采煤沉陷生态修复工程近地表特性

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摘 要:【目的】采煤沉陷对矿区生态环境问题产生恶劣影响，周边人民生活和生产质量严重下降，资源开发与环境保护问题和建设用地与工矿用地问题成为矿区社会经济发展的突出矛盾之一。为响应国家打造绿色矿山的政策，一系列采煤沉陷生态修复工程相继推出，明确采煤地表塌陷对矿区生态恢复工程的影响，探寻因地适宜的沉陷区生态林退化的更新复壮技术，为风沙采煤沉陷区植被恢复及衰退林的保育提供理论依据和科学手段。【方法】采用对比分析和时空互代法，从植被配置模式（5a 小叶杨（*Populus simonii*）、20a 小叶杨、20a 沙柳（*Salix psammophila*）、20a 沙蒿（*Artemisia desertorum*）、20a 小叶杨+沙柳、20a 沙柳＋沙蒿、2a 杨柴（*Hedysarum laeve*））、工程年限（2、5、20a）2 个方面，研究鄂尔多斯市伊金霍洛旗采煤沉陷生态修复工程实施过程中林下植被特性、地表生物结皮、枯落物蓄积量和含水量、土壤温度、湿度和土壤养分等变化特征。【结果】结果表明：工程年限为 20a 的乔灌混交型（小叶杨＋沙柳）和乔木（小叶杨纯林）、灌木（沙柳纯林）型样地较灌灌混交型（沙柳＋沙蒿）和半灌木（沙蒿）、草本（2a 杨柴）型样地更有利于提高林下植被多样性，且小叶杨＋沙柳乔灌混交型样地的林下植被地上生物量、枯落物量、地下生物量、土壤有机质、全氮与全磷含量均显著高于其他 6 种样地。小叶杨+沙柳样地的生物结皮从盖度和厚度来判断发育程度最佳、20a 小叶杨林地次之，杨柴样地和沙蒿样地无结皮。随年限延长，小叶杨林地林下植被多样性、枯落物量（增加 59.78%）、枯落物自然含水率（增加 56.53%）、土壤温度（增加 3.97%）、有机质（增加 24.81%）及全氮（增加 21.44%）含量呈递增趋势，土壤全磷（减少 13.00%）、含水率（减少 3.13%）递减。【结论】不同配置模式中，小叶杨＋沙柳乔灌混交型样地各项指标综合表现最佳，随工程年限延长，对促进采煤沉陷区生态修复、植被演替、植被生产力提升、矿区土壤肥力提高等作用愈强。建议该区域采煤沉陷生态修复工程中应推广小叶杨+沙柳乔灌混交型模式为主，以期为采煤沉陷区植被建设取得更好的生态效益。

关键词: 采煤沉陷区；生态修复工程；植被特性；生物结皮；土壤肥力

Near-surface characterization of coal mining subsidence ecological remediation projects

Abstract:【Objective】Coal mining subsidence has a bad impact on the ecological and environmental problems in the mining area, and the quality of life and production of the neighboring people has seriously declined, and the problems of resource development and environmental protection, as well as the problems of land for construction and land for industry and mining, have become one of the prominent contradictions in the socio-economic development of the mining area.In response to the national policy of building green mines, a series of coal mining subsidence ecological restoration projects have been launched one after another, to clarify the impact of coal mining surface collapse on the ecological restoration projects in mining areas, to explore the renewal and rejuvenation techniques of ecological forest degradation in subsidence areas suitable for local conditions, and to provide theoretical basis and scientific means for the restoration of vegetation cover in the wind and sand mining subsidence areas and conservation of declining forests. 【Method】Using comparative analysis and spatiotemporal

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intergenerational method, we investigated the understory vegetation in the implementation of the coal mining subsidence ecological restoration project in Yijinholo Banner, Ordos City, in terms of the vegetation configuration pattern (5a *Populus simonii*, 20a *Populus simonii*, 20a *Salix psammophila*, 20a *Artemisia desertorum*, 20a *Populus simonii* + *Salix psammophila*, 20a *Salix psammophila* + *Artemisia desertorum*, 2a *Hedysarum laeve*), and 2 project years (2, 5 and 20a), to study the change characteristics of understory vegetation characteristics, surface biological crust, deadfall accumulation and water content, soil temperature, humidity, and soil nutrients during the implementation of the ecological restoration project of coal mining subsidence in YijinhuoLuo Banner of Ordos City.【Result】The results showed that the tree-irrigation hybrid (*Populus simonii* + *Salix psammophila*), tree (*Populus simonii* pure forest) and shrub (*Salix psammophila* pure forest) types with a project period of 20a were more conducive to increasing the diversity of understory vegetation than the shrub-irrigation hybrid (*Salix psammophila* + *Artemisia desertorum*), half-shrub (*Artemisia desertorum*), and herbaceous (2a *Hedysarum laeve*) types, and that the above-ground biomass, litter, below-ground biomass, soil organic matter, and the content of total nitrogen and phosphorus of the understory vegetation in the *Populus simonii* + *Salix psammophila* tree-irrigation type was significantly higher than that in the other six types of sample sites.The biological crust of the *Populus simonii* + *Salix psammophila* was the best developed in terms of cover and thickness, followed by the 20a *Populus simonii* stand, and no crust in the *Populus simonii* and *Artemisia desertorum* sample. The understory vegetation diversity, litter volume (increased by 59.78%), litter natural water content (increased by 56.53%), soil temperature (increased by 3.97%), organic matter (increased by 24.81%), and total nitrogen (increased by 21.44%) contents of the poplar woodland showed an increasing trend with the extension of years, while the soil total phosphorus (decreased by 13.00%), and the water content (decreased by 3.13%) showed a decreasing trend. 【Conclusion】Among the different configuration modes, the *Populus simonii* + *Salix psammophila* tree-irrigation type sample plot has the best comprehensive performance of various indicators, and with the extension of the project period, it has a stronger role in promoting the ecological restoration of the coal mining subsidence area, vegetation succession, the enhancement of the productivity of the vegetation, and the improvement of the soil fertility in the mining area, and so on. It is suggested that the *Populus simonii* + *Salix psammophila* arbor-irrigation type model should be promoted in the ecological restoration project of coal mining subsidence in this region, to achieve better ecological benefits for the construction of vegetation in coal mining subsidence areas.

Key words: soil fauna; mixed modes; community structure; functional group; larch plantations.