Response of Plant Community Distribution to Environmental Factors in Piedmont Desert Grasslands of the Southern Tianshan Mountains: A Case Study of Baicheng County (Postprint)

Authors: Lu Yuanbo[1,2,3], Yan Cheng[1,3], Song Chunwu1,3,4, Li Yajuan5, Lai Chengyun 5

Date: 2023-08-26T00:00:00+00:00

Abstract

To investigate the response of plant community distribution to terrain and soil factors in the piedmont desert grassland of Baicheng County on the southern slope of the Tianshan Mountains, this study selected typical areas of the Baicheng piedmont desert grassland for investigation. The relationship between plant community distribution and terrain and soil factors in the mountainous desert grassland was examined using the dominance method and Canonical Correspondence Analysis (CCA). The results showed that: (1) Species diversity differed between the shrub and herb layers across different survey sample points. At east slope sample points, the Shannon-Wiener index, Pielou index, and Simpson index all demonstrated higher values for shrubs than for herbs, whereas at west slope and north slope sample points, these indices all showed higher values for herbs than for shrubs; (2) CCA results indicated that the order of influence of terrain factors on plant communities was: slope aspect (SA) > slope gradient (SG) > slope position (SP), while the order of influence of soil factors was: soil moisture in the 30-100 cm layer (SMC-2) > soil total porosity (STP) > soil moisture in the 0-30 cm layer (SMC-1). Terrain and soil factors exert a certain filtering effect on the formation of different plant communities, with soil moisture in the 30-100 cm layer and slope aspect being the key factors influencing plant community distribution in the piedmont desert grassland of Baicheng County on the southern slope of the Tianshan Mountains.

Full Text

Response of Plant Community Distribution in the Pre-Montane Desert Grassland on the Southern Slope of Tianshan Mountain to Environmental Factors: A Case Study in Baicheng County

LU Yuanbo[1,2,3], **YAN Cheng**[1,3], **SONG Chunwu**[1,3,4], **LI Yajuan**[5], **LAI Zhaoyun**[5]

[1] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China
[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] National Engineering Research Center for Desert Oasis Ecological Construction, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China
[4] Mosuo Bay Desert Research Station, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Shihezi 832000, Xinjiang, China
[5] Xinjiang Baicheng Runhua Coal Industry Co., Ltd., Baicheng 842300, Xinjiang, China

Abstract

To investigate the response of plant community distribution to topographic and soil factors in the pre-montane desert grassland of Baicheng County on the southern slope of Tianshan Mountain, we selected a typical area for field investigation. Using the dominance method and canonical correspondence analysis (CCA), we examined the relationships between plant community distribution and topographic and soil factors in the montane desert grassland. The results revealed significant differences in species diversity between shrub and herb layers across sample sites. Specifically, the Shannon-Wiener, Pielou, and Simpson indices on the eastern slope indicated higher values for shrubs than herbs, whereas on the western and northern slopes, these indices showed higher values for herbs than shrubs. CCA results demonstrated that topographic factors influenced plant communities in the following order of importance: slope aspect > slope gradient > slope position. Soil factors affected plant communities in this sequence: soil moisture in the 30-100 cm layer (SMC-2) > total soil porosity (STP) > soil moisture in the 0-30 cm layer (SMC-1). Both topographic and soil factors exerted selective effects on plant community formation. Soil moisture in the 30-100 cm layer and slope aspect emerged as the key factors controlling plant community distribution in the pre-montane desert grassland of Baicheng County on the southern slope of Tianshan Mountain.

Keywords: terrain factors; soil factors; southern slopes of the Tianshan Mountains; cold and arid areas; canonical correspondence analysis

1.1 Study Area Overview

The study area is located in the northern foothills of Baicheng County, Aksu Prefecture, Xinjiang (42°5 33 –42°5 36 N, 81°55 43 –81°55 55 E), with an average elevation of approximately 2200 m. The region experiences a temperate continental arid climate, characterized by an annual average temperature of 7.6 °C, extreme maximum temperature of 38.3 °C, extreme minimum temperature of -28.0 °C, and a frost-free period of 133–163 days. Annual sunshine duration averages 2789.7 hours. Precipitation is concentrated between May and September, accounting for 60%–70% of the annual total, with an average annual precipitation of approximately 170.0 mm [1]. The predominant soil types are montane chestnut soil and montane brown calcic soil. Vegetation on the lower piedmont terraces is dominated by *Caragana turfanensis* as the constructive species in the shrub layer, accompanied by *Achnatherum splendens*, *Ceratoides latens*, and other species. The herb layer is primarily composed of *Artemisia frigida* and *Festuca ovina* as constructive species, with *Potentilla chinensis* and *Allium mongolicum* as companion species [2].

