Impacts of Urban Land Use/Land Cover Changes on Regional Landscape and Vegetation Species Diversity:
Beijing as an Example from 1970’s to 2000’s

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- Background introduction
- Methods and data
- Results
- Conclusions
General Information about Beijing

<table>
<thead>
<tr>
<th>Total area (km²)</th>
<th>16,808</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountainous area (km²)</td>
<td>10,418</td>
</tr>
<tr>
<td>Plain area (km²)</td>
<td>6,390</td>
</tr>
<tr>
<td>Maximum altitude (m)</td>
<td>2,303</td>
</tr>
<tr>
<td>Minimum elevation (m)</td>
<td>18</td>
</tr>
<tr>
<td>Average annual temperature (°C)</td>
<td>11.8</td>
</tr>
<tr>
<td>Annual range of temperature (°C)</td>
<td>30.4</td>
</tr>
<tr>
<td>Average annual precipitation (mm)</td>
<td>470-660</td>
</tr>
<tr>
<td>Frostless period (plain area/mountainous area) (days/yr)</td>
<td>190/170</td>
</tr>
<tr>
<td>Surface water resource (10⁹ m³)</td>
<td>25.99</td>
</tr>
<tr>
<td>Ground water resource (10⁹ m³)</td>
<td>29.21</td>
</tr>
<tr>
<td>Vascular bundle plants species</td>
<td>2056</td>
</tr>
<tr>
<td>Vertebrate species</td>
<td>343</td>
</tr>
<tr>
<td>Population</td>
<td>16,330,000</td>
</tr>
<tr>
<td>Population Density (km⁻²)</td>
<td>971.6</td>
</tr>
</tbody>
</table>

Land Use Map of Beijing, 2004
Dasiphora fruticosa & Caragana jubata

Quercus mongolica

Larix principis-rupprechtii

Quercus liaotungensis

Bothriochloa ischaemum

Vitex negundo var. heterophylla

Spiraea triloba

Ostryopsis davidiana & Lespedeza bicolor

Glycine max

Continus coggyria var. cinerea

Prunus persica

Lespedeza bicolor
Methods and data

Natural vegetation

- RS data: TM, ETM+
- GIS Analysis
- Land use & land cover changes
- Species diversity
- Communities Characteristic distribution
- Field Survey
- Sample plots
- Climate data
- Quantitative analysis

Urban vegetation

- RS data: SPOT
- GIS Analysis
- Urban vegetation Distribution pattern
- Sample plots
- Line transect
- Biodiversity & distribution
- Quantitative analysis
Data Collection

1. Field survey

Sample plots for natural vegetation: 72 arbor sample plots, with total area of 32,575 m², shrub sample area is 5,900 m².

Sample plots for urban vegetation: total area is 8,000 m²; line transect along pavements counts for 18 km.

2. DEM
Methods and data

Data Collection

3. Climate Factors

**Heat:** *AMT, WI, MTWM, MTCM, ART*

**Moisture:** *AP, GSP, Im*

**Integrated:** *PER, PET, AET*

*AMT* refers to annual mean temperature; *WI* refers to warmth index; *MTCM* refers to mean temperature of the warmest month; *MTCM* refers to mean temperature of the coldest month; *ART* refers to annual range of temperature.

*AP* refers to annual precipitation; *GSP* refers to growth season precipitation; *Im* refers to wet index.

*PER* refers to potential evapotranspiration rate; *PET* refers to potential evapotranspiration; *AET* refers to actual evapotranspiration.
4. Remote Sensing Data

<table>
<thead>
<tr>
<th>Main RS Images</th>
<th>Affixation</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>path code</td>
</tr>
<tr>
<td>1978-6-12</td>
<td>MSS132-32</td>
</tr>
<tr>
<td>1984-10-2</td>
<td>TM123-32</td>
</tr>
<tr>
<td>1992-5-18</td>
<td>TM123-32</td>
</tr>
<tr>
<td>2001-5-19</td>
<td>TM123-32</td>
</tr>
</tbody>
</table>

**SPOT**: SPOT5 of panchromatic band, with 2.5 m spatial resolution, on Sept, 2002.
Methods and data

Data Processing

1. RS data processing

In order to reduce the disturbance of homologous spectrum from different objectives, the images were divided into 6 different altitude segments by DEM according to the regulations of vegetation distribution and the impacts of human activities.

