

青藏高原高寒草地的气候变化适应性管理探讨

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【摘要】青藏高原高寒草地生态系统的生物多样性在国家生态安全、食物安全和弘扬中华草原生态文明中具有突出的战略地位。但气候变化和人类活动的加剧对青藏高原高寒草地生态系统格局和功能产生了深刻影响。因此,本文提出了高寒草地适应气候变化的管理框架:首先,探究气候变化下高寒草地生态系统边界的迁移方向和速率,阐明气候变化对高寒草地生态系统格局和功能变化的调控机制。其次,基于生态系统多功能指标量化青藏高原高寒草地退化等级,并根据高寒草地健康等级状况,提出适应性的围栏生态保护管理措施。但是由于围栏工程对不同水热地区的高寒草地恢复效应具有时空异质性,因而需要利用高寒草地围栏联网控制实验,研究与高寒草地生态系统格局和功能变化密切耦合的控制要素,判断不同高寒草地生态系统功能恢复到自我可持续的关键阈值,并揭示稳态跃变的机理。同时,定期开展适应性管理的效应评估,判断是否需要改进管理体系,进而提出最佳的适应气候变化的管理策略。

【关键词】适应性管理;气候变化;高寒草地;生态系统功能;青藏高原

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1 气候变化和人类活动威胁高寒草地生态安全

2020年8月28日,习近平总书记在中央第七次西藏工作座谈会上强调“把青藏高原打造成为全国乃至国际生态文明高地”,为深入推进青藏高原生态保护和高质量发展指明了方向。

青藏高原山水林田湖草沙冰系统的生态文明建设离不开其高寒草地的适应性管理。脆弱而敏感的高寒草地是青藏高原主要的生态系统,面积近21亿亩(1.4亿公顷),占整个高原面积的53%左右^[1]。在国家生态安全、食物安全和弘扬中华草原生态文明中具有突出的战略地位^[2]。因此,高寒草地对青藏高原的生态文明建设极为重要。只有加强高寒草地适应性管理,才能实现青藏高原人与自然、人与社会和谐共生、良性循环、全面发展和持续繁荣^[1,3-4]。

具体而言,高寒草地具有支撑畜牧业发展、防风固沙、涵养水源、保持水土、调节气候和维护生物多样性等重要生态功能^[5-7]。如何针对不同高

寒草地生态系统进行适应性管理以推进生态文明建设是打造青藏高原生态文明高地的核心问题。青藏高原由于其地质、地貌和气候的多样性,形成了丰富的草原生物多样性^[8]。喜马拉雅山、喀喇昆仑山和昆仑山的联结,阻挡了印度季风和西风对青藏高原的水汽输送^[9]。但在高原“抽气系统”的影响下,东亚季风带来的水汽被源源不断地抽提到高海拔的青藏高原,因而在高原面上形成了从东南到西北递减的降雨梯度^[7]。受长期降水梯度的影响,植被类型分异明显,形成了高寒草甸、高寒草原和荒漠草原逐步过渡的草地生态系统多样性、物种多样性和景观多样性。

目前,青藏高原高寒草地生态主要面临着气候变化和人类活动两大挑战。有研究指出气候变化,特别是气候异常事件、夏季强降水是青藏高原植被变化的重要影响因素^[10-12]。气候变化与生态系统关键要素(植物—土壤—生物)的强烈相互作用改变群落植被物种组成、群落结构和功能,共同推动整个生态系统结构、物质循环和功能的平衡迁移^[13-15]。此外,持续减少的冻土活动层厚

度^[16],以及缺乏科学规划的围栏和放牧等生态系统管理措施导致部分地区草地发生严重退化,甚至沙化^[17-18]。气候变化和人类活动对高寒草地生态系统格局和功能产生深刻的影响,因此亟须通过对不同高寒草地生态系统资源进行长期监测,并提出适应性的管理措施,才能有效地推进青藏高原生态文明建设。

2 青藏高原高寒草地的适应性管理

气候变化和人类活动等诸多因素威胁着脆弱的高寒生态系统的可持续发展^[19-20],促使科学家审慎思考气候变化对于高寒草地现在和未来的影响,需要更科学合理的方法妥善管理高寒草地自然资源和生态系统^[17,21]。在应对气候变化和人类活动时,青藏高原高寒草地资源管理和生态系统管理措施缺乏系统性且具有诸多不确定性,这样的不确定性亟须一个能够容错、持续改进和不断创新的科学管理体系^[22],即适应气候变化和人类活动的管理体系(图1):在气候变化背景下,人类面临各种挑战,需要多尺度相结合研究生态系统格局与功能,明确草地健康属性,进而因地制宜地对草地进行分类—协调—合作,并基于管理措施中对环境—生物—土壤的动态监测,制定能够适应新环境的最佳管理策略,以促进生态可持续发展。