1.2 Experimental Design

To eliminate the influence of elevation on vegetation diversity, we selected a representative hill at 2200 m elevation with four slope aspects as the survey site. Vegetation surveys were conducted in August 2021, the period of peak community diversity. We established sample plots on the eastern, western, southern, and northern slopes, with three slope positions (upper, middle, and lower) on each aspect. At each position, we set up 5 m × 15 m quadrats for shrub layer investigation, recording species, quantity, plant height, and crown width. Within each large quadrat, we established three 1 m × 1 m herb quadrats to record herbaceous species, plant height, coverage, and quantity. For soil sampling, we collected layered samples at 10 cm intervals from 0–100 cm depth in the middle slope position of each aspect, totaling 10 samples per aspect. We measured soil moisture content, bulk density, and total porosity for the 0–30 cm and 30–100 cm layers across all sample sites.

1.3 Research Methods

1.3.1 Community Classification and Ordination

We classified communities using the dominance method, identifying dominant species based on important values and classifying communities according to dominant species composition. Communities were named following the principles outlined in *Chinese Vegetation* [3]. We performed canonical correspondence analysis using Canoco 4.5 software to identify the most significant environmental factors correlated with plant communities. In CCA ordination diagrams, the length of each environmental factor arrow indicates its relative importance, while the angle between arrows represents the correlation between factors. We used SPSS 26.0 for Pearson correlation analysis, ANOVA, and created visualizations with Origin 2021.

1.3.2 Important Value

Important value reflects the dominance degree of a species within a community [4]. The formulas are:

Shrub layer important value = (relative height + relative frequency + relative dominance)/3
Herb layer important value = (relative height + relative frequency + relative coverage)/3

1.3.3 Species Diversity

Community surveys included community coverage, species composition, quantity, and height [5]. We used species richness, Shannon-Wiener diversity index, Simpson diversity index, Pielou evenness index, and important value as analytical indicators [6].

Richness index (S) = number of species in the quadrat
Simpson index: $D = 1 - \Sigma(Pi)^2$
Shannon-Wiener index: $H' = -\Sigma Pi \ln Pi$
Pielou evenness index: $J = H'/\ln S$

Where Ni is the individual number of species i, N is the total individual number of all species, Pi represents the proportion of species i individuals, and S is the total number of species.

1.3.4 Soil Factor Measurement

Soil moisture content was determined using the oven-drying method [7]. Soil bulk density and total porosity were measured using the ring knife immersion method [8].

---

2 Results and Analysis

2.1 Community Species Composition and Classification Under Different Terrain Conditions

Our survey identified 17 plant species across all sample sites, including 6 shrub species and 11 herb species belonging to 13 genera. Shrubs were predominantly from Fabaceae, Chenopodiaceae, and Tamaricaceae (2 species each, totaling 17.64% of all species). Herbs were most abundant in Asteraceae (6 species, 35.29%), followed by Poaceae, Liliaceae, and Rosaceae (2 species each, 35.29%

total). Important values revealed that *Caragana turfanensis*, *Acantholimon kokandense*, *Reaumuria soongonica*, and *Ceratoides latens* occurred across all sample belts. *Caragana turfanensis* showed the highest important value on eastern, western, and southern slopes as the constructive shrub species, with *A. kokandense*, *R. soongonica*, and *C. latens* as major companion species. On the northern slope, *A. kokandense* had the highest important value as the constructive species, with *C. turfanensis* as the main companion. *Kalidium foliatum* and *Alhagi sparsifolia* were only found on the middle slope of the southern aspect with low important values, appearing as occasional species. In the herb layer, *Artemisia frigida*, *Potentilla bifurca*, *Allium mongolicum*, and *Festuca ovina* were distributed across all sample sites with varying community status. Except for *Achnatherum splendens* which showed relatively high important values where present, other herb species had low important values and appeared as occasional community members.

