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Original Research Paper

Study on Vegetation Recovery of Gas Fields in Sichuan Province, China

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ABSTRACT

Many gas fields are located in China. During the exploitation and transport of gas, environmental effects are unavoidable. In order to analyse the vegetation recovery of gas field in Sichuan Province, the vegetation growth in gas field and around the gas field (undisturbed field) was investigated via plot survey. The vegetation diversity, biomass and recovery period in gas field and undisturbed field were compared. The results showed that (1) recovered gas fields were dominated by grass species, (2) the full recovery of biomass and vegetation coverage requires 3 to 5 years, and (3) the recovery of species diversity takes more than 7 years. This research is beneficial for the environmental restoration of gas fields in southwest China.

INTRODUCTION

Many gas fields are located in Sichuan Province, China (Ran et al. 2005). Because of the area's complex geology, the exploitation of gas has a significant impact on the surrounding area, which is in need of environmental protection (Racicot et al. 2014, Gomiero et al. 2013, Kumpula et al. 2012, Soromotin 2011, Penning et al. 2014). According to its function, gas exploitation can be classified into the construction of the gas field, pipelines, crossing projects, roads and stockyards. Each practice has a unique impact on vegetation (Xu & Liu 2007).

The construction of a gas field leads to permanent land-use change (Wang 2009). The former forest or farm land is seriously disturbed and converted into highly compacted roads and buildings. The recovery of vegetation is low in this area. The construction of a pipeline is small-scale, with a short disturbance period and limited effects on vegetation (Fan et al. 2010). However, in more complex landforms, severe erosion may occur during large rainfall events, so timely protective measures, such as planting grass, are necessary (Sidorchuk & Grigorev 1998, Zuazo & Pleguezuelo 2009). Buildings across roads or rivers temporarily disturb vegetation, which can rapidly recover with adequate precipitation (Liu & Gao 2012, Cheng et al. 2003). The most significant impact during gas exploitation results from the construction of roads. During this activity, the natural vegetation is cleared while lands are flattened and compacted. Human disturbance is high, even after construction, so the recovery of vegetation is difficult. Sewage reservoirs are temporary, and their effects on plant growth differ according to the components of the sewage. If the components are advantageous to plant growth, then vegetation recovery will improve; however, if the components are harmful to plant growth, then vegetation recovery will be hindered, and the soil may be contaminated.

The recovery of a gas field is an important aspect of environmental recovery (Yu et al. 2002). This research focuses on the recovery of roadside slopes, pipelines and sewage reservoirs because of the characteristics of gas exploitation and the climate of Sichuan Province.

STUDY AREA

The study areas included the Moxi, Jinhua, Longgang, Pingluo and Zitong gas fields, which are located southeast of Chengdu, Sichuan, China (E92°21'-108°12', N26°03'-34°19'), which has a subtropical humid monsoon climate. The average temperature of the coldest month is 5-8°C and the average temperature of the warmest month is 26-29°C. The frost-free season ranges from 280 to 350 days. The active cumulative temperature above 10°C ranges from 4500 to 6000°C. The annual precipitation ranges from 900 to 1200 mm.

The landforms in the study area are basins and hills. The soils are atteration, including purple, yellow and paddy soils. The study area is within the main crop area in Sichuan Province. The surrounding areas are farmlands and forests with complex plant cover and high species richness. The native vegetation is subtropical evergreen broadleaved forests, dominated by bamboo, pine, cypress, *Quercus paulownia, Metasequoia,* mulberry and *Citrus* trees.

MATERIALS AND METHODS

Sample plot selection: The gas fields are located in hills and plains. According to the conditions of vegetation recovery, 200 grass plots were selected. Along each pipeline and road, 5 plots were selected (1m × 1m for grass plots). In other study areas, 5 grass plots were selected.

The slope aspect, slope position, degree, longitude, latitude and elevation were measured in each plot. The species, number of individuals, average height, ground cover and above-ground biomass were recorded for the grass plots. The species, number of individuals, average height, canopy and coverage were recorded for scrub plots (Zhang et al. 2013, Zhang & Yang 2014a,b). The fresh biomass weight was measured in the field and then oven-dried (80°C) to measure the dry weight. The species, coverage, height and life forms (climb, intercrescence and parasitism) were recorded for vines.

