Plant Community Survey of National Photovoltaic and Energy Storage Empirical Experiment Platform (Daqing Base)

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Abstract [**Objectives**] This study was conducted to explore the characteristics of natural grassland plant communities in the National Photovoltaic and Energy Storage Empirical Experiment Platform (Daqing Base), so as to provide data reference for local grassland resources. [**Methods**] June to July, 2022, standard plot site investigation was carried out to investigate vegetation species, relative height, relative coverage, relative abundance, relative frequency and dominance in the National Photovoltaic and Energy Storage Empirical Experiment Platform in Datong District, Daqing City of Heilongjiang Province, and to analyze plant community structures in the photovoltaic DC field. [**Results**] The photovoltaic DC field contained 22 species of plants, of which *Suaeda salsa* was the common species. The dominant species in photovoltaic DC field were *Leymus chinensis*, *Eleocharis intersita*, *Carex duriuscula* and *Carex rugurosa*. [**Conclusions**] The dominant vegetation types were Poaceae and Cyperaceae in the natural grassland of the National Photovoltaic and Energy Storage Empirical Experiment Platform (Daqing Base).

Key words Photovoltaic DC field; Plant community; Distribution characteristics

Natural grasslands are the largest terrestrial ecosystem in China, playing an important role in developing animal husbandry and maintaining biodiversity and ecological balance[1]. Daqing City is located in the central part of the Songnen Plain and the southwestern part of Heilongjiang Province, where the natural vegetation is mainly composed of meadow grasslands, lowland saline meadows, and swamps, and there are a variety of plant species and abundant grassland resources[2]. Photovoltaic power generation systems are a type of power generation system that utilizes photovoltaic cells to directly convert solar radiation energy into electrical energy[3]. They are generally built on natural grasslands and are widely used in Daqing City. Grassland plant communities under photovoltaic panels are complex in structure and have a distinct spatial structure. Therefore, the investigation of grassland status in photovoltaic systems can provide basic data for further development and utilization of this type of grassland. In this study, a background survey was conducted on the natural grassland in the National Photovoltaic and Energy Storage Demonstration Experimental Platform in Datong District, Daqing City, Heilongjiang Province from June to July 2022 to study vegetation species, relative height, relative coverage, relative abundance, relative frequency, and dominance of plant communities, providing a strong practical support for local grassland supervision departments to rationally use and optimize the management of the grassland in the experimental platform.

Received: February 1, 2023 Accepted: April 3, 2023
Supported by Daqing "Jiebangguashuai" Science and Technology Key Project in the New Energy Field (2021BD05).
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Materials and Methods

General situation of the study area

The National Photovoltaic and Energy Storage Demonstration Experimental Platform (Daqing Base) is the world's first outdoor photovoltaic and energy storage demonstration experimental platform built in Datong District, Daqing City, Heilongjiang Province. The area has a flat terrain and diverse surface environment, and thus shows the advantage of conducting large-scale and continuous outdoor demonstration experiments under the same conditions[4]. The grassland in this area is mainly composed of herbaceous plants, and it is a natural grassland that has not been improved and is used for animal husbandry.

Survey methods

Setting of sample plots Six survey plots were set up in the study area according to the type of photovoltaic panels (Table 1).

Table 1 Settings of sample plots

Sample plot No.	Sample plot type	Longitude	Latitude
Sample plot 1	Area I	124.871° -124.873°	46.151° -46.157°
Sample plot 2	Area II	124.871° -124.880°	46.155° -46.156°
Sample plot 3	Area III	124.878° -124.881°	46.171° -46.172°
Sample plot 4	Area IV	124.877° -124.882°	46.181° -46.182°
Sample plot 5	Area V	124.884° -124.888°	46.183° -46.184°
Sample plot 6	Area VI	124.880° -124.887°	46.191° -46.197°

Experimental instruments Scissors (Deli Group Co., Ltd.); steel tape measures (Deli Group Co., Ltd.); GPS locator (Beijing Chuang Yu Xing Tong Science & Technology Co., Ltd.);

sample circle (0.1 m^2); portable quadrat frames (1 m × 1 m).