The total area was divided into 10 land cover categories:
- conifer forests
- broadleaf forests
- mixed forests
- shrubs
- grasslands
- sub-alpine meadow
- farmland
- settlements
- water body
- bare land
<table>
<thead>
<tr>
<th>Land cover types</th>
<th>Definition &amp; main components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conifer forests</td>
<td>It includes warm-temperate conifer forests, such as <em>Pinus tabulaeformis</em> and <em>Platycladus orientalis</em>, and cold-temperate conifer forests, such as <em>Larix principis-rupprechtii</em>.</td>
</tr>
<tr>
<td>Broadleaf forests</td>
<td>It includes oak forests, valley shaws, <em>Tilia</em> forests, <em>Populus</em> &amp; <em>Salix</em> forests and plantations in low elevation area.</td>
</tr>
<tr>
<td>Mixed forests</td>
<td>It indicates broadleaf and conifer mixed forest, most of which consists of <em>Pinus</em> &amp; <em>Quercus</em>.</td>
</tr>
<tr>
<td>Shrubs</td>
<td>Secondary vegetation types with complex components, formed as human disturbance to primary forests. The main shrub types in Beijing include <em>Vitex negundo</em> var. <em>heterophylla</em>, <em>Spiraea</em>, <em>Corylus heterophylla</em>, <em>Prunus armeniaca</em> var. <em>ansu</em> and <em>Lespedeza</em>.</td>
</tr>
<tr>
<td>Grasslands</td>
<td>An unstable vegetation type as primary vegetation was destroyed, mostly consisted with xerophilous herbages such as <em>Bothriochloa ischaemum</em> and <em>Themeda japonica</em>, some shrubs distribute in it occasionally.</td>
</tr>
<tr>
<td>Sub-alpine meadow</td>
<td>Distribute at top of slopes above 1800m, mostly includes <em>Carex</em>, <em>Hemerocallis minor</em>, <em>Sanguisorba officinalis</em>, <em>Polygonum bistorta</em> and <em>Trollius chinensis</em>.</td>
</tr>
<tr>
<td>Farmland</td>
<td>Including large area cropland in plain area and intercrop land in suburb.</td>
</tr>
<tr>
<td>Settlements</td>
<td>Including built-up territory, rural residential area and large buildings such as airports.</td>
</tr>
<tr>
<td>Water body</td>
<td>Including reservoirs, rivers, lakes and wetlands.</td>
</tr>
<tr>
<td>Bare land</td>
<td>Including light reflectivity area such as no vegetation covered region and wasteland.</td>
</tr>
</tbody>
</table>
Methods and data

Data Processing

2. Forest communities structure and the relationships with environment

2.1 Quantitative characteristics of communities structure

\[ H, H_{\text{max}}, D, D_{\text{max}}, BA, N, IV \]

2.2 Species Diversity

\[ S, H', E, D \]

\[
H' = - \sum_{i=1}^{S} P_i \ln P_i \quad E = H'/\ln S \quad D = 1 - \sum_{i=1}^{S} P_i^2
\]
Methods and data

Data Processing

2.3 Community classification and ordination

TWINSPAN, CCA

2.4 Climate factors simulation

\[ T = aLAT + bLON + cELE + d \]

\[ P = aLAT + bLON + cELE + d \]
Methods and data

Data Processing

3. Land use changes and landscape structure analysis

3.1 Conversion matrix

\[ D_{ij} = \frac{S_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{n} S_{ij}} \]

3.2 Landscape structure analysis

Patch Characteristics: \( S, P, N, \bar{S}, \bar{P}, f_i, P/A \)

\[ \bar{S} = \sum_{j=1}^{n} \frac{a_{ij}}{n_i} \]
Results

Landscape change process in the past 30 years

1. Land cover changes process

![Graph showing land cover changes from 1978 to 2001]
Land cover changes from 1970s to 2000s
Results

Landscape change process in the past 30 years

1. Land cover changes process

**Result 1.1:** Great urbanization process occurred in Beijing from city central zones to suburban areas during past 30 years, and the intensity gradually declined with the increase of the distance from core zones.