Based on species important values and reference to *Flora of Xinjiang*, we classified the vegetation into five community types (Table 3). Community I (*Caragana turfanensis-Festuca ovina*) showed the highest species richness, dominated by *C. turfanensis* and *F. ovina*. Community IV (*Reaumuria soongonica-Artemisia frigida*) exhibited the lowest richness, dominated by *R. soongonica* and *A. frigida*. Community V (*Acantholimon kokandense-Festuca ovina+Potentilla bifurca*) had intermediate richness, dominated by *C. turfanensis*, *A. kokandense*, and *F. ovina*.

2.2 Species Diversity Characteristics Under Different Terrain Conditions

Species richness objectively reflects the number of species in a habitat. As shown in Figure 2, both shrub and herb layer richness peaked at the southern upper slope sample site. Except for the western upper slope, herb layer richness exceeded shrub layer richness at all other sample sites. Diversity indices serve as important metrics for ecosystem function and structural stability [9]. The Shannon-Wiener, Simpson, and Pielou indices for the shrub layer were greater than those for the herb layer on eastern and southern slopes, but smaller on western and northern slopes. On the southern slope, the Simpson index showed herb layer < shrub layer at the upper slope, herb layer > shrub layer at the middle slope, and herb layer < shrub layer at the lower slope. The Pielou index demonstrated herb layer > shrub layer at the upper slope, shrub layer > herb layer at the middle slope, and herb layer > shrub layer at the lower slope.

2.3 Soil Environmental Characteristics Under Different Terrain Conditions

Analysis of soil factors in the 0–30 cm layer across slope aspects and positions revealed significant differences ($P < 0.05$) in soil moisture, bulk density, and total porosity among sample sites (Table 4). Soil moisture was highest at the southern upper slope (10.39%) and lowest at the western upper slope (0.85%).

Bulk density was greatest at the eastern upper slope (1.61 $g \cdot cm^{-3}$) and smallest at the southern upper slope (1.09 $g \cdot cm^{-3}$). Total porosity was largest at the southern upper slope (58.87%) and smallest at the eastern upper slope (39.35%). These results indicate spatial heterogeneity in soil environmental characteristics across sample sites.

2.4 Canonical Correspondence Analysis of Plant Community Diversity Indices and Environmental Factors

To identify the dominant factors controlling shrub community distribution, we performed CCA on 12 species diversity indices and 7 environmental factors (Figure 3). Diversity indices included shrub richness, herb richness, shrub layer Shannon-Wiener index, herb layer Shannon-Wiener index, shrub layer Simpson index, herb layer Simpson index, shrub layer Pielou index, and herb layer Pielou index. Environmental factors comprised slope aspect (SA), slope position (SP), slope gradient (SG), soil moisture in the 0–30 cm layer (SMC-1), soil moisture in the 30–100 cm layer (SMC-2), soil bulk density in the 0–30 cm layer (SBD), and total soil porosity in the 0–30 cm layer (STP).

The CCA ordination (Table 5) showed that the first axis explained 62.37% of community variation, while the second axis explained 12.44%, with a cumulative explanation of 49.93%. SMC-2 and STP showed positive correlation with the first axis and negative correlation with the second axis. SMC-1 and SBD showed negative correlation with both axes. Sample sites S1, S4, and S7 were distributed in the upper ordination space, primarily on sunny slopes with harsh soil conditions. Sites S3, S6, S9, and S12 clustered in the lower left quadrant, mainly on shady slopes with better soil conditions. As environmental factors changed, *Reaumuria soongonica* and *Acantholimon kokandense* communities gradually transitioned toward *Caragana turfanensis* communities. The importance ranking of environmental factors was: SA > SMC-2 > STP > SG > SP > SMC-1 > SBD, indicating that slope aspect and soil moisture in the 30–100 cm layer were the primary factors influencing plant community distribution.