Survey methods The sample plot survey was conducted from June 8 to 20, 2022 by the sampling method. Each survey plot was set up with 3 survey quadrats, with a quadrat size of 1 m × 1 m. A GPS locator was used to determine the longitude and latitude of each sample plot, and data such as name, coverage, height and number of plants were recorded for various quadrats. Next, 0.1 m^2 sample circles were determined by throwing in the same direction within each plot to record the types and frequency of plants appearing within the circle, and the measurement was performed ten times to determine the frequency of each plant species. Next, the relative coverage, relative height, relative abundance, relative frequency and dominance of each species were calculated. The calculation methods of characteristic indexes of each plant community were given below[5].

Calculation method for relative coverage:

Relative coverage (%) = (Coverage of plants of a certain species/Sum of coverage of all plants in the quadrat) × 100

Calculation method for relative height:

Relative height (%) = (Height of plants of a certain species/Sum of heights of all plants in the quadrat) × 100

Calculation method for relative abundance:

Relative abundance (%) = [Number of plants (clumps) of a certain species/Total number of plants (clumps) of all species in the quadrat] × 100

Calculation method for relative frequency:

Relative frequency (%) = (Frequency of plants of a certain species appearing in sampling in the sample plot/Sum of frequency of all plants appearing in sampling in the sample plot) × 100

Calculation method of dominance:

Dominance (%) = (Relative coverage + Relative height + Relative abundance + Relative frequency)/4 × 100

Data analysis

All measurement indexes were calculated using the average value, and the measured data were collated and processed using Excel 2010. Tables are drawn and analyzed.

Results and Analysis

Vegetation species

In this study, 6 different sample plots in the photovoltaic electric field of Datong District were analyzed for plant species. After statistics, a total of 22 plant species belonging to 21 genera in 10 families were indentified, including 4 species in Poaceae, 4 species in Cyperaceae, 5 species in Compositae, 1 species in Rosaceae, 2 species in Polygonaceae, 2 species in Chenopodiaceae, 1 species in Typhaceae, 1 species in Plumbaginaceae, 1 species in Plantaginaceae, and 1 species in Ranunculaceae. The distribution of species is shown in Table 2.

The composition of plant species was relatively rich among the 6 plots, among which plot 3 accommodated the most plant species, 18 species in total, and plot 5 comprised the least plant species, with only 5 species. *Suaeda salsa* was a common species in the 6 plots. *Axyris amaranthoides* and *Typha angustifolia* were endemic species in plot 2. *Limonium bicolor*, *Gramineae hierochloe glabra*, *Plantago major*, *Scorzonera austrica* and *Ixeris polycephala* were endemic species in plot 3. In the 6 plots, *Puccinellia tenuiflora*, *Leymus chinensis*, *Potentilla anserina*, *Heleocharis intersita*, *Carex duriuscula*, *Polygonum sibiricum*, *Inula britanica*, and *S. salsa* were eight common plant species.

Table 2 Vegetation species and distribution in National Photovoltaic and Energy Storage Demonstration Experimental Platform (Daqing Base)

Sample plot No.	Vegetation species
Sample plot 1	*P. tenuiflora*, *L. chinensis*, *Phragmites australis*, *P. anserina*, *H. intersita*, *C. duriuscula*, *P. sibiricum*, *I. britanica*, *S. salsa*
Sample plot 2	*C. duriuscula*, *P. tenuiflora*, *A. amaranthoides*, *P. sibiricum*, *T. angustifolia*, *Scirpus planiculmis*, *H. intersita*, *S. salsa*
Sample plot 3	*Carex rugulosa*, *P. anserina*, *P. australis*, *P. sibiricum*, *H. intersita*, *C. duriuscula*, *S. planiculmis*, *L. chinensis*, *S. salsa*, *L. bicolor*, *Taraxacum mongolicum*, *G. hierochloe glabra*, *P. tenuiflora*, *I. britanica*, *P. major*, *Scorzonera austriaca*, *I. polycephala*, *Artemisia anethifolia*
Sample plot 4	*S. salsa*, *P. australis*, *S. planiculmis*, *C. rugulosa*, *H. intersita*, *P. anserina*, *Halerpestes cymbalaria*, *I. britanica*, *C. duriuscula*, *Polygonum aviculare*
Sample plot 5	*S. salsa*, *H. intersita*, *P. aviculare*, *L. chinensis*, *P. tenuiflora*
Sample plot 6	*L. chinensis*, *P. tenuiflora*, *P. australis*, *P. anserina*, *H. intersita*, *S. planiculmis*, *S. salsa*, *H. cymbalaria*

