括空间组成、空间构型和空间相关等多个方面^[38],还是影响景观连通性、稳定性以及破碎化空间格局的原动力^[56]。为减缓农业景观中生物多样性快速持续下降的态势及其对生态系统服务引起的负效应,欧美多国于 20 世纪 90 年代分别提出了一系列应对计划和措施^[57-58],措施中主要包括在农业景观中保留自然和半自然非农生境、发展有机农业等。其后的大量实验研究显示:通过保留非农生境,开展有机农业等提高农业景观组成异质性措施的实施,有效的提高了植物、鸟类、地表动物等的物种多样性和部分生态系统服务(如天敌控制效应)^[59-62],而景观构型异质性同样会影响到不同物种的多样性和生态系统服务^[63-66],因此研究人员开始对组成和构型异质性对生物多样性影响的重要性进行比较。Jackson & Fahrig 通过模型模拟分析了破碎化景观中生境数量和景观构型间对种群遗传结构的影响效应,结果显示景观组成对种群遗传结构的影响更大^[67];Arroyo-Rodríguez 等的研究也发现在破碎化雨林景观中,景观组成对叶口蝠科物种多样性的影响要高于景观构型^[68];Santana 等对欧洲农业景观中探讨景观组成和构型异质性对农田鸟类多样性的综合影响效应时发现,景观组成对鸟类多样性的影响更为强烈和直接,而构型异质性的影响则相对要弱得多^[69]。随着研究的进一步深入,发现景观组成和构型会同时对生物多样性和生态系统服务产生影响,但其相对重要性会因生物类群、景观尺度、大区域景观背景、生态系统服务类别等的不同而引起一定的波动^[70-74]。如 Steckel 等在德国草地生态系统(包括粗放管理的草原和集约管理的牧草地)的研究发现,250m 尺度上的景观组成能有效的提高穴居蜂(cavity-nesting bees)和胡蜂(wasps)的物种多度以及胡蜂物种丰富度,而在 1500m 尺度上景观构型异质性提高了寄生率^[70]。Duflot 等在法国西部的农业景观中研究了景观组成和构型对步甲和维管植物 γ 多样性的相对影响效应,结果显示二者会同时影响步甲群落,而只有景观组成会影响到植物群落;且步甲种类组成差异会随着各景观中林-农覆盖比例和草-农边界长度的差异增大而增大,植物物种组成变化也因景观中农作物覆盖比例差异增加而增大^[73]。同时,由于景观构型的测算常常依赖于生境数量,因此在实际工作中要想分别独立测算景观组成和景观构型对生物多样性和生态系统服务的影响效应具有相当大的挑战^[30, 75],但该方面研究的进行对于揭示景观异质性对生物多样性的影响机制和制定更有效的保护策略具有重要意义^[76]。

3.2 时间异质性

景观时间异质性是指景观空间结构在不同时段的差异性^[38]。前期研究者多从景观格局动态变化的角度探讨了景观的时间异质性特征及其驱动因素^[77-80]。后来研究人员开始关注景观格局变化对生物多样性等的影响效应。由于历史数据的获取存在一定的难度,该方面的研究仍较少,但现有研究发现,景观异质性变化对生物多样性等的影响存在“时滞(Time lag)”效应,同时受“灭绝债务(Extinction debt)”的影响,生物多样性等的响应与景观异质性变化并不同步,而是存在一定的滞后,且这种影响效应会因物种类群的不同而存在显著差异^[81-85]。如 Parody 等通过对美国密歇根州北部 50 年鸟类调查数据的研究发现,随着土地利用方式和景观格局的改变,尽管区域内鸟类总物种丰富度基本没有变化,但其群落组成(功能群)结构却发生了显著变化^[81];Lindborg 在欧洲北部农业景观中探讨了与植物分布密切相关的 4 类生活史性状与当前和历史景观构型间的关系差异性,结果显示不同物种与当前和历史景观构型的关系存在显著差异,但从长远来看,历史上景观连接度和草地面积的下降将引起草地群落由越来越多的无性系繁殖长寿命植物和具备持久种子库的植物物种所占据。据此作者认为景观构型的时间与空间效应在塑造草地植物群落组成中同样重要^[83]。Krauss 等

通过对欧洲农业景观中 147 块残存半自然草地中的研究发现,景观格局的变化对不同生物类群产生影响的时间存在差异:当前草地专性维管植物(寿命长)物种丰富度与几十年前的景观格局间关系更为密切,呈现出明显的“灭绝债务”;而草地专性蝶类(寿命短)物种丰富度只与当前生境面积存在显著关系,与 40 年前的景观格局间的关系并不显著,即动物相比植物对景观异质性变化更为敏感^[85]。新近的研究开始关注其与空间异质性间的交互作用,及其对生物多样性和生态系统服务的综合影响效应^[19, 86-88]。