---

3 Discussion

The family, genus, and species composition of plant communities effectively reflect changes in community characteristics. Under different terrain conditions, variations in plant community structure create important conditions for niche complementarity and facilitate positive succession [10]. Our study identified 17 plant species, with Asteraceae, Fabaceae, Chenopodiaceae, and Poaceae as the dominant groups, indicating strong ecological adaptability to poor soil and arid environments, consistent with findings by Yang Xiaomei et al. [11]. Important value serves as a comprehensive quantitative indicator of a species' status and role in a community [12]. Through the dominance method, we classified the vegetation into five community types. Communities I, II, and V (*Caragana turfanensis* communities) were distributed mainly on upper and middle slope positions across aspects, while communities III and IV (*Acantholimon kokandense* and *Reaumuria soongonica* communities) occurred primarily on lower slope positions. High soil bulk density reduces total porosity, limiting root activity space and decreasing plant-available soil moisture. Conversely, excessively low bulk density increases porosity but destabilizes the soil profile, impairing water storage capacity [13]. Sample sites S4, S7, and S10 had sandy gravel texture with low bulk density, high porosity, and strong permeability, creating unfavorable water retention conditions. Steeper slopes accelerate water loss and increase erosion risk, resulting in shallow, infertile soils [14]. *Caragana turfanensis* exhibits strong drought tolerance, poor soil adaptation, and low-temperature resistance during the growing season, with well-developed root systems [15], enabling it to dominate under these harsh conditions. With decreasing slope position, gravel content declines, fine soil particles increase, and soil conditions improve, supporting greater plant diversity and community type transitions [16]. Herb layer species including *Festuca ovina*, *Artemisia frigida*, and *Achnatherum splendens* share characteristics of drought tolerance, poor soil adaptation, and extensive root systems [17]. *Festuca ovina* secretes abundant mucilage that binds fine sand particles, forming a protective soil-root complex on slope surfaces [18], allowing it to dominate on upper slope positions. *Artemisia frigida* thrives on southern slopes where sandy soils replace gravelly textures with decreasing slope position [19]. *Achnatherum splendens*, with moderate drought tolerance, prefers deep soil layers [20] and thus occurs only on lower slope positions where soil depth is greater. Future ecological restoration should adopt shrub-herb combinations, selecting appropriate species based on specific soil and terrain conditions.

Species diversity represents a critical measure of ecosystem functional complexity [21]. The southern upper slope exhibited the highest shrub richness, likely due to favorable heat conditions on this sunny slope combined with optimal bulk density and porosity for plant growth. Western and northern slopes showed greater herb richness than eastern and southern slopes, consistent with findings by Wang Ziting et al. [22]. Shannon-Wiener and Simpson indices were greater in shrub layers on sunny slopes but greater in herb layers on shady slopes, aligning with results from Wang Mei et al. [23]. This pattern reflects that *Caragana turfanensis* and *Reaumuria soongonica* are heliophilous shrubs benefiting from abundant heat, while more herb species thrive in the better soil moisture conditions of shady slopes [24]. Except for the northern slope, Pielou and Simpson indices for both layers showed upper and middle slope positions > lower slope positions, consistent with Hao Lingying's [25] research on forest structure. These findings suggest that for ecological restoration, sunny slopes with good heat but poor moisture should prioritize shrubs, while shady slopes with poorer heat but better moisture should emphasize shade-tolerant herbs.

CCA effectively reveals relationships between plant communities and environmental factors while reflecting species ecological differentiation [26]. Our results identified slope aspect and soil moisture in the 30–100 cm layer as the primary factors controlling community distribution. Slope aspect significantly influences community characteristics and species diversity [27], a finding confirmed by our study. In arid regions, soil moisture is the main limiting factor for plant growth [28], with 20–60 cm soil moisture being particularly critical for shrub survival [29], similar to our results. Vertical distribution of soil moisture affects water utilization patterns, creating distinct ecological niches [30]. Young's research on perennial herbs showed root distribution changes with precipitation, with deep-rooted perennials accessing deeper soil moisture during droughts (242 mm annual precipitation) [31], consistent with our finding that deep soil moisture (SMC-2) significantly influences shrubs. Our CCA selected seven environmental factors explaining 62.37% of community variation, a robust result. However, soil chemical properties and climatic factors not included in our analysis may also affect community characteristics [32]. Additionally, human disturbance and interspecific interactions warrant further investigation.