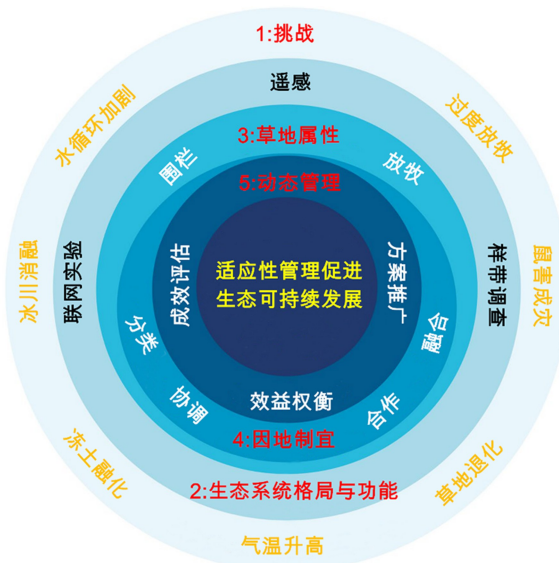


图1 适应性管理促进生态可持续发展

2.1 适应气候变化的高寒草地管理

适应性管理的对象是高寒草地,管理目标是

维持和改善高寒草地生态系统多功能。首先,气候变化对高寒植被地理格局和过程产生深刻的影响,但不同高寒草地生态系统对气候变化响应的表现形式不一致^[23]。而未来的气候变化将更为剧烈,对于敏感而脆弱的高寒草地生态系统而言,分析生态系统变迁阈值对未来气候变化的响应以及生态系统边界的迁移如何反过来影响气候变化的方向和速度尤为重要^[24]。但是,当前缺乏关于气候变化对青藏高原高寒草地生态系统变迁的调节机制及生态系统迁移对气候变化的反馈作用的系统性阐释^[25-26]。因此,充分研究高寒草地生态系统变迁过程中不同阶段植物—土壤—生物的动态特征和耦合关系,深入挖掘高寒草地迁移的机制和驱动力,明晰高寒草地变迁机理,尤其是生态系统跃变的关键生态阈值(图2),对完善高寒草地生态系统边界迁移理论和脆弱的生态系统保护和修复等至关重要,可为青藏高原生态安全屏障建设与生态文明建设提供科学依据。

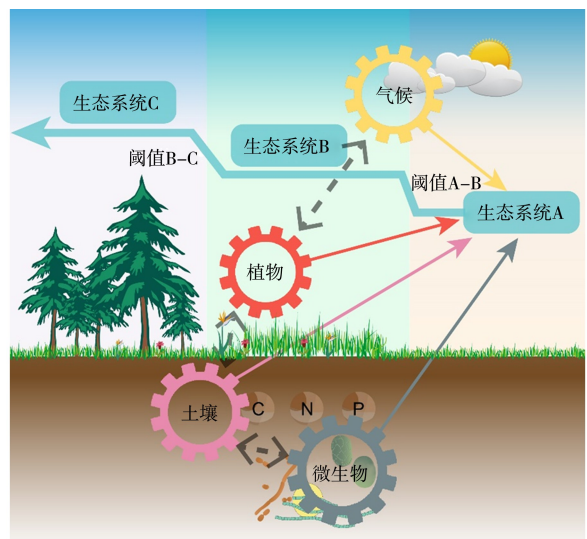


图2 气候变化驱动生态系统格局与功能迁移

2.2 退化高寒草地的适应性管理

针对草原退化制约牧区生产、生态建设及社会发展等重大问题,国家相继实施了一系列围栏措施^[17]。但以往对于不同草地类型退化等级划分标准并不统一,各种关键指标曾被用来进行等级划分^[27-31]。多样的草地退化等级划分造成退化评估存在很大的不确定性^[32-33],并不能满足适应性管理的需求。因为草地退化被定义为草地生态系统多功能的丧失,因此可以采用生态系统多

功能指数作为诊断草地退化与否的指标^[34]。本研究认为应基于生态系统多功能指数对青藏高原高寒草地生态系统退化重新进行退化等级划分,并根据草地健康状况,提出因地制宜的适应性管理政策(图3)。具体而言:在生态功能重要、生态环境敏感脆弱区外围必须围栏(比如冻土融化严重的地区,在发生冻融后,减少人类干扰,防止冻融次生灾害发生);对未退化或者已经恢复的草

地,进行适度放牧,以实现系统效益最大化;对潜在退化和正在恢复的草地,要继续加强围栏管理,以提升生态系统多功能(比如鼠害严重的地区,要加强生物防治、生态防治,不要化学防治);对重度退化和水热条件不好的草地,可以选择人工补播结合土壤养分及微生物调控等重要辅助措施严格进行围栏管控,始终坚持生态优先的适应性管理政策。