**Result 1.2:** The area of natural vegetation has been increasing. Forests and other natural vegetation types were relatively stable in mountainous areas with high elevation.

**Result 1.3:** The farmland area has been shrinking and fragmentation is being aggravated.
## Results

**Landscape change process in the past 30 years**

2. Transformation of land cover types

### Percentage of land cover transformation in Beijing Area

<table>
<thead>
<tr>
<th>land types</th>
<th>1978</th>
<th>1984</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>forests</td>
<td>shrubs</td>
<td>grasslands</td>
</tr>
<tr>
<td>1978</td>
<td>78.3</td>
<td>18.3</td>
<td>1</td>
</tr>
<tr>
<td>1984</td>
<td>25.5</td>
<td>61.7</td>
<td>0.1</td>
</tr>
<tr>
<td>1992</td>
<td>7.4</td>
<td>47.4</td>
<td>15.6</td>
</tr>
</tbody>
</table>
## Results

### Landscape change process in the past 30 years

#### 2. Transformation of land cover types

<table>
<thead>
<tr>
<th>land types</th>
<th>forests</th>
<th>shrubs</th>
<th>grasslands</th>
<th>meadow</th>
<th>farmland</th>
<th>settlement</th>
<th>water body</th>
<th>bare land</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>81.8</td>
<td>12.7</td>
<td>1.7</td>
<td>0</td>
<td>1.8</td>
<td>1.3</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>8.3</td>
<td>80.4</td>
<td>7.6</td>
<td>0</td>
<td>2.2</td>
<td>0.5</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>3.7</td>
<td>39.5</td>
<td>40.6</td>
<td>0</td>
<td>0.7</td>
<td>4</td>
<td>0.4</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>10.8</td>
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<td>76.3</td>
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<td>0</td>
<td>0</td>
<td>6.7</td>
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<tr>
<td></td>
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<td>0</td>
<td>77.1</td>
<td>13.2</td>
<td>2.1</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.4</td>
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<td>13.1</td>
<td>75</td>
<td>2.6</td>
<td>3.3</td>
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<td>1.2</td>
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<td>1.7</td>
<td>0</td>
<td>13.2</td>
<td>12.7</td>
<td>67.7</td>
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</tr>
<tr>
<td></td>
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<td>4</td>
<td>0.1</td>
<td>27.3</td>
<td>15.6</td>
<td>2.1</td>
<td>44.8</td>
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<tr>
<td>2001</td>
<td>82.8</td>
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<td>0</td>
<td>2.1</td>
<td>1.4</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>16.3</td>
<td>66.6</td>
<td>14.1</td>
<td>0</td>
<td>1.7</td>
<td>0.3</td>
<td>0.1</td>
<td>1</td>
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<tr>
<td></td>
<td>10.8</td>
<td>17</td>
<td>49.6</td>
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<td>12.5</td>
<td>3.5</td>
<td>0.5</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>9.9</td>
<td>6.2</td>
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<td>71.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>1.4</td>
<td>2.6</td>
<td>0</td>
<td>68.5</td>
<td><strong>20.1</strong></td>
<td>1.6</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>0.6</td>
<td>1.1</td>
<td>0</td>
<td>15.5</td>
<td><strong>71.9</strong></td>
<td>2.2</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>2.1</td>
<td>2.6</td>
<td>3.5</td>
<td>0</td>
<td>19.7</td>
<td>20.6</td>
<td><strong>44.6</strong></td>
<td>6.9</td>
</tr>
<tr>
<td>bare land</td>
<td>4.7</td>
<td>2.0</td>
<td>10.6</td>
<td>0.8</td>
<td>31.5</td>
<td>23.1</td>
<td>1.3</td>
<td>25</td>
</tr>
</tbody>
</table>

Percentage of land cover transformation in Beijing Area
Results

Landscape change process in the past 30 years

2. Transformation of land cover types

Result 2.1: The main transformation occurred to farmland is settlement, which suggests a urbanization process.