Calculating the vegetation indicators: Three indexes were applied to evaluate the vegetation diversity. Richness index (Ma) (Ma et al. 1994a), Simpson index (D) (Ma et al. 1994b), Pielou evenness index (J) (Onaindia et al. 2004).

$$IV = RH\,I + RCO + RFE \quad ...(1)$$

Where, RH I is the average relative height; RCO is the relative coverage; and RFE is the relative frequency.

$$Ma = (S-1)/\ln N \quad ...(2)$$

$$D = 1-\Sigma Pi^2 \quad ...(3)$$

$$J = H/Hmax \quad ...(4)$$

Where, S is the number of species in a sample plot; N is the number of individuals in a sample plot; Ni is the number of individuals of the species i; Pi = Ni/N; H = -ΣPilnPi; Hmax is the maximum H, Hmax = LnS.

Both data analysis and data process were conducted using Excel 2010.

RESULTS AND ANALYSIS

The gas fields disturbed the forests, grasslands and farmlands. Farmland was excluded in this research. Gas exploitation has avoided disturbing farmland as much as possible. Most disturbed lands recovered as grasslands and some of them recovered as scrublands. The construction of roads disturbed grasslands and scrublands. A few pipelines crossed forests dominated by *Pinus massoniana, Cupressus funebris* and *Podocarpus nagi*, where the ground cover was poor. Sewage reservoirs usually recovered as farmland or grassland. As a result, this research focused on the recovery of the coverage, species and diversity along roadside slopes, pipelines and sewage reservoirs.

Mountainous Area

Community biomass in different recovery periods: Biomass is the dry weight of vegetation per unit area and is a direct indicator of the productivity of an ecosystem. The decreased percentage of biomass is calculated by subtracting the grass biomass in the disturbed plots from that in the undisturbed plots. A biomass decrease of less than 1% indicates the full recovery of biomass. As shown in Fig. 1 (a) to

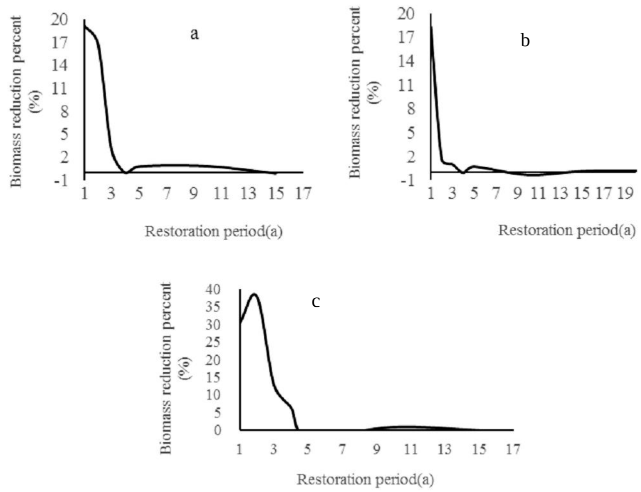

Fig. 1: Percent reduction of road slopes (a), pipe slopes (b) and reclaimed land of cesspits (c).

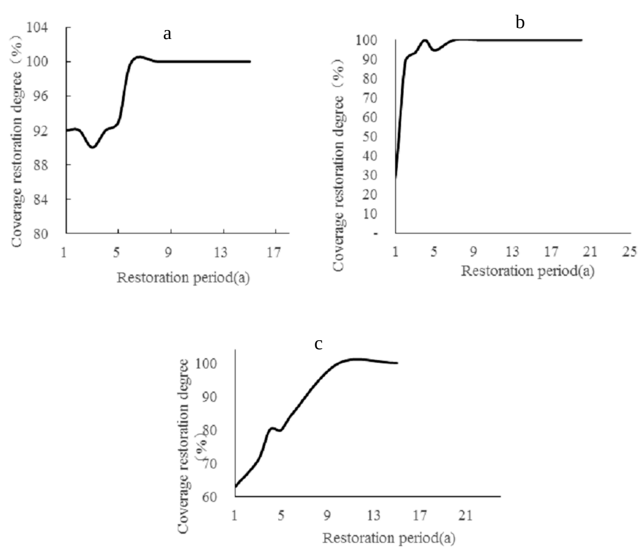

Fig. 2: Coverage restoration of road slopes (a), pipe slopes (b) and reclaimed land of cesspits (c).