Characteristics of plant communities in sample plots

The characteristic values of plant communities in the 6 sample plots are shown in Table 3. In plot 1, the average height of all plants was 27.12 cm; the relative coverage of *P. tenuiflora* was the largest, at 24.27%; the relative abundance of *H. intersita* was the largest, at 63.96%; the relative frequency of *L. chinensis* was the largest, at 19.95%; and the dominance of *H. intersita* in plot 1 was the highest, at 24.3%. In sample plot 2, the average height of vegetation was 28.77 cm; the relative coverage and relative abundance of *C. duriuscula* were the largest, at 38.98% and 37.48%, respectively; the relative frequency of *S. planiculmis* was the highest, at 20.34%; and *C. duriuscula* was the vegetation with the highest dominance in sample plot 2, and the dominance was 23.58%. In sample plot 3, the average height of vegetation was 25.45 cm; and *L. chinensis* was the vegetation with the highest relative coverage, relative abundance and relative frequency, which were 22.49%, 17.16% and 19.44% respectively, in the sample plot, and the dominance of *L. chinensis* was also the highest, at 16.59%. In sample plot 4, the average height of vegetation was 28.16 cm; the relative coverage and relative abundance of *H. intersita* were the highest, at 42.49% and 71.18%, respectively; the relative frequency of *S. salsa* was the highest, at 36.14%; and *H. intersita* was the vegetation in the sample plot showing the highest dominance of 34.4%. In sample plot 5, the average height of vegetation was 32.34 cm; the relative coverage of *L. chinensis* was the highest, at 46.11%; the relative abundance

of S. salsa was the highest, at 35.83%; the relative frequency of *P. tenuiflora* was the highest, at 45.45%; and the dominance of *L. chinensis* in sample plot 5 was the highest, at 32.04%. In sample plot 6, the average height of vegetation was 36.24 cm; the relative coverage and relative frequency of *L. chinensis* were the highest in the sample plot, at 46.32% and 18.77%, respectively; the relative abundance of *P. tenuiflora* was the highest, at 28.27%; and the dominance of *L. chinensis* in sample plot 6 was the highest, at 29.29%.

Table 3 Vegetation characteristic values of National Photovoltaic and Energy Storage Demonstration Experimental Platform (Daqing Base) %

Sample plot No.	Vegetation type	Relative coverage	Relative height	Relative abundance	Relative frequency	Dominance
Sample plot 1	*P. tenuiflora*	24.27	20.17	1.65	5.74	12.96
	L. chinensis	14.56	21.74	9.56	19.95	16.45
	P. australis	9.71	15.65	1.33	10.72	9.35
	P. anserina	4.85	4.95	4.20	10.72	6.18
	H. intersita	11.65	14.11	63.96	7.48	24.30
	C. duriuscula	14.56	14.76	14.02	17.46	15.20
	P. sibiricum	7.77	6.64	0.20	13.72	7.08
	I. britanica	2.91	4.71	0.08	4.24	2.99
	S. salsa	9.71	6.19	4.99	9.98	7.72
Sample plot 2	*P. tenuiflora*	16.92	22.68	2.09	16.95	14.66
	H. intersita	10.94	12.20	10.81	11.86	11.45
	C. duriuscula	38.98	11.10	37.48	6.78	23.58
	P. sibiricum	2.74	13.14	1.03	10.17	6.77
	S. salsa	0.62	1.75	3.71	15.25	5.33
	A. amaranthoides	5.88	8.15	16.99	18.64	12.42
	T. angustifolia	2.05	12.19	1.65	0	3.97
	S. planiculmis	21.88	18.79	26.25	20.34	21.82
Sample plot 3	*P. tenuiflora*	21.94	11.56	5.65	10.28	12.36
	L. chinensis	22.49	7.26	17.16	19.44	16.59
	P. australis	14.99	11.14	17.23	9.17	13.13
	P. anserina	6.58	2.67	8.13	5.56	5.73
	H. intersita	0.88	6.94	14.68	2.78	6.32
	C. duriuscula	1.65	4.27	6.10	8.89	5.23
	P. sibiricum	0.99	6.9	2.37	5.56	3.95
	I. britanica	1.10	2.43	14.00	9.72	6.81
	S. salsa	2.19	2.20	3.84	11.94	5.05
	S. planiculmis	0.22	9.52	1.13	5.56	4.11
	C. rugulosa	21.94	11.17	2.94	0	9.01
	L. bicolor	1.10	3.49	0.23	0	1.20
	T. mongolicum	0.55	1.87	0.90	2.78	1.53
	G. hierochloe glabra	1.65	5.63	3.39	2.78	3.36
	P. major	0.99	2.89	0.90	2.78	1.89
	Takhtajaniantha austriaca	0.44	4.46	0.50	0	1.35
	I. polycephala	0.11	2.86	0.2	0	0.79
	A. anethifolia	0.22	2.72	0.68	2.78	1.60
Sample plot 4	*P. australis*	0.32	6.84	0.30	18.88	6.58
	P. anserina	6.37	7.20	6.39	13.25	8.30
	H. intersita	42.49	15.89	71.18	8.03	34.40
	C. duriuscula	0.32	13.82	4.16	10.84	7.29
	I. britanica	0.53	3.98	0.61	6.83	2.99
	S. salsa	31.33	7.69	10.57	36.14	21.43
	S. planiculmis	1.12	10.82	0.50	6.02	4.62
	C. rugulosa	15.93	22.63	5.12	0	10.92
	H. cymbalaria	0.74	1.79	0.40	0	0.73
	P. aviculare	0.85	9.33	0.91	0	2.77
Sample plot 5	*P. tenuiflora*	0.10	29.25	0.02	45.45	18.71
	L. chinensis	46.11	40.62	32.33	9.09	32.04
	H. intersita	28.82	17.72	31.55	27.27	26.34

