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Effects of biological soil crusts on soil fertility restoration in the hilly Loess Plateau region, China

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Soils in the Loess Plateau region of China, with its deep, loose loess (a loamy eolian deposit), was extremely erodible, fragile, degraded and continuously losing its productivity due to severe water erosion. With a module of more than10 000 Mg km^{-2} yr^{-1}, soil erosion used to be the most serious ecological issue in the region. Therefore, an eco-project named "Grain for Green" that aimed to rehabilitate the degraded ecosystems through vegetations restoration in the western parts of China, including the Loess Plateau region since 1999. The major approach of the "Grain for Green" project was converting low-yielding farmlands on slopes of 25˚or more back into wood or grass lands. Biological soil crusts (biocrusts) formed and developed quickly on soil surface in the abandoned slopes along with vascular plants succession due to the reduced human disturbance. In the hilly Loess Plateau region, biocrusts had been shown to form on the soil surface in the first year following cropland abandonment and only a further eight to ten years for biocrusts to achieve a coverage of 70%-80%, which exerted profound effects on soil properties and stability.

In the study, soil nutrients, including total nitrogen (TN), available nitrogen (AN), total phosphorus (TP), available phosphorus (AP), available potassium (AK) and organic material (OM), were investigated in 0 to 40years revegetated grasslands with biocrusts developed in order to determine the role of biocrusts in soil fertility restoration. The acetylene reduction assay (ARA) and a semi-open countertop CO_2 gas exchange system under controlled laboratory conditions were used to explore the rates of nitrogen and carbon fixation in biocrusts layer. Field plot experiment was conducted to monitoring the losses of nutrients with runoff and sediment. The results indicated that there was a significant increase in soil nutrients contents in the soil of biocrusts and the 2cm beneath biocrusts. Soil nutrients accumulation rates with developing ages of biocrusts showed an exponential relation during the first 20 years. The average contribution of 1 m^2biocrusts on nutrients accumulation in 0-4cm soil per year during the first 20 years were approximately 50.15 g OM, 1.95 g TN, 0.44 g TP, 0.16 g AN, 0.01 g AP and 0.13 g AK.

The reasons of the effects of biocrusts on the nutrients accumulation were laid in the N and C fixation function in organisms of biocrusts and sediments loss controlling from slopes. The average N-fixation rates in the activated cyanobacteria and moss dominant biocrusts in the research region were 197.5 $\mu molC_2H_4 \cdot m^{-2} \cdot s^{-1}$ and 121.7 $\mu molC_2H_4 \cdot m^{-2} \cdot s^{-1}$, respectively. The C fixation rates (net photosynthesic rates) were 1.9 umol $CO_2 \cdot m^{-2} \cdot s^{-1}$ and 5.0 umol $CO_2 \cdot m^{-2} \cdot s^{-1}$ for the activated cyanobacteria and moss dominant biocrusts. The results of the field runoff plots showed that 30-60% soil loss was reduced by the early developed cyanobacteria biocrusts, and no soil loss was found in the well developed moss dominant biocrusts plots. Therefore, although the content of soil nutrients was increased, there was no significant increase in soil nutrients losses with sediment. Results of the study suggested that biocrusts played a significant role in the degraded ecosystem restoration for its contribution on soil nutrients accumulation and soil stability in the hilly Loess Plateau region.