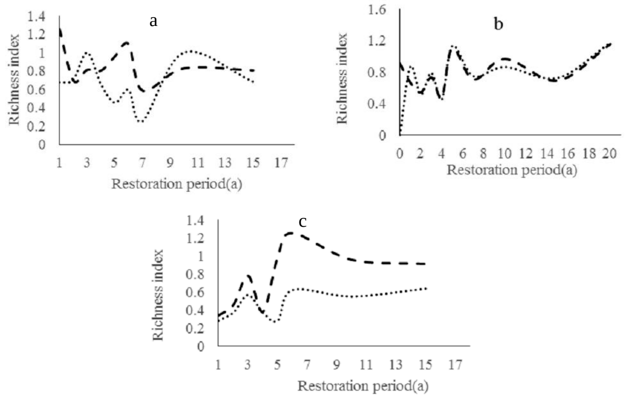

Fig. 3: Richness index.

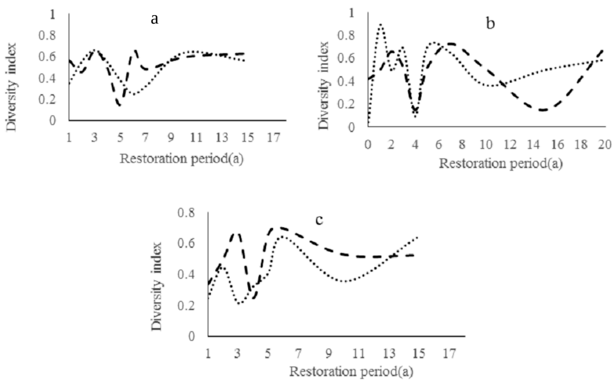

Fig. 4: Diversity index.

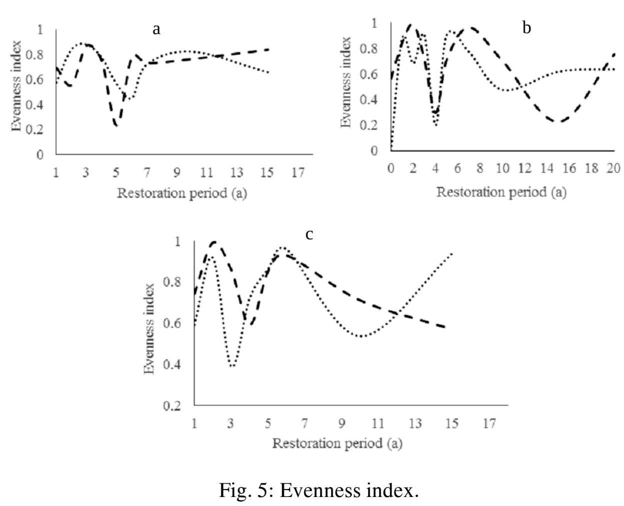

Fig. 5: Evenness index.

Note: ------ The indexes in a non-disturbed area (richness index, diversity index and evenness index); ...... The indexes in a disturbed area (richness index, diversity index and evenness index); "a" indicates road slopes, "b" indicates pipeline projects, and "c" indicates reclaimed land of cesspits.

Fig. 1(c), the grass biomass over roadside slopes, pipelines and sewage reservoirs increased rapidly with the length of the recovery period. Full recovery was fastest alongside the pipeline (2 years), followed by roadside slopes (3 years). The biomass recovery was slowest in sewage reservoirs (5 years).

Grass coverage in different recovery periods: The recovery of grass coverage differed among roadside slopes, pipelines and sewage reservoirs. As shown in Fig. 2 (a), the grass coverage on roadside slopes was 90% recovered in 1 to 5 years and was 100% recovered after 5 years. As shown in Fig. 2 (b), the grass coverage along the pipeline was 30% within 3~6 years and reached 100% after 6 years. As shown in Fig. 2 (c), at least 10 years were needed for the total linear recovery of grass coverage in sewage reservoirs. The results indicated that road construction hardly affected roadside vegetation. Pipeline construction severely disturbed nearby vegetation, which recovered after 2 years. Vegetation recovery in sewage reservoirs was slow, i.e., it needed a longer recovery period.

Diversity in different recovery periods: As shown in Figs. 3 to 5, during the study period, most plots had significantly different Ma, J and D compared with the undisturbed plots. However, as the recovery period lengthened, the difference between the disturbed and undisturbed plots decreased. The D of some disturbed plots was the same as that of undisturbed plots within 7 to 10 years. The results indicated that the recovery period of the diversity of grass species was longer than that of biomass and coverage.