---

4 Conclusions

Based on vegetation surveys and measurements of topographic and soil factors, we analyzed plant diversity indices and performed canonical correspondence analysis to explore how plant communities in the pre-montane desert grassland of Baicheng County respond to environmental factors. The main conclusions are:

1) Plant diversity indices showed that, except for species richness, other diversity indices were greater in shrub than herb layers on eastern and southern slopes, but greater in herb than shrub layers on western and northern slopes. Plant species in the study area were few and unevenly distributed, with a few dominant species occupying large niches.

2) Analysis of plant diversity and environmental factors revealed that slope aspect and soil moisture in the 30–100 cm layer (SMC-2) were the primary factors influencing plant diversity in the pre-montane desert grassland of Baicheng County on the southern slope of Tianshan Mountain. Slope gradient, slope position, soil bulk density, and total soil porosity also significantly affected plant diversity.

References

[1] Wang Jianming, Zhong Yueming, Zhang Tianhan, et al. Plant species richness patterns and water energy dynamics in the Black Gobi Desert, China[J]. Plant Science Journal, 2016, 34(4): 530-538.

[2] Song Jingjing, Fang Jianmin, Su Shouxiang, et al. Study on the species diversity of herbaceous communities in marshlands along the middle and lower

reaches of the Yangtze River[J]. Anhui Forestry Science and Technology, 2022, 48(5): 3-7, 20.

[3] Yuan Xiaoqiang, Wang Min, Zhang Xianhua, et al. Study on the relationship between species diversity and biomass of typical desert grassland communities around Urumqi[J]. Acta Agrestia Sinica, 2022, 30(5): 1253-1262.

[4] Wang Gongxin, Jing Changqing, Dong Ping, et al. Study on biomass estimation and influencing factors of desert grassland in Xinjiang[J]. Acta Agrestia Sinica, 2022, 30(7): 1862-1872.

[5] Chen Chen, Jing Changqing, Xing Wenyuan, et al. Desert grassland dynamics in the last 20 years and its response to climate change in Xinjiang[J]. Acta Prataculturae Sinica, 2021, 30(3): 1-14.

[6] Wang Caie. Spatial Pattern of Vegetation and Soil Nutrients and Soil Erosion of Degraded Alpine Meadows and Shrub of Hillside in the Headwaters Regions of Three River on Tibetan Plateau[D]. Lanzhou: Lanzhou University, 2021.

[7] He Qihua, He Yonghua, Bao Weikai. Research on dynamics of soil moisture in arid and semiarid mountainous areas[J]. Mountain Research, 2003, 21(2): 149-156.

[8] Tao Juanping, Wang Yukun, Liu Fenggui, et al. Identification and determination of its critical values for influencing factors of cultivated land reclamation strength in region of Brahmaputra River and its two tributaries in Tibet[J]. Transactions of the Chinese Society of Agricultural Engineering, 2016, 32(15): 239-246.

[9] Hu Yongchun, Fan Xinyu, Shao Yizhen, et al. Effects of topographic and light factors on bryophytes functional traits in Baiyun Mountain National Forest Park[J]. Journal of Henan Agricultural University, 2021, 55(1): 89-96.

[10] Campbell F W, Kulikowski J J, Levinson J. The effect of orientation on the visual resolution of gratings[J]. The Journal of Physiology, 1966, 187(2): 427-436.

[11] Ziadat F M, Taimeh A Y. Effect of rainfall intensity, slope, land use and antecedent soil moisture on soil erosion in an arid environment[J]. Land Degradation & Development, 2013, 24(6): 582-590.

[12] Bardelli T, Gómez J, Brandón M, et al. Effects of slope exposure on soil physico-chemical and microbiological properties along an altitudinal climosequence in the Italian Alps[J]. Science of the Total Environment, 2017, 575: 1041-1055.

[13] Veresoglou S D, Mamolos A P, Thornton B, et al. Medium term fertilization of grassland plant communities masks plant species linked effects on soil microbial community structure[J]. Plant and Soil, 2011, 344: 187-196.

[14] Li Jiwen, Yin Benfeng, Sophia S, et al. Effects of moss mortality on soil water evaporation and infiltration of moss-dominated biological soil crusts[J].

Acta Ecologica Sinica, 2021, 41(16): 6533-6541.

[15] Chen Shuangshuang, Zhu Ninghua, Zhou Guangyi, et al. Vegetation and soil physical characteristics of artificial arbor forests under different grades of rocky desertification[J]. Ecology and Environmental Sciences, 2022, 31(1): 52-61.

