

Spatial variation in ecosystem service relationships in alpine ecosystems: A case study of the Daxing'anling forest area, Inner Mongolia

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Abstract: **【Objective】** To achieve sustainable ecosystem management, it is necessary to understand the complex relationships among multiple ecosystem services (ESs), especially in alpine ecosystems of the Northern Hemisphere where ESs have undergone significantly degradation. Therefore, a comprehensive exploration must be performed, from multiple time and spatial scales and perspectives, into the relationships between and spatio-temporal changes of different ESs under climate warming. **【Method】** We selected the Daxing'anling forest area, Inner Mongolia (DFAIM), which is both a sensitive, alpine ecosystem and an important ecological barrier in northern China, as the study area. We analyzed the local and overall relationships among four key ESs, soil conservation, water yield, carbon storage and habitat quality, using multiple methods at different time and spatial scales in 2013 and 2018. Further, we used the K-means clustering to identify ecosystem service bundles (ESBs) at different scales, and we proposed sustainable management strategies to optimize the ESs in this alpine ecosystems. **【Result】** The main findings were as follows: (1) Most ES pairs had very significant synergistic relationships, but their synergistic strength did not increase from 2013 to 2018. The high-high synergies were mainly concentrated in the central DFAIM, while trade-offs and low-low synergies were concentrated in areas with more human interference. (2) Trade-offs dominated the relationships among all four ESs, which were widely distributed and significantly increased over time. The high synergies among all ESs were concentrated in the central and southern parts, but they decreased significantly over time. (3). The optimal number of ESBs in the DFAIM was 5 in both 2013 and 2018, at both the grid-scale and the forest management unit-scale. The distribution of ESBs was more fragmented at the grid-scale, but was relatively aggregated at the forestry management unit-scale. Changes in ESBs at the forestry management unit-scale became more pronounced over time. **【Conclusion】** The local relationships between ES pairs were moderated and synergistic, but became more competitive over time. The overall relationships of the four ESs were dominated by trade-offs, with a significant increase in trade-off effects over time. Therefore, we suggested using our proposed ESB to optimize ES management. These results can guide the implementation of sustainable integrated management strategies to optimize ESs supply levels in alpine ecosystems.