Plains Area

Community biomass in different recovery periods: According to Figs. 6 and 7, the biomass of road slopes and pipe slopes in the plains area increased significantly as the recovery years increased. The biomass of pipe slopes in disturbed areas recovered to a natural level after 2 years, while the biomass of road slopes recovered to a natural level after 3 years. Compared with the restoration effect in mountainous areas, the plains area had the same effect.

Grass coverage in different recovery periods: Along road and pipe slopes in the plains area, the restoration rates reached 100% after 4-5 years. After 1 year, the coverage reached 70% on road slopes. Over the next 1-4 years, the coverage gradually increased to 100% (Fig. 8). One year after embedding the pipe, the coverage reached 40%. Over the next 1-5 years, the coverage gradually increased to 100% (Fig. 9). The coverage restoration was better on disturbed road slopes than on pipe slopes. Compared with the road slopes, the embedded pipe experienced more severe disturbance, so the restoration period of the pipe slopes was longer than that of the road slopes.

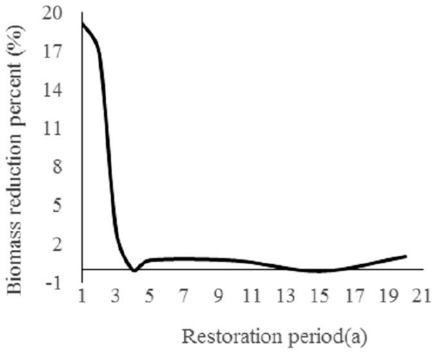

Fig. 6: Percent biomass reduction on road slopes.

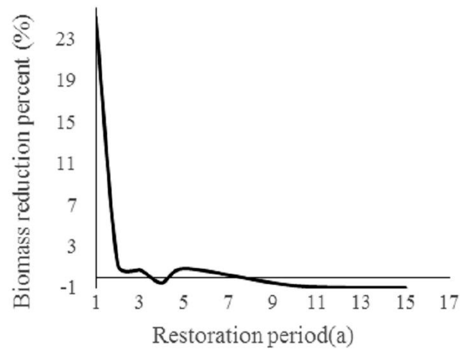

Fig. 7: Percent biomass reduction on pipe slopes.

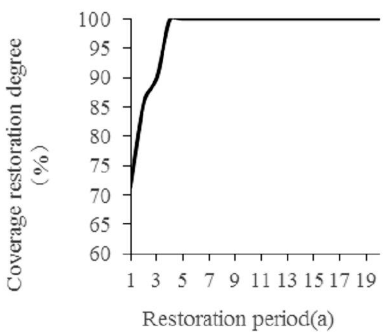

Fig. 8: Degree of coverage restoration of road slopes.

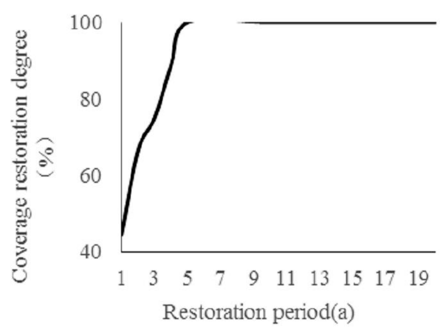

Fig. 9: Degree of coverage restoration of pipe slopes.

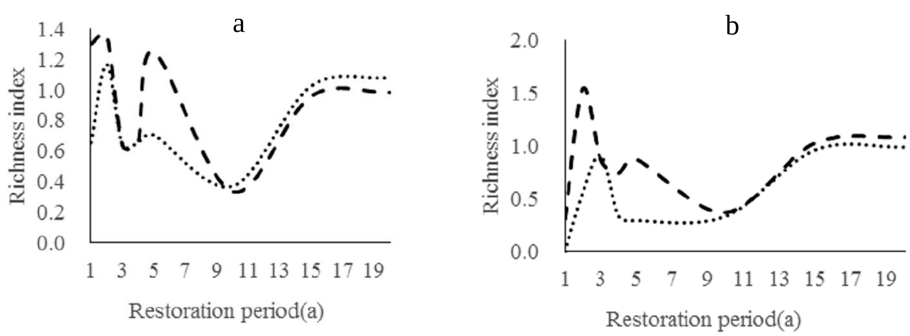

Fig. 10: Richness index ("a" indicates road slopes, and "b" indicates pipe slopes).

Diversity of grass species in different recovery periods: The trends in the grass species diversity along road slopes and pipes in the plains area were nearly the same, particularly after 10 years. The community richness index of the road and pipe slopes were nearly the same, while the difference in the diversity and evenness indexes were obvious after 10 years. The changes indicated that the number of species in disturbed areas reached the natural level as the restoration period increased, while the species compositions were different.

Comparison of Restoration Periods in Project Areas

Restoration period of biomass and coverage in different project areas (road slopes, pipeline slopes and reclamation land of cesspit) are given in Table 1.

According to Table 1, the community biomass trends in mountains and plains were the same. The restoration period of pipe slopes, road slopes and reclaimed land of cesspits in mountains were 2, 3 and 5 years, respectively. The community coverage trends in mountains and plains were the same: road slopes, pipe slopes, reclaimed land of cesspits (only in

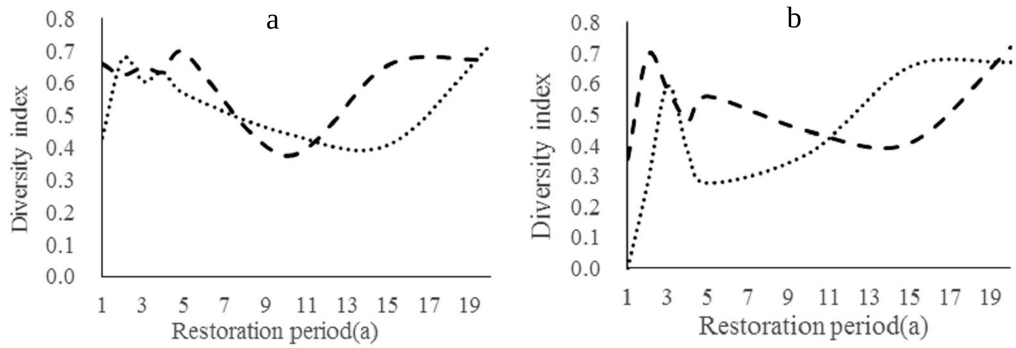

Fig.11: Diversity index (“a” indicates road slopes, and “b” indicates pipe slopes).

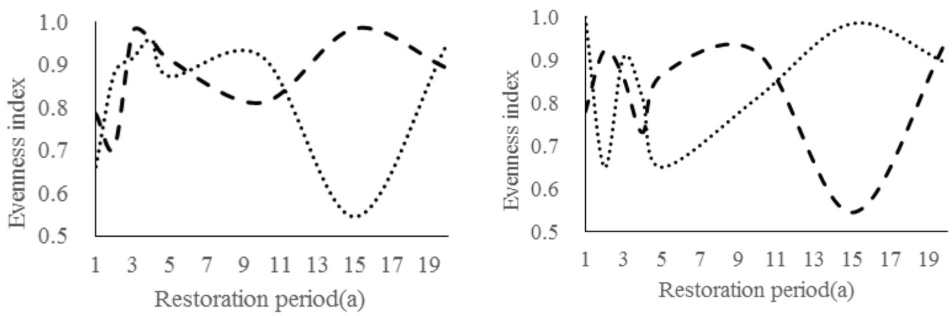

Fig.12: Evenness index (“a” indicates road slopes, and “b” indicates pipe slopes).

Table 1: Restoration periods of projects in disturbed areas.

	Restoration period of biomass (a)		Restoration period of coverage (a)	
	Mountain area	Plains area	Mountain area	Plains area
Road slopes	3	3	1	4
Pipe slopes	2	2	2	5
Reclaimed land of cesspits	5		10	

mountains); the restoration in mountains was faster than that of plains. The recoveries of vegetation coverage on road slopes, pipe slopes and reclaimed land of cesspits in mountain areas were 1, 2 and 10 years, respectively. The recoveries of vegetation coverage on road slopes and pipe slopes in plains area were 4 and 5 years, respectively.

DISCUSSION AND CONCLUSION

Both biomass and vegetation coverage in the project areas of gas fields increased as the restoration period increased. Biomass on pipe slopes reached the natural level after 2-3 years in both mountains and plains. Biomass on road slopes required 3-4 years, and reclaimed land of cesspits required at least 5 years to recover to the natural level. Coverage on pipe slopes needed 9 years, and reclaimed land of cesspits needed at least 10 years to recover to the natural level in mountains. The coverage restoration period of road and pipe slopes was at least 4 years and 5 years, respectively, in the plains area.

According to the analysis, the diversity in mountains and plains needs a long period to recover to the natural level. Most of the project areas did not reach the natural level during the research period, but the change diminished over time. This study will be helpful for environmental protection in southwestern China, especially for vegetation construction in projects area.

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