

# 中国生态 交错带

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## ECOTONE OF CHINA

中国环境科学出版社

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ECOTONE OF  
CHINA

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中国生态评估

Ecological Assessment of China

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## 中文摘要

生态交错带 (Ecotone) 是生态系统中凡处于两种或两种以上的物质体系、结构体系、能量体系与功能体系之间所形成的生态界面, 以及围绕该界面向外延伸的过渡带空间域 (牛文元, 1990)。由于生态交错带具有边缘效应的显著性、植被分布的非连续性、景观结构的异质性、生态界面的波动性、环境的脆弱性以及物质与能量的高流动性等自然属性, 已成为当今生态学研究的重要区域之一。

中国地域广阔, 自然环境复杂多变, 人文历史变革源远流长, 孕育着具有不同尺度、不同类型和不同环境特征的生态交错带, 如森林草原交错带、农牧交错带、荒漠绿洲交错带、海陆交错带等。选取典型生态交错带, 深入研究其空间分布规律、自然环境特征、景观动态格局及其生态脆弱性, 有利于全面掌握生态交错带的自然演变规律, 为促进区域生态保护与优化经济发展提供必要支撑。

(1) 森林草原交错带 (Forest-steppe ecotone or Forest-grassland ecotone) 是一类典型的生态交错带, 它是以草原植被为主体, 景观上呈森林与草原两类植被镶嵌或插花分布, 结构上具有显著边际效应或过渡带特征的一个呈连续分布的空间域。在中国境内, 森林草原交错带主要分布于北方温带区域, 主体位于东北平原西部, 内蒙古高原东部的温带草原区和河北坝上高原山地森林外围区, 环境特征为年均降水量 350~500 mm, 平均海拔 600~950 m, 湿润度 0.6~1.0, 林草地面积占区域总面积 80%以上。

过去 50 年, 随着全球气候变化和人类活动的共同影响, 交错带林

线上移、植被退化、草地沙化、水土流失日趋激烈，并已严重制约区域资源环境、经济社会的可持续发展。以水热因子、植被特征、土地利用与景观格局变化为基础，运用农业气象学、群落生态学、景观生态学以及环境生态学等理论和方法，分析了区域群落结构、物种多样性水平、土地利用及景观格局动态变化规律，对森林草原交错带边界变迁进行了定量判定；建立了包括自然因素、人为因素和经济表现与社会表现在内的生态脆弱性评价指标体系，运用主成分分析和 GIS 相结合的方法，综合评价了森林草原交错带的生态脆弱性，明确了区域生态脆弱性时空特征及其诱发因素，为有效制定科学合理的生态保护模式提供理论依据。

(2) 北方农牧交错带 (Farming-pastoral ecotone) 是我国农业区与牧业区之间的过渡地带，在景观上表现为草地、林地和农田的大面积交错分布，在经济结构上表现为种植业、畜牧业和林业多种生产方式并存格局。

北方农牧交错带处于亚洲季风的尾闾，由于年际降水变率较大，导致交错带土地利用方式频繁转变，并促使农牧界线多次进退。为深入研究北方农牧交错带界线变迁的生态效应，从自然气候和土地利用两个方面对交错带的地理界线进行了重新界定，为客观分析其历史演变规律及其驱动力奠定了科学基础。同时，利用遥感和 GIS 技术，结合生态学方法，以北方农牧交错带近 20 年植被 NPP 和覆盖度变化为基础资料，探讨了气候和土地利用变化对交错带植被的影响，并从景观生态效应角度揭示了交错带界线变迁引起的生态系统结构变化和生态系统服务功能的价值变化规律，不仅丰富了全球气候变化和土地利用变化对区域生态系统的影响及其理论内涵，而且对调整土地利用政策、增强适应气候变化能力和提升生态系统服务功能辐射效应具有重要科学价值。

(3) 西北荒漠绿洲交错带 (Desert-oasis ecotone) 是中国西部地区

贴近绿洲边缘的荒漠地带，地貌上主要分布于西部干旱、寒冷地区的山前地带、山间盆地、河流谷地及丘陵平原等地带，空间上呈现零星分布状态，在地理区域主要分布在河套平原外围、贺兰山以西、河西走廊、天山南北、乌鞘岭、祁连山、阿尔金山、昆仑山以北广大绿洲边缘地区。