Result 2.2: Some shrubs changed into forests, which results in the “conversion of farmland back to forests” policy.

Result 2.3: Most forests have been reserved and it revealed the effect of long-term maintenance of ecological conservation.
Results

Landscape change process in the past 30 years

3. Landscape pattern analysis

With GIS, we calculated the parameters at every stages include:

- each landscape type patch total area,
- the area percentage,
- patch total perimeter,
- numbers of patches,
- average area of different kind of patches,
- average perimeter of patches, and
- shape index \((P/A)\).
Result 3: Most land cover types with area shrinking suggested fragmentation tendency during the past 30 years. The landscape characteristic parameters also verified the urbanization process.
Results

Landscape change process in the past 30 years

4. Relationship between land cover changes and landform factors
Area-frequency distributions of land cover types along slope gradient.
Area-frequency distributions of land cover types at all aspects.
Results

Landscape change process in the past 30 years

4. Relationship between land cover changes and landform factors

**Result 4.1**: Landform has great impacts to the distribution of land cover types. Natural vegetation types mostly distribute in area with elevation more than 100m. Forests have more domination in area above 800 m, while shrubs turn out domination at the elevation range from 100 to 1,000 m. The largest transformation area from shrubs to forests occurred at the range elevation range from 500 to 1,000 m.

**Result 4.2**: Farmland and settlements mainly distribute in plain area, and shrub has obvious domination at slope range of 5°-10°. With the increasing of slope, the forests turn out more domination.

**Result 4.3**: Aspect has impacts to the distribution of forests, shrubs and farmland.
**Community Characteristics**

1. **Species component**

   Dominative arbor families:
   - Fagaceae
   - Betulaceae
   - Salicaceae
   - Pinaceae

   **Result 5:** The component of forest communities in Beijing is comparatively simple with other forests in China.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compositae</td>
<td>50</td>
</tr>
<tr>
<td>Rosaceae</td>
<td>25</td>
</tr>
<tr>
<td>Liliaceae</td>
<td>23</td>
</tr>
<tr>
<td>Ranunculaceae</td>
<td>20</td>
</tr>
<tr>
<td>Leguminosae</td>
<td>19</td>
</tr>
<tr>
<td>Gramineae</td>
<td>14</td>
</tr>
<tr>
<td>Violaceae</td>
<td>11</td>
</tr>
<tr>
<td>Campanulaceae</td>
<td>10</td>
</tr>
<tr>
<td>Umbelliferae ...</td>
<td>10 ...</td>
</tr>
</tbody>
</table>
Community Characteristics

2. Classification & ordination

With TWINSPLAN, all sample plots were classified into 9 forest types:

- *Quercus variabilis*, *Q. aliena* + *Q. acutissima*,
- *Picea tabulaeformis* + *Q. acutissima*, *Larix principis-rupprechtii*,
- *Betulaceae*,
- *Q. mongolica*, *P. tabulaeformis* + *Q. mongolica* + *Populus* & *Betulaceae*,
- *Q. liaotungensis*.