[16] Xiong Binmei, Lei Yun, Wang Zhengxiang, et al. Effects of topography on plant species richness and distribution in Qizimei Mountain Nature Reserve[J]. Acta Botanica Boreali-Occidentalia Sinica, 2016, 36(11): 2307-2313.

[17] Sun Ningting, Wang Xiaoyan, Zhou Hao, et al. Effects of kind and incorporation depth of biochars on water movement and nitrogen and phosphorus loss in purple soil[J]. Acta Pedologica Sinica, 2022, 59(3): 722-732.

[18] Zhang Liyun. Basic characteristics of natural grassland in Baicheng Basin, Xinjiang[J]. Chinese Journal of Grassland, 1982(2): 9-13.

[19] Luo Jinhai, Che Zicheng, Zhou Ningchao, et al. Geochemistry and isotopic geochemistry of dacites from the lower Permian Xiaotikanlike formation in the southern margin of South Tianshan Mountains, and its tectonic significances[J]. Acta Geologica Sinica, 2013, 87(1): 29-37.

[20] Liang Yan, Huang Yong. Distribution and risk assessment of highway collapse disaster in the mountainous area of the southern slope of the Tianshan Mountains[J]. Journal of Highway and Transportation Research and Development (Applied Technology Edition), 2014(10): 109-113.

[21] Abibaimu Keremu. Analysis of the Floristic Characteristics of Seed Plants in Baicheng Basin, Xinjiang[D]. Urumqi: Xinjiang Normal University, 2016.

[22] Wang Wei, Pei Hao, Wang Xinting. A logistic analysis on vegetation classification system based on dominant species with an illustrational scheme[J]. Biodiversity Science, 2016, 24(2): 136-147.

[23] Pang Jiushuai, Yuan Yangchen, Zhou Miaomiao, et al. Species niche of *Clematis acerifolia* Maxim. community[J]. Acta Ecologica Sinica, 2022, 42(8): 3449-3457.

[24] Cheng Siqi, Zhu Yajing, Qi Ji. Introduction and planting of several sandy plants in Beijing Botanical Garden[C]//Beijing Garden Association, Beijing Municipal Bureau of Landscape Architecture, Beijing Park Management Center. 2010 New Beginnings of Beijing Gardening. Beijing: China Forestry Publishing House, 2010: 3.

[25] Feng Ling, Yu Lifei, Wang Yang, et al. The effects of the functional redundancy and functional diversity on the community stability in different stages of the plant communities restoration in Karst vegetation[J]. Ecology and Environmental Sciences, 2022, 31(4): 670-678.

[26] He Fanglan, Liu Shizeng, Li Changlong, et al. Study on composition and diversity of phytocoenosium in Gobi region of Hexi, Gansu[J]. Journal of Arid Land Resources and Environment, 2016, 30(4): 74-78.

[27] Hou Mudan, Wang Mingjiu, Li Zhiqiang, et al. Effects of grazing intensity on the characteristics of vegetative production of three plants in the *Stipa breviflora* steppe[J]. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 2009, 30(1): 71-75.

[28] Yang Xiaomei, Yao Tuo, Wang Lide, et al. Community structure and plant diversity under different degrees of degraded grassland in Tianzhu, Gansu[J]. Acta Agrestia Sinica, 2018, 26(6): 1290-1297.

[29] Hu Wenge, Zhao Yadong, Yan Ping, et al. The preliminary analysis of soil microbial community of planting *Achnatherum splendens* (Trin) Nevski under saline and alkali land environment[J]. Ecology and Environment, 2007, 16(1): 197-200.

[30] Song Li, Yang Xiyun, Mi Meixia, et al. Study on soil bulk density characteristics of park green space in Taiyuan City[J]. Journal of Shanxi Agricultural Sciences, 2020, 48(5): 779-783.

[31] Dong Qiguang, He Jing. Effects of soil bulk density change on crop yield[J]. Nongjia Keji, 2018(11): 99-100.

[32] Yang Mingjie, Yang Guang, He Xinlin, et al. Stem sap flowing characteristics of *Haloxylon ammodendron* and its response to soil moisture in arid area[J]. Yangtze River, 2018, 49(6): 33-38.

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