荒漠绿洲交错带全年气候极端干旱，年降水量多数地区不足 200 mm，蒸发量大于 2 500 mm，而且昼夜温差大，风沙活动强烈，农牧业自然灾害发生频率大；主体植被为稀疏灌丛化草地，植物种类少，群落结构简单，植被覆盖度平均在 10%~30%之间，是一个发育在西北干旱极干旱地区绿洲边缘的非线性生态过渡带。荒漠绿洲交错带主要生态问题是气候持续干旱，山体雪线上移，水资源极度短缺，土地荒漠化趋势激烈，生态环境极度脆弱。在 ArcGIS 软件的支持下，利用不同时段 TM 和 MODIS 影像资料，对荒漠绿洲交错带生态环境脆弱性进行综合评价，结果表明，我国的荒漠绿洲交错带中等以上脆弱面积已占到区域总面积的 67.2%，而且，区域风沙活动强烈，天然植被严重退化，荒漠化面积呈持续扩展态势。主要驱动因素是受全球气候变化和强烈人为活动的共同影响，水资源的极度短缺，加剧了区域生态系统的退化过程。因此，确立基于水资源承载力的区域生态保护与建设模式是实现可持续发展的有效途径。

(4) 西南川滇农牧交错带 (Farming-pastoral zone of the Chuan-Dian region in China) 是我国中东部农业区向西部青藏高原牧业区过渡的东西向农牧交错带的代表区域，也是农田、林地、草地在垂直带上分布比较明显的典型交错带。有关西南川滇农牧交错带的地理界定和空间分布，迄今为止仍存在着较大的学术争议，而且随着人为经济活动的日趋频繁，人口—资源—环境之间的矛盾日益突出，生态退化、水土流失导致社会贫困不断加剧。选择西南川滇农林牧交错带，开展交错带地理界定和生态脆弱性评价研究，以期为区域生态保护和可持续发

展奠定科学基础。

以农业气候指标为主、结合农业经济指标和土地利用指标对西南川滇农林牧交错带进行了地理界定,结果表明,西南川滇农林牧交错带在空间上主要分布在海拔 2 500~4 500 m,  $\geq 10^{\circ}\text{C}$  积温等值线 500~4 000 $^{\circ}\text{C}$ , 最热月平均气温  $\geq 10^{\circ}\text{C}$ 、最冷月平均气温  $\geq -10^{\circ}\text{C}$  的范围之内。借助 RS/GIS 技术方法,利用 1988 年、1995 年和 2000 年三期 TM 数据,分析了西南川滇农林牧交错带自然环境特征、景观格局时空变化及其对生态系统服务功能的影响,表明不合理的土地利用方式和资源开发模式,是加剧区域生态退化过程的主要因素。提出用生态敏感度、生态弹性度和生态压力度作为区域生态脆弱性评价的基本判定指标,并运用综合指数法、层次分析法和 RS/GIS 相结合的评价方法,对区域生态脆弱性进行了综合评价,明确了区域生态现状及其诱发因素,提出了切合实际的生态保护和建设的对策建议,为促进区域可持续发展和维护长江中上游生态安全提供了科学依据。

(5) 海陆交错带 (Marine-terrestrial interlaced zone) 是近岸海洋生态系统与陆地生态系统之间的过渡区或生态界面。我国地处太平洋西岸,海陆疆域辽阔,海陆交错带面积约 10 万  $\text{km}^2$ , 南北地跨温带、暖温带、亚热带和热带四大气候区域,是我国生物多样性的富集区和关键物种的重要栖息地。主要包括河口生态系统、湿地滩涂生态系统、沿海潮间带生态系统、红树林生态系统、珊瑚礁生态系统、海湾生态系统、岛屿生态系统等多种类型。