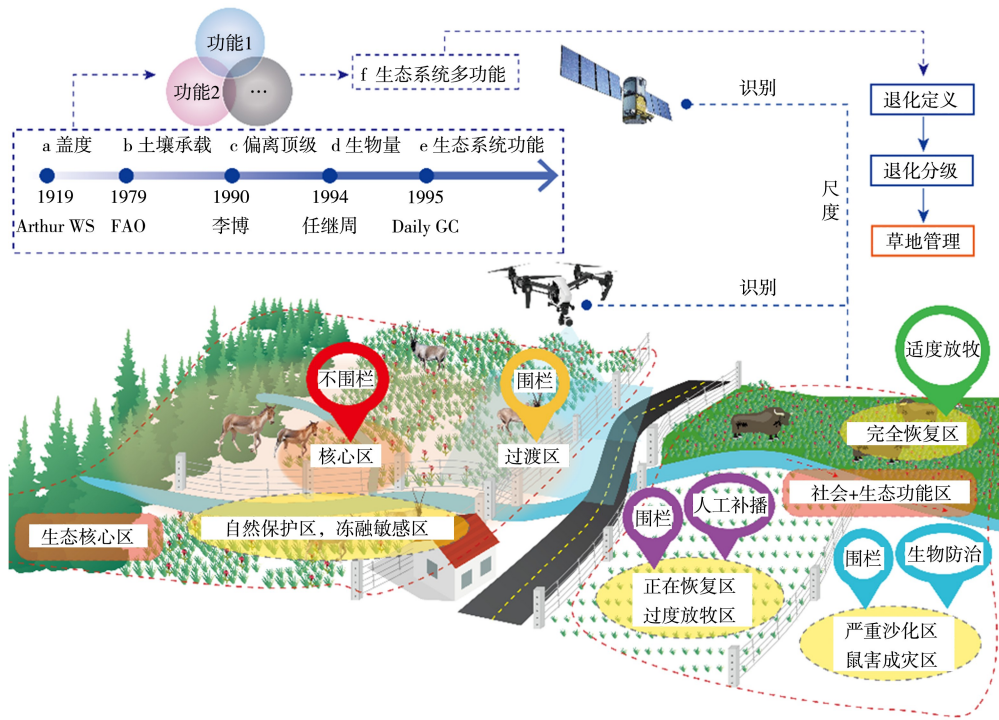


图3 高寒草地状态诊断及管理

2.3 适应高寒草地管理的优化围栏政策

虽然合理设置草原围栏可以提高生态系统功能,恢复退化草地的生产力,遏制草地退化趋势^[17,35-36],但围栏工程对生态系统功能的效应具有时空差异性^[17]。

首先,不同水热梯度和草地类型导致围栏对生态系统功能的作用并不一致,且作用的关键生态阈值与机理未知^[17]。温度和水分是影响青藏高原高寒草地生态系统生产力的重要因子^[4],但围栏时不同高寒草地类型功能对温度和降水变化的敏感性并不相同^[37-38]。比如,对于干旱和半干旱地区的高寒荒漠草原和高寒草原而言,围栏对土壤和植物固碳功能没有显著影响,却能显著增加湿润地区高寒草甸的固碳功能^[39]。

其次,围栏年限对高寒草地生态系统多功能

有正面或负面的作用。短期围栏短禁牧提高了植物物种多样性和生产力^[2,17],围栏内植被得到保护,草本植物生长茂盛,光合作用强,生态系统功能得到提升^[39]。但更长时间的围栏却会给生态系统功能带来负面作用^[17,40]。比如,有研究表明,短期(≤ 5 年)和中长期(5—15年)围栏封闭管理导致土壤pH值分别显著降低了0.09和0.27($p < 0.001$)^[41],围栏后土壤pH值的减低不仅导致物种多样性的丢失,也不利于土壤微生物的生存和多样性维持^[42]。

可见,由于受气候、植被群落结构、土壤养分和微生物等多因素的交互作用,不同围栏年限对高寒草地生态系统功能的效应具有时空差异性^[17,36]。要想揭示其中的关键生态学过程与机理,需要对不同水热地区、不同围栏年限下高寒草

地生态系统功能的关键生态要素进行监测和阈值研究(图4),并通过分析生态系统功能对环境 and 围栏梯度的非线性响应特征及状态转变机理,提出适应高寒草地管理的优化围栏政策。