(Continued)

(Table 3)

Sample plot No.	Vegetation type	Relative coverage	Relative height	Relative abundance	Relative frequency	Dominance
	S. salsa	24.50	6.21	35.83	18.18	21.18
	P. aviculare	0.40	6.20	0.30	0	1.72
Sample plot 6	*L. chinensis*	46.32	27.15	24.90	18.77	29.29
	P. tenuiflora	15.44	25.67	28.27	14.44	20.96
	P. australis	15.44	18.00	8.96	18.05	15.11
	P. anserina	10.29	4.19	4.30	16.25	8.76
	H. intersita	8.75	10.45	30.48	10.83	15.13
	S. planiculmis	3.24	11.85	2.62	14.44	8.04
	S. salsa	0.21	1.45	0.12	7.22	2.25
	H. cymbalaria	0.31	1.24	0.35	0	0.48

Discussion

The National Photovoltaic And Energy Storage Demonstration Experimental Platform (Daqing base) was built in the Songnen Plain in the west of Heilongjiang Province, with special physical geography and climate conditions and rich vegetation types[6]. The results of this study showed that there were obvious types of plant communities in the photovoltaic field, including 22 species, mainly belonging to Poaceae, Cyperaceae, and Compositae, which is similar to the results of study by Li *et al.* [7] on the grassland vegetation in the east of Daqing City. *S. salsa* was a common vegetation species in the 6 sample plots under investigation, which might be related to the soil type of grasslands in Daqing City. Wang *et al.* [7] found that the soil of grasslands in Daqing City belonged to saline-alkali soil, with a pH value above 8, which seriously affects the germination and rejuvenation of plant roots. Song *et al.* [8] showed that *S. salsa* has strong salt resistance and can remove salt and heavy metals from saline soil, making it suitable for growing in saline-alkali environments. Therefore, *S. salsa* grows most widely in photovoltaic field grasslands.

The dominance of vegetation can reflect the ecological advantages of vegetation in the regional sample plots[9]. In this study, it was found that the vegetation with the highest dominance in sample plot 1 to sample plot 6 was in the following order: *H. intersita*, *C. duriuscula*, *L. chinensis*, *H. intersita*, *L. chinensis*, and *L. chinensis*, which indicated the dominant plants growing in the photovoltaic experimental platform area were plants of Poaceae and Cyperaceae. Ji *et al.* [10] demonstrated through experiments that forage grasses in Poaceae have stronger salt tolerance than general vegetation and are pioneer plants in improving saline-alkali soil, while Cyperaceae plants are an important component of terrestrial ecosystems, playing an important role in sand fixation and soil protection, soil improvement, and other aspects[11]. Therefore, plants of Poaceae and Cyperaceae are suitable for growing in natural grassland areas within photovoltaic electric fields, and in future grassland management, it is necessary to focus on protecting such vegetation.

Conclusions

A total of 22 plant species grew in the natural grassland in the National Photovoltaic and Energy Storage Demonstration Experimental Platform (Daqing Base). The dominant vegetation types in the photovoltaic electric field were Poaceae and Cyperaceae, which are forage grasses that herbivorous livestock prefer to feed on and can be further developed and utilized.

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Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU