Postprint: Population Distribution Patterns of Desert Caragana Based on Ripley's K(r) Function

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Abstract

Using Ripley' s K-function from point pattern analysis, we examined the spatial patterns and associations among different age classes of *Caragana roborovskyi* populations, a typical desert vegetation species, at Laohutai in Gaolan County, central Gansu, across various slope aspects. The results revealed that Class I and II populations dominated the entire population, with favorable regeneration status, representing an increasing population. On north slopes, Class I populations exhibited clustered distribution across all study scales, while Class II, III, and IV populations showed random distribution. On northwest slopes, Class I populations displayed significant clustering, Class II showed clustered distribution at small scales but random distribution at large scales, and Class III and IV populations were randomly distributed at all scales. On southwest slopes, all age classes exhibited random distribution at all scales. Across different slope aspects, Class I and II populations showed negative correlation at small scales, becoming uncorrelated as scale increased; Class III and IV populations were uncorrelated across the entire study scale; and other age-class combinations exhibited negative correlations. The natural regeneration of *C. roborovskyi* populations is influenced not only by interspecific and intraspecific competition but also by habitat conditions associated with different slope aspects. When using *C. roborovskyi* for restoration and reconstruction of soil erosion areas in the arid region of central Gansu, a shrub spacing of 4 m is recommended for southwest and south slopes, and 3 m for northwest and north slopes.

Full Text

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2 Study Area and Methods

2.1 Study Site and Data Collection

Two sample plots were established in the study area, located at 808 m elevation with a slope gradient of 6.75%. The large plot measured 95 cm × 80 cm, while the small plot measured 22 cm × 17 cm. Three slope aspects were investigated: north, northwest, and southwest.

[Figure 3a: see original paper] illustrates the spatial distribution of individuals within the sample plots, while [Figure 3b: see original paper] depicts the spatial distribution of different age classes. As shown in [Figure 3b: see original paper], the size variation among age classes is evident, with individuals in Class I being the smallest. The spatial coordinates of each individual were digitized from field diagrams using GetDataGraphDigitizer 2.25 software.

The *Caragana roborovskyi* population was divided into four age classes based on size measurements: Class I (1.47-2.05 cm diameter), Class II (intermediate size), Class III (2.9–5.0 m height), and Class IV (largest individuals). For analysis, individuals with heights between 3–5 m were classified as Class IV, while those in Class I and II represented smaller size categories. The spatial patterns of Classes III, I–IV, II–III, and II–IV were analyzed separately, with Class I–III showing distinct distribution characteristics. The 0–5 m spatial scale was selected for comprehensive analysis of all age class patterns.

Data processing was conducted using Excel 2010 and Programita 2014 software packages. Monte Carlo simulations with 999 permutations were employed to generate confidence envelopes for the Ripley' s K-function analysis. The minimum spatial scale was set at 0.85 cm for fine-scale pattern detection, with an upper limit of 20 cm for small-scale aggregation analysis.

2.2 Spatial Pattern Analysis

The spatial distribution patterns varied significantly across slope aspects and age classes. On the north slope, Class I individuals exhibited clustered distribution across all spatial scales, while Classes II, III, and IV showed random distribution patterns. On the northwest slope, Class I displayed obvious aggregation, Class II showed small-scale aggregation transitioning to random distribution at larger scales, and Classes III and IV were randomly distributed at all scales. On the southwest slope, all age classes were randomly distributed across the entire range of scales.

Interspecific spatial associations revealed that Classes I and II were negatively correlated at small scales (0–2 m), with the correlation becoming neutral as scale increased. Classes III and IV showed no significant correlation at any spatial scale. Furthermore, all age classes exhibited negative correlations with each other, indicating intense competition for resources.

The regeneration of *C. roborovskyi* was influenced by both intraspecific and interspecific competition, as well as by habitat conditions specific to each slope aspect. The spatial segregation hypothesis was supported by the observed distribution patterns, where surviving individuals showed scale-dependent associations. These findings align with previous research on species coexistence mechanisms in arid environments.

2.3 Management Implications

For restoration and soil erosion control projects in central Gansu Province, the planting density of *C. roborovskyi* should be adapted to slope aspect. A 4 m spacing between shrubs is recommended for southwest and south-facing slopes, while a 3 m spacing is more appropriate for northwest and north-facing slopes. These spacing recommendations account for the observed spatial patterns and competition dynamics, ensuring optimal establishment and growth while maximizing erosion control effectiveness.

The spatial pattern analysis demonstrates that *C. roborovskyi* populations exhibit aspect-dependent distribution patterns, with regeneration success being closely linked to microsite conditions and competitive interactions. Management strategies should consider these scale-dependent processes to enhance restoration outcomes in degraded arid landscapes.

References

[1] Hestenes M R, Stiefel E. Methods of conjugate gradients for solving linear systems[J]. Journal of Research of the National Bureau of Standards, 1952, 49(6): 409-436.

[2] Fletcher L, Reeves C M. Function minimization by conjugate gradients[J]. Computer Journal, 1964, 7(2): 149-154.

[3] Skoglund J, Verwijst T. Age structure of woody species population in relation to seed rain, germination and establishment along the river Dalalven, Sweden[J]. Vegetatio, 1989, 82(1): 25-34.

[4] Greig P, Smith P G, Anderson J A, et al. Quantitative Plant Ecology[M]. London: Blackwell Scientific, 1983.

[5] Zhang Pujin, Qing Hua, Zhang Lei, et al. Population structure and spatial pattern of *Caragana tibetica* communities in Inner Mongolia shrub-encroached grassland[J]. Chinese Journal of Plant Ecology, 2017, 41(2): 165-174.

[6] Wang Lei, Sun Qiwu, Hao Chaoyun, et al. Point pattern analysis of different age class *Taxus chinensis* var. *mairei* individuals in mountainous area of Southern Anhui Province[J]. Chinese Journal of Applied Ecology, 2018, 29(1): 18-24.

[7] Ma Xiaoli, Zhao Chengzhan, Zhang Qian, et al. Spatial pattern and spatial association of *Melica przewalskyi* and *Artemisia frigida* in degraded grassland[J]. Chinese Journal of Ecology, 2013, 32(2): 299-304.

[8] Raventos J, Wiegand T, De L M. Evidence for the spatial segregation hypothesis: A test with nine-year survival data in a Mediterranean shrubland[J]. Ecology, 2010, 91(7): 2110-2120.

[9] Yan Haibing, Han Youzhi, Yang Xiuqing, et al. Spatial distribution patterns and associations of tree species in typical natural secondary mountain forest communities of Northern China[J]. Acta Ecologica Sinica, 2010, 30(9): 2311-2321.

[10] Song Yuyang, Li Yuanyuan, Zhang Wenghui. Analysis of spatial pattern and spatial association of *Haloxylon ammodendron* populations at different developmental stages[J]. Acta Ecologica Sinica, 2010, 30(16): 4317-4327.

[11] You Haizhou, Liu Xingliang, Miao Ning, et al. Individual association and scale effect of spatial pattern of *Quercus aquifolioides* populations along elevation gradients[J]. Acta Ecologica Sinica, 2010, 30(15): 4004-4011.

Note: Figure translations are in progress. See original paper for figures.