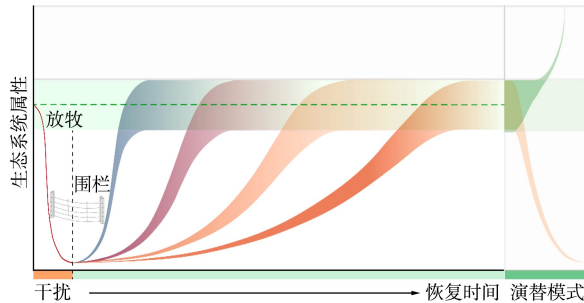


图4 围栏工程对高寒草地生态系统功能效应阈值的诊断

2.4 高寒草地适应性动态管理框架

针对上述青藏高原高寒草地生态系统保护和修复中面临的关键问题(气候变化与人类活动驱动高寒草地生态系统结构、格局、过程与功能的变化),我国应尽快部署相关领域的重点研发计划,组织多部门形成研究团队进行联合攻关;构建卫星—无人机—地面生态系统综合立体监测与评估体系,建立健全长时间序列、全数据项的高质量数据库和生态环境监测网络,掌握气候变化后生态系统格局与功能迁移状况,确定草地健康和恢复情况,判断生态系统功能何时已经转换为自我持续性状态与程度,并引入第三方评估机制和公众参与机制,综合考虑生态效益和经济效益,定期开展适应性管理的效应评估,判断是否需要持续改进管理体系,从而设计出最佳的适应性管理策略(图5)。

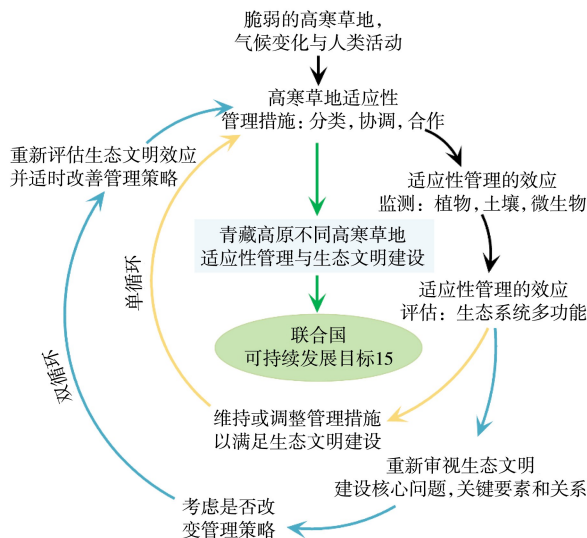


图5 高寒草地适应性动态管理框架

3 结论

青藏高原未来气候变化、人类活动的加剧和不稳定性的增加,势必对高寒草地生态系统格局与功能产生强烈的影响,这对高寒草地的生态保护、体系优化、生态治理修复、生态文明建设等提出了更高要求。因此,本研究提出了高寒草地适应性管理体系,并基于过去环境变化管理措施中的可控结果,制定能够适应新环境的最佳管理策略,以提高管理决策的科学性。适应气候变化和人类活动的管理体系着重强调对不同高寒草地生态系统的关键生态要素进行长期监测,并对生态系统结构、功能和过程变换进行解析,明晰高寒草地生态系统格局和功能跃变的关键驱动阈值和机理。这对探寻气候变化背景下生态系统演替机制、生态系统功能变化和恢复机理有着重要意义,并可为高寒草地应对气候变化提供预警,为青藏高原生态文明建设提供技术支撑。

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Climate change adaptive management of alpine grassland on the Tibetan Plateau

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Abstract: The biodiversity of the alpine grassland ecosystem on the Tibetan Plateau plays an important role in national ecological security, food security and promoting the ecological civilization of the grassland. However, climate change and the intensification of human activities have generated a profound impact on the distribution and function of alpine grassland ecosystem on the Tibetan Plateau. Therefore, the paper proposes a management framework for alpine grassland adaptation to global climate change; firstly, exploring the migration direction and rate of alpine grassland ecosystem boundary under climate change, and further clarifying the regulatory mechanism of climate change on the change of alpine grassland ecosystem pattern and function; moreover, the degradation levels of alpine grasslands on the Tibetan Plateau should be quantified based on multi-functional ecosystem indicators, and adaptive fenced-ecological protection and management measures should be proposed according to the health status of alpine grasslands. However, the restoration effect of the fencing project on the alpine grassland in different hydrothermal areas has spatial and temporal heterogeneity. Therefore, it is necessary to use the fence network control experiment of alpine grassland to study the key control elements that closely coupled with the change of alpine grassland ecosystem pattern and function, and to determine the key threshold for the restoration of different alpine grassland ecosystem functions to self-sustainable, and to reveal the mechanism of the steady-state transition. At the same time, the effect of adaptive management should be evaluated regularly to determine whether the management system needs to be improved, so as to propose the best management strategy to adapt to global changes.

Keywords: adaptive management; climate change; alpine grassland; ecosystem function; Tibetan Plateau