**Result 6**: The vegetation can indicate the component of communities and habitat characteristics.

TWINSPLAN classification
2. Classification & ordination

**Result 7.1:** Elevation is the principal factor to determine the vegetation distribution.

**Result 7.2:** Different community types have different inclinations to landform and other geographic factors.

Canonical Correspondence Analysis (CCA) for ordination
Results

Community Characteristics

3. Relationships between biodiversity & environmental factors

CCA for relationship between species diversity and environmental factors
### Results

<table>
<thead>
<tr>
<th>Environmental factors</th>
<th>N</th>
<th>$H_{\text{max}}$</th>
<th>$D_{\text{max}}$</th>
<th>BA</th>
<th>tree layer</th>
<th>shrub layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$S$</td>
<td>$H'$</td>
</tr>
<tr>
<td>LON</td>
<td>0.14</td>
<td>0.17</td>
<td>0.34**</td>
<td>0.45***</td>
<td>0.19</td>
<td>0.06</td>
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<td>LAT</td>
<td>0.33**</td>
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<td>0.02</td>
<td>0.21</td>
<td>-0.34**</td>
<td>-0.31**</td>
</tr>
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<td>ELE</td>
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<td>0.27*</td>
<td>0.28*</td>
<td>0.22</td>
<td>0.19</td>
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<td>SLO</td>
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<td>-0.11</td>
<td>-0.11</td>
<td>-0.22</td>
<td>0.1</td>
<td>0.16</td>
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<tr>
<td>ASP</td>
<td>-0.02</td>
<td>0.04</td>
<td>0.2</td>
<td>0.22</td>
<td>-0.07</td>
<td>-0.24*</td>
</tr>
<tr>
<td>AMT</td>
<td>-0.11</td>
<td>-0.25*</td>
<td>-0.32**</td>
<td>-0.35**</td>
<td>-0.25*</td>
<td>-0.2</td>
</tr>
<tr>
<td>WI</td>
<td>-0.13</td>
<td>-0.22</td>
<td>-0.3*</td>
<td>-0.33**</td>
<td>-0.27*</td>
<td>-0.21</td>
</tr>
<tr>
<td>MTWM</td>
<td>-0.1</td>
<td>-0.25*</td>
<td>-0.32**</td>
<td>-0.34**</td>
<td>-0.26*</td>
<td>-0.21</td>
</tr>
<tr>
<td>MTCM</td>
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<td>-0.33**</td>
<td>-0.35**</td>
<td>-0.25*</td>
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<td>0.23*</td>
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</tr>
<tr>
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<td>-0.17</td>
<td>-0.18</td>
<td>-0.15</td>
<td>-0.17</td>
<td>-0.18</td>
</tr>
<tr>
<td>GSP4-10</td>
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<td>-0.18</td>
<td>-0.18</td>
<td>-0.15</td>
<td>-0.18</td>
<td>-0.19</td>
</tr>
<tr>
<td>Im</td>
<td>0.11</td>
<td>-0.05</td>
<td>0.04</td>
<td>0.16</td>
<td>0.03</td>
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</tr>
<tr>
<td>PER</td>
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<td>-0.2</td>
<td>-0.34**</td>
<td>-0.48***</td>
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<tr>
<td>PET</td>
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<td>-0.24*</td>
<td>-0.3*</td>
<td>-0.33**</td>
<td>-0.26*</td>
<td>-0.19</td>
</tr>
<tr>
<td>AET</td>
<td>-0.04</td>
<td>-0.17</td>
<td>-0.18</td>
<td>-0.15</td>
<td>-0.17</td>
<td>-0.18</td>
</tr>
</tbody>
</table>

*: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$

Correlation of communities structure and biodiversity index with environmental factors
Community Characteristics

3. Relationships between biodiversity & environmental factors

**Result 8.1**: Generally, the community structures of tree layer and biodiversity have been declined in low elevation area in Beijing area, resulting in intensive exploitation of human being.