时滞效应、灭绝债务、连带灭绝(co-extinctions)效应^[89-92],以及景观格局各不同异质性特征间交互作用的存在,要求人们必须用长远和警惕的目光来看待和管理景观格局变化,现有的景观格局异质性的改变及其引起的生境丧失和破碎化等或许在当前并未引起大量物种多样性和生态系统服务的下降,但在不久的将来,可能就会引起灾难性的后果。但由于数据获取的限制性,景观格局变化对不同生物类群产生影响的具体时间仍不清楚,很多时候仍然只是推测。

3.3 功能异质性

关于景观异质性的分类之前主要分为组成异质性(compositional heterogeneity)和构型/结构异质性(configurational heterogeneity)两大类^[93],不管任何景观要素都可以直接定义为以上两类,但却完全不考虑其与不同生物类群间的关系和影响。很多研究发现不同生物类群/功能群对景观异质性指数的响应存在显著差异^[94],因此基于不同生物类群提出了功能异质性的概念^[30, 95]。研究人员基于功能异质性和功能连接度等角度探讨了景观异质性对鸟类^[95]、大型食草动物^[96]、传粉蜂类^[97]、大型兽类^[98]、昆虫^[99-100]等不同生物类群的影响效应。结果证实了功能异质性分类在探讨二者关系中的有效性。但由于功能异质性在类别划分过程中一方面缺乏统一的标准,另一方面关于各物种或类群对环境需要(如生境质量)的研究仍然缺乏大量的实验数据,因此功能异质性的研究过程中多采用定性或半定量的方法,缺乏定量研究。

3.4 景观异质性影响的多尺度效应

尺度问题始终是贯穿地理学和生态学研究的重要论题^[101],更是景观生态学研究的核心问题和学科特色所在^[29, 42]。景观异质性对生物多样性和生态系统服务的影响具有强烈的尺度效应^[102-105],一方面,物种多样性和生态系统服务对景观异质性指数存在一定的敏感(最佳)尺度^[106-107],另一方面不同的生物类群和生态系统服务类型对景观异质性的响应尺度(幅度和粒度)也是不一致的^[59, 85, 108-109]。如 Gabriel 等通过对不同空间尺度下有机农业措施对不同生物类群多样性的影响研究发现,草本植物、蚯蚓、传粉者、蝶类和地表节肢动物等在不同空间尺度上(田块、生境和区域)的响应和格局存在显著差异^[108];Krauss 等的研究发现,景观破碎化对植物和蝶类产生的影响在时间尺度上存在显著差异^[85];Mattsson 等的研究发现,在局地尺度上,景观异质性对鸟类集合的影响要比空间自相关更重要^[110]。同时,不同尺度上,人类活动和管理措施引起的生态效应也存在差异^[111-112]。生物多样性和生态系统服务的保护策略和措施必须在景观和区域尺度上才更具备可行性^[113],为保护生物多样性(不同生物类群)和维持生态系统服务(不同类型)而制定的措施不可能做到放之四海而皆准,必须考虑在不同尺度上的变化特征^[114-117]。由于景观异质性、群落结构、人类活动等影响因子间的交互复合效应的存在,如何定量拆分出各类因子对不同生物类群影响的相对效应及其随时空尺度的变化就显得尤为重要^[53, 118-119],而在景观和区域尺度上,当需要对多个生态系统服务和不同生物类群保护进行权衡时更明显^[120-121]。

3.5 景观背景效应

景观是空间幅度上一个相对的概念,小到几百平方米,大到几百、几千平方千米都可以称之为景观,因此谈论景观异质性的时候也存在这个问题。研究人员在探讨农业环境计划的措施对生物多样性和生态系统服务的影响效应时发现,取样区周边更大范围内的景观背景的异质性特征会对土地利用变化、景观异质性、农业管理措施等对生物多样性和生态系统服务的影响效应产生交互作用,并强烈地影响着保护措施的施行效用^[8, 53, 66, 122-124]。如 Rösch 等的研究发现,在简单景观背景下,景观破碎化与昆虫丰富度呈显著负相关,而在复杂景观中,这种负效应会消失^[125];Lindborg 等在有大量半自然草地残存的农业景观背景中研究发现,小斑

块生境中能保有更多的物种丰富度,但在高强度管理景观中,物种丰富度会随距离半自然景观的距离增大而减少,且会存在较高的 β 多样性^[126]。根据这些相关研究,研究人员提出了“中度景观复杂度假说 (intermediate landscape-complexity hypothesis)”:在简单景观中(只简单的用自然生境存在比例来表示,5%—20%的自然生境存在),有机农业、休耕地、半自然生境等的存在能显著提高非农生物多样性,而在复杂景观中这种效应则很难显现^[8,124,127-128]。但目前仍然缺乏更多的实证数据来验证该假说,尤其复杂度的界定阈值和指标仍有待于进一步探讨^[8]。