20 世纪以来,由于现代化工业化进程的不断加快,海陆交错带生态环境受到不同程度的影响,主要表现为气候灾害频发,海岸带侵蚀加剧,滩涂湿地面积不断减小,土壤次生盐渍化加重;水体污染严重,红树林、珊瑚礁、滨海湿地等海岸生态系统持续退化,系统自净能力减弱,生态系统服务功能下降等。因此,充分利用 3S (GPS, GIS, RS) 技术,开展海岸带生态安全性评估,科学划分海岸带生态功能区,建



立自然保护区和重要生态功能保护区，并利用生物技术和工程技术相结合的方法修复受损生态系统，是当前和今后一段时间面临的主要问题，也是提升海陆交错带生态服务功能的有效措施。

**关键词：**生态交错带；空间分布；环境特征；生态脆弱性评价；可持续发展

## **Abstract**

Ecotone is the ecological interface formed between two or more of the material system, structural system, energy system and functional system within the ecological system, as well as the transitional space unit extending from this interface (Niu, 1990). Due to its characteristics of marginal effects, noncontinuous vegetation distribution, heterogeneous landscape structure, undulating ecological interface, fragile environment and high fluidity substances and energy, ecotone has become one of the important research fields of ecology study today.

Because of the vastitude of territory and complexity of natural environment, as well as the long history of human reform, China is endowed with different types of ecotones with different dimensions and various environmental characteristics, such as forest-grassland ecotone, farming-pastoral ecotone, desert-oasis ecotone and marine-terrestrial ecotone. The selection of a typical ecotone and then intensive study on its spatial distribution pattern, environmental characteristics, dynamic landscape structure and ecological fragility are useful for fully grasping the natural/evolutional law of the ecotone and providing necessary support to promote the regional ecological conservation and optimize the economic development.

(1) Forest-steppe ecotone (or forest-grassland ecotone) is a typical ecotone which is dominated by grassland vegetation, it's a continuous space

unit where the landscape is covered by the alternating forests and grasslands and the structure is the marginal effects or transitional zones. In China, forest-steppe ecotone is mainly distributed in the temperate zone in northern provinces and the main part is in the west Northeast Plain. The temperate grassland is in the east part of Inner Mongolia Plateau and the peripheral areas of the highland forest is in Bashang Plateau of Hebei Province, as to its environmental characteristics: the annual precipitation is 350~500 mm, the average altitude is 600~950 m, the humidity is 0.6~1.0 and the area of forest and grassland accounts for over 80% of the total area.

During the past 50 years, with the concern impact of global climate change and human activities, the forest line of the ecotone has risen to a higher altitude, the vegetation degradation, the grassland desertification and the water and soil erosion has been aggravated, which has severely restricted the sustainable development of the regional resource environment and the social economy. Based on the hydrothermic factors, vegetation features, land utilization and the change of landscape structure, uses agricultural meteorology, community ecology, landscape ecology and environment ecology to analysis the regional community structure and the level of species diversity as well as land utilization and dynamic change of landscape structure for making a quantitative judgment on the boundary movement of the forest-steppe ecotone. The indicator system of ecological fragility assessment has been established comprising natural factors, human factors, economic performance and social performance, a comprehensive assessment has been conducted to the ecological fragility of the forest-steppe ecotone by using the method of main factor analysis and GIS technology, and the spatial-temporal characteristics and causative factors of regional ecological fragility have been found out, so as to provide the

theoretical basis for effectively formulating the scientific and reasonable mode of the ecological conservation.

(2) Northern farming-pastoral ecotone is the transitional zone between China's farming land and pastoral land. It is a large area alternating distribution of grassland, forest land and farming land, and in terms of economic structure and manifested as the coexistence of crop farming, animal raising and forestry.

Located in the tail of the Asian monsoon and because of the fluctuation between annual precipitations, the pattern of land utilization in northern farming-pastoral ecotone has changed frequently, and the boundary between farming land and pastoral land has moved back and forth repeatedly. In order to further study the ecological effects caused by the boundary movement of the northern farming-pastoral ecotone, the geographical boundary of this ecotone has been redefined in the aspects of natural climate and land utilization, which has provided the scientific basis for conducting an objective analysis on its historical evolution pattern as well as its driving force. At the same time, by using remote sensing technology, GIS technology, the method of ecology and based on the basic data on the change of vegetation NPP and cover degree of the northern farming-pastoral ecotone in the past 20 years, the impact on the ecotone vegetation caused by climate change and land utilization have been explored, and the law of the ecosystem structural change and the value change of the ecosystem service function caused by the boundary movement of the ecotone have been disclosed in the angle of landscape ecological effects, which has not only enriched the theoretical connotation of the impact on and response to regional ecosystem by global climate change and the change of land utilization, but also provided the important scientific meaning for

strengthening the capability of adapting to climate change and enhancing the radioactive effects on the service function of the ecosystem.

(3) Northwest desert-oasis ecotone is the desert zone close to the oasis in western region of China , which sporadically distributed in the foreland, basins, valleys, hills and plains in the western arid and cold region and geographically located in the peripheral areas of Hetao Plain, western areas of Helan Mountain, Hexi Corridor, southern and northern part of Tianshan Mountain, as well as the peripheral areas of the big oasis lying north to Wushao, Qilian, Altun and Kunlun Mountains.

In desert-oasis ecotone, the climate is extremely arid all year round, with annual precipitation less than 200 mm but evaporation larger than 2,500 mm in most areas. In addition, the temperature between daytime and nighttime is large, there is also strong movement of sandstorms causing frequent natural disasters to the agriculture and animal husbandry. The main vegetation is the sparse shrub grassland with few types of plants, simple structure of the community and 10%~30% average vegetation coverage, so it is a nonlinear ecological transitional zone developed in the marginal area of the oasis in northwestern arid and extremely arid regions. The mainly ecological problem in desert-oasis ecotone is the continuous arid climate, the rising snow lines in mountain, the extremely shortage of water resource, the increasingly serious land desertification and the extremely fragile eco-environment. With the support of ArcGIS and by using TM and MODIS images taken from different periods, the results of the comprehensive assessment on the ecological fragility of desert-oasis ecotone showed that the area of desert-oasis ecotone with medium-above fragility has reached 67.2% of the total area in the region, and due to strong movement of sandstorms and the serious degradation of the natural vegetation, the

desertification area is growing. The main driving factor is the extremely shortage of water resource caused by global climate change and intense human activities which have escalated the degradation of the regional ecosystem. Therefore, the establishment of the mode of regional ecological conservation and construction based on the carrying capacity of the water resource is the effective way for realizing sustainable development.

(4) Chuan-Dian Farming-pastoral ecotone of southwest China represent the area of the east-to-west farming-pastoral ecotone transiting from the eastern and central agricultural regions to the western pastoral region of Qinghai-Tibet Plateau, which is also a typical ecotone with distinctive distribution of farming land, forest land and grassland in an altitudinal belt. As to the geographical definition and spatial distribution of the farming-pastoral ecotone of Chuan-Dian region in southwest China, there are still dispute in the academia, on the other hand, with the increasingly frequent human economic activities, the population-resource-environment conflict is becoming more and more serious, and the social poverty caused by ecological degradation and water and soil loss has become more and more severely. Therefore, the farming-pastoral ecotone of Chuan-Dian region in southwest China has been chosen for conducting research on the geographical definition and ecological fragility of the ecotone, so as to provide a scientific basis for regional ecological conservation and sustainable development.

Based on the indicator of agricultural climate, the agricultural economic indicator as well as land utilization indicators, geographical definition has been conducted on the farming-pastoral ecotone of Chuan-Dian region in southwest China, The results showed that the spatial distribution of this ecotone is mostly within the area at the altitude of

