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基于元胞自动机的喀斯特石漠化格局模拟研究

Pattern simulation of karst rocky desertification based on cellular automata

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作者	单位	E-mail
王晓学	中国科学院生态环境研究中心城市与区域国家重点实验室, 北京 100085; 北京林业大学水土保持学院, 北京 100083; 中国科学院研究生院, 北京 100049	
李叙勇	中国科学院生态环境研究中心城市与区域国家重点实验室, 北京 100085	
吴秀芹	北京林业大学水土保持学院, 北京 100083	wuxq@bjfu.edu.cn

中文摘要:

西南喀斯特山区的石漠化问题是目前我国西部地区最为突出的地域环境问题之一,其迅速发展已经严重影响到当地人们的生产生活。以导致石漠化发生发展的自然、人文因子为切入点,通过模拟影响喀斯特系统地表覆被变化的基本生态过程(如植物定居、植物死亡、水蚀风蚀引起的土地退化以及岩石成土过程等),利用随机元胞自动机具有的简单邻域规则产生复杂空间格局的特点,使喀斯特系统地表覆被植被-裸土-裸岩状态在一定概率下发生状态转换,并结合RS和GIS技术,构建了简单、有效的喀斯特石漠化模拟及预测模型(KarstCA)。以典型喀斯特石漠化地区关岭县为研究区,在自然、人文驱动因素共同影响以及只考虑自然驱动因素情景下,KarstCA模型模拟的研究区2007年石漠化空间分布格局的差异主要分布在中部和南部,其主要是不同空间范围上人类活动作用方式和强度差异所致。在16a中(1992-2007年)喀斯特地区地物(植被-裸土-裸岩)丰度变化成非线性关系,当植被覆达到54%以上并继续增加时,裸岩发展趋势与之呈明显的负相关($P<0.01$)。在模拟期内人类活动对研究区石漠化的发展起到抑制作用,人类活动的正效应(植树造林等)与负效应(乱砍滥伐、过度放牧等)在一定程度上抵消了植被总面积的剧烈变化趋势。将地表过程耦合进元胞自动机模型,突破了以往该类研究只通过概率考虑状态转换,而对其机理认识的不足;同时本研究考虑了自然、人文驱动因素在不同空间尺度上作用于石漠化现象的复杂性,对于探索这些因素是如何作用于地表过程及其贡献率等研究具有一定的参考价值。

English Summary:

Desertification in the karst mountain regions of southwest China is one of the most challenging environmental issues in western China because of its severe negative effects on the local community. Based on natural and cultural factors that cause rocky desertification occurrence and development, a simple, effective simulation and prediction model for karst rocky desertification was constructed to gain an improved understanding of the process and mechanism of rocky desertification development (KrastCA). This model effectively incorporated ecological processes, including plant colonization, plant mortality, land degradation, and soil formation with the local facilitation of the plant. The random cellular automata model, which can generate complex spatial patterns via simple rules, was employed to make state transition between vegetation, bare soil, and rock in a certain probability. Combined with the remote sensing(RS) and geographic information system(GIS) technology, rural settlements were extracted from TM image, and vegetation-bare soil-rock composition abundance images using the linear spectral unmixing approach, which is the initial state of the KrastCA model. The typical karst areas in Guanling County were selected as the study areas. KarstCA model simulation results performed better forecast (73.4% accuracy) when natural and human factors were considered compared with incorporating only natural factors (56.7% accuracy). This outcome suggests that the model used in this study effectively incorporated the key ecological processes that affected rocky desertification occurrence and development. By considering both natural and human factors and natural factor alone, KrastCA model indicated that spatial distribution differences in rocky desertification mainly focused on the center and north of the study area in 2007, which mainly depended on the intensity and scales of human activities. The land cover (vegetation, bare soil, and rock) in karst regions showed nonlinearity during 1992 to 2007 (16 years). The trend of vegetation covering ≥ 54% showed a significantly negative correlation with rocky areas ($P<0.01$). This finding strengthens the importance of vegetation in combating rocky desertification. Human activities hampered the development of rocky desertification in the study area during the simulation period. To some extent, the positive effects of human activities (e.g afforestation) and the negative effects (e.g deforestation, overgrazing, etc.) partially counteracted the dramatic changes in the vegetation area. However, the landscape tended to fragmentize. This study attempted to couple the surface process model into the cellular automata model, breaking through the previous study modeling surface process only by the state transition probability, and lack of understanding its mechanism. In addition, this study took into account the complexity of natural and human drivers in different spatial scales to act on the rocky desertification. The findings of this study shed light on the effects and contributions of these factors on surface processes.

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地址:北京海淀区双清路18号 邮编:100085 电话:010-62941099 E-mail : shengtaixuebao@rcees.ac.cn