**Result 8.2**: Biodiversity of shrub layer has been significantly impacted by heat and humidity; and species diversity ascends with the increase of humidity.
Results

1. Green land distribution

- Arbor: 15.5%
- Shrub: 17.4%
- Built-up: 2.1%
- Water: 13.8%
- Farm land: 51.2%
Results

Urban green land

2. Species diversity

- All sample plots
  - + Digitaria sanguinalis 马唐
  - + Oxalis corniculata 酢浆草
  - + Broussonetia papyrifera 枸树
  - + Metaplexis japonica 萝摩
  - + Rhamnus utilis 冻绿
  - + Phragmites australis 芦苇
  - + Galium aparine 萝草
  - + Viola prionantha 早开堇菜
  - + Rubia cordifolia 茜草
  - + Chloris virgata 虎尾草
  - + Tribulus terrestris 茺藜

Group 1
- 1–23, 28, 48–80
  - - Rhamnus utilis 冻绿
  - - Phragmites australis 芦苇
  - - Galium aparine 萝草
  - + Viola prionantha 早开堇菜
  - + Rubia cordifolia 茜草

Group 2
- 48–50, 53–56, 59, 71, 72, 74, 76
  - 1–23, 28, 51, 52, 57, 58, 60–70, 73, 75, 77–80

Group 3
- 25–27, 29–47
  - - Oxalis corniculata 酢浆草
  - - Broussonetia papyrifera 枸树
  - - Metaplexis japonica 萝摩
  - + Chloris virgata 虎尾草
  - + Tribulus terrestris 茺藜

Group 4
- 26, 29–31, 33, 39–41, 45–47

Sample plot code:
- Garden-a: 1;
- Garden-b: 2–6;
- Garden-c: 7–12;
- Garden-d: 13–22;
- Garden-e: 23–47;
Results

Urban green land

2. Species diversity

<table>
<thead>
<tr>
<th></th>
<th>Group1</th>
<th></th>
<th>Group2</th>
<th></th>
<th>Group3</th>
<th></th>
<th>Group4</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>SD</td>
<td>mean</td>
<td>SD</td>
<td>mean</td>
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<td>SD</td>
</tr>
<tr>
<td>$S'$</td>
<td>11</td>
<td>3.39</td>
<td>16</td>
<td>4.9</td>
<td>23</td>
<td>4.72</td>
<td>22</td>
<td>4.55</td>
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<tr>
<td>$H'$</td>
<td>2.08</td>
<td>0.31</td>
<td>2.37</td>
<td>0.34</td>
<td>2.79</td>
<td>0.22</td>
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<tr>
<td>$E$</td>
<td>0.87</td>
<td>0.04</td>
<td>0.88</td>
<td>0.05</td>
<td>0.9</td>
<td>0.03</td>
<td>0.88</td>
<td>0.01</td>
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<tr>
<td>$D$</td>
<td>0.83</td>
<td>0.05</td>
<td>0.86</td>
<td>0.06</td>
<td>0.92</td>
<td>0.02</td>
<td>0.9</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Species diversity of herbaceous layers in different types of plant communities categorized by TWINSPAN
Results

Urban green land

2. Species diversity

**Result 9.1:** From TWINSPAN classification, it indicates that human disturbance and moisture is the main two factors which distinguish community categories.

**Result 9.2:** The calculation results of biodiversity parameters indicate that communities with higher evenness have more stable structures among communities which have the same species richness. Some sites with more species richness in fact result in the disturbance of human being, because the annual and biennial species proportion is much higher.
Results

Urban green land

3. Hedges along pavements

Hedges play an important role in urban landscape decoration, air purification, noise declination, dust adsorption and erosion prevention. From the survey, it indicates that at the highway sections with higher coverage, usually have more biodiversity. Aboriginal tree species is more suitable for the pavement afforestation.
Conclusions

Landscape changes are greatly impacted by human activities. The impact intensity depends on landform, moisture, heat and other environmental factors.

Urbanization process brings significant changes to landscape. With the landscape changing, the biodiversity and the community structure of nature vegetations has also been disturbed.
Conclusions

No matter the rehabilitation of nature vegetation, or the afforestation of pavements in urban area, native species plays important role during the whole process.

As an important ecological function of communities, biodiversity can suggest many characteristics of ecosystem itself and other impact factors. Biodiversity of vegetations is not only decided by the succession process of communities, but also impacted by human and environmental factors. Generally, the former has more influence than the latter.
Thanks for attention!