2,500~4,500 m where the accumulated temperature isoline is  $500^{\circ}\text{C} \sim 4000^{\circ}\text{C}$  and the average temperature of annual hottest and coldest months are  $\geq 10^{\circ}\text{C}$  and  $\geq -10^{\circ}\text{C}$  respectively. By using RS/GIS technology and based on TM data of 1988, 1995 and 2000, analysis has been conducted on the characteristics of the natural environment of the farming-pastoral ecotone of Chuan-Dian Plateau, the spatial and temporal change of the landscape structure and its impact on the service functions of the ecosystem. The results showed that irrational pattern of land utilization and resource exploitation is the main factor accelerating the regional ecological degradation. Ecological sensitivity, ecological flexibility and ecological pressure have been proposed as the basic indicators for assessing the regional ecological fragility, and by using the composite index, analytic hierarchy process and RS/GIS technology, comprehensive assessment has been conducted on the regional ecological fragility, as a result, the regional ecological status and its causative factors has been defined, and the recommendations suitable for practical ecological conservation and construction have been proposed, which has provided a scientific basis for promoting regional sustainable development and maintained the ecological safety in the upper and middle reaches of Yangtze River.

(5) Marine-terrestrial ecotone is the transitional area and the ecological interface between coastal marine ecosystem and land ecosystem. China, located in the west bank of Pacific Ocean, has large area of territorial land and sea. The area of marine-terrestrial ecotone is about  $100,000\text{km}^2$  where the temperate zone, warm temperate zone, subtropical zone and tropical zone are ranging from north to south, thus forming the biodiversity concentrated area and the important habitat for keystone species. The main ecosystems include estuary ecosystem, wetland ecosystem, ecosystem of

inter-tidal zone in coastal areas, mangrove ecosystem, coral reef ecosystem, gulf ecosystem and island ecosystem.

Since the beginning of the 20<sup>th</sup> century, due to the accelerating industrialization, the eco-environment of the marine-terrestrial ecotone has been influenced by the frequent climate disasters, aggravating coastal erosion, shrinking area of wetland, aggravating soil secondary salinization, serious water pollution, continuous degradation of the ecosystems of mangrove, coral reef and coastal wetland, weakening capability of system self-cleaning, and declining service functions of the ecosystem. As result, based on the fully use of 3S (GPS, GIS, RS) technology, scientific division of the ecological function areas in coastal belt and construct nature reserve, important ecological function conservation areas and restoration of the damaged ecosystem through using biotechnology and project technology would become the main challenges at present and in the future, which is also the effective measures for improving the ecological service functions of marine-terrestrial ecotone.

**Key words:** Ecotone; Spatial distribution; Environmental characteristics; Ecological fragility assessment; Sustainable development



# 前 言

生态交错带 (Ecotone) 是指两个群落或两类生态系统之间的过渡带, 具有脆弱、敏感和易变等特性。生态交错带自 1905 年由 F. E. Clements 提出以来, 历经一个世纪的研究与发展, 其生态学理论已在社会实践中得到了深化和完善, 并对指导生态环境保护和工农业发展发挥了重要的指导作用。特别是 20 世纪 70 年代以来, 在典型生态系统研究的基础上, 生态交错带逐步成为生态学研究的重点。

生态交错带具有特定的自然属性, 如边缘效应的显著性、植被分布的非连续性、景观结构的异质性、生态环境的脆弱性等。这些独特的自然属性决定着生态交错带研究对探索自然生态规律和保护生态环境具有重要且不可替代的科学作用。生态交错带既是生物多样性丰富地区, 也是全球气候变化敏感区。近年来, 有更多的研究从遗传水平探索生态交错带生物多样性产生的原因, 认为生态交错带栖息地的多样化创造了物种形态的多样化, 并随之产生了可遗传的多样化物种。环境梯度的变化可能导致物种形态的变异、交配方式的变异, 生殖隔离通过生态交错带进化并延续。

随着全球气候变化研究的不断深入, 许多科学家着眼于生态交错带对全球变化的响应与反馈机制研究, 认为生态交错带是一个对水热环境变化极其敏感的地带, 温度升高、气候干旱对生态交错带植被变化有显著影响, 如森林向草地的侵入、荒漠向绿洲的侵蚀、海岸带的退蚀等。为此, 生态交错带越来越引起科学家和政府官员的关注。

中国地域广阔, 地质、气候、植被等生态类型复杂多变, 孕育了不同类型、不同尺度和不同规模的多种生态交错带, 不仅为科学研究