3.6 种间差异及种间相互作用

景观异质性对生物多样性的影响效应会因功能群、扩散能力、食性等的不同而存在显著差异^[76,94,108,129]。Bertrand 等在法国西部农业景观中研究了步甲对景观空间和时间异质性的响应,结果显示,尽管总物种多度随着时间异质性的升高而增加,但不同类群对空间和时间异质性的响应并不一致,扩散能力强的物种多度与空间异质性强烈正相关,而扩散能力弱的物种多度仅与作物的时间动态正相关^[87]。Carrara 等对鸟类的研究也发现,专性种 (specialist) 鸟类比广幅种 (generalist) 对景观异质性的响应更为强烈^[130]。为维持传粉服务的正常供给,人类大量养殖蜜蜂,但从景观和区域尺度上来看,农业景观中随着大量开花作物 (Mass-flowers crops) 花期过后,人工蜂会大量溢出到邻近的自然生境中并对其他野生传粉者产生强烈影响和伤害^[131-132]。同时,有研究发现,景观异质性变化对生物多样性影响负效应的产生主要源于专性种的下降,因为专性种更喜同构生境,而广幅种更倾向于异构生境^[133]。

由于营养级联效应的存在^[134-136],景观格局变化和人类活动对区域内生物多样性的影响会通过食物网在不同物种间进行传递,并进而影响着区域内部分生态系统服务的供给:如农田面积的增加尽管会减少区域鸟类多样性,但由于农田能提供更多的资源供鸟类、哺乳动物和蝶类等使用,因此会反而在一定程度上促进了这些物种的增加^[137]。因此,农林复合系统常能因有更高的果实多样性和多样化的群落结构而吸引更多的鸟类^[7,138],而某些鸟类的增加一方面会成为农业景观中控制虫害爆发的重要天敌生物^[139-140],一定程度上能提高作物产量^[141];另一方面也会通过营养级联效应改变原有的天敌控制系统^[140]。Weterings 等的研究还发现景观格局变化引起了水域和陆地上蚊子天敌种群的变化,从而进一步强烈影响到蚊子种群的变化,并进一步影响着登革热的扩散和传播^[136]。

4 展望

在全球变化与可持续发展的宏观背景下,农业景观的持续健康发展是关乎人类福祉的最主要因素之一,如何基于生物多样性保护和生态系统服务维持提出合理的保护策略和措施是当前的热点和难点,且仍存在着一些问题需要进一步探讨。

(1) 不同景观异质性特征对生物多样性和生态系统服务的影响效应、机制和阈值分析。目前关于景观异质性对生物多样性和生态系统服务的影响研究仍以空间异质性为主,时间异质性和功能异质性的探讨仍有待进一步加强。另外,尽管有研究证实了景观格局变化对生物多样性的影响存在“时滞”效应,但在不同尺度上、不同物种间该时滞的阈值仍不清楚。未来进行区域景观规划和生物多样性保护措施的施行时,必须重视评估当前的扰动在未来可能会产生的重大影响^[142]。

(2) 跨尺度、多因素、多物种类群与多生态系统服务的综合及其交互作用研究。景观异质性的变化会同步引起不同尺度上多种环境要素的改变,而不同生物类群和生态系统服务对这种变化的响应却存在显著差异。在未来的研究中一方面需要进一步明确物种对景观格局变化的响应尺度,从而能制定更有效的管理方案和措施,另一方面也需要从跨景观的多种尺度上出发,综合考虑多种因素的变化,从而进一步明确景观格局变化对区内及区外不同物种和生态系统服务所产生的不同后果^[143-144]。且目前有关生物多样性与生态系统功能(服务)间的关系研究多集中在中小尺度,而这种关系是否能够扩大到景观尺度上从而变为人类福祉所需的生态系统服务仍需要更多的探讨^[5]。

(3) 权衡的、综合的观点。不同生物物种多样性、不同生态系统服务间常存在此消彼长的态势。多数研究在探讨生物多样性保护时提出的景观规划建议多是基于一种或几种生物类群而提出的,但这种措施的施行很可能会对其他物种产生不利的影响,在采取措施以提高某种物种多样性或提高某项生态系统服务的同时,必须严格评估该措施的施行对其他物种或生态服务的负效应。如农业景观中自然、半自然生境的存在能有效提高生物多样性和生态系统服务,但在某些情况下也可能对生物控制服务产生负效应^[145]。

(4) 景观异质性与生境面积的权衡:大量的研究认为景观异质性的提高可以有效的增加区域物种多样性,但一方面景观异质性的提高可以增加生态位从而提高物种丰富度,另一方面随着异质性的提高将降低单个物种的可利用有效生境面积,因而会产生所谓的“随机绝灭”^[146-147],也就是生境面积与景观异质性的权衡(area-heterogeneity trade-off)问题。

尽管存在一定的争论和大量的科学问题待研究,但景观异质性貌似仍然是解决农业生产与生态功能间权衡的最有效手段^[148],将生物多样性与生态系统服务结合起来考虑是区域农业景观管理策略制定的未来^[149]。但由于不同区域的景观特征与生物多样性是持续易变的,同时具体的保护策略和措施又必须在景观和区域尺度上才更具备可行性^[150],所以保护生物多样性和维持生态系统服务而制订的保护措施不可能做到放之四海而皆准。农业景观中生物多样性保护和生态系统服务维持的持续性研究仍将任重而道远。

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