Machine Learning Based Grassland Degradation Assessment on the Qinghai Tibet Plateau, China
CONTENTS

01 | Background

02 | Material and method

03 | Results
   a. Eco-geographical regions for grassland
   b. Grassland monitoring indicators
   c. Grassland degradation assessment

04 | Future work
1.1 Grassland degradation

Grassland area, global 25 %, China 40 %;
Grassland degradation, A process of retrogressive succession in which the composition, structure and function of grassland ecosystem changed significantly (Wang et al., 2023; Wang et al., 2016)

causeing soil erosion, loss of biodiversity, and reduction of ecosystem services.
1.2 Degradation monitoring

Grassland degradation RS monitoring articles from 1990 to 2023

<table>
<thead>
<tr>
<th>Indicators</th>
<th>None D.</th>
<th>Slight D.</th>
<th>Moderate D.</th>
<th>Severe D.</th>
<th>Extreme D.</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>&gt;90</td>
<td>80-90</td>
<td>50-80</td>
<td>15-50</td>
<td>&lt;15</td>
<td>Xue et al., 2009</td>
</tr>
<tr>
<td>Coverage</td>
<td>&gt;90</td>
<td>75-90</td>
<td>60-75</td>
<td>30-60</td>
<td>&lt;30</td>
<td>Cao et al., 2019</td>
</tr>
<tr>
<td>NPP</td>
<td>0-10</td>
<td>10-20</td>
<td>20-50</td>
<td>&gt;50</td>
<td>-</td>
<td>Jiang et al., 2007</td>
</tr>
<tr>
<td>GDI</td>
<td>&lt;13.9</td>
<td>13.9-33.5</td>
<td>33.5-52.4</td>
<td>52.4-68.4</td>
<td>68.4-87</td>
<td>Wen et al., 2010</td>
</tr>
<tr>
<td>GDI₉</td>
<td>≥0.5162</td>
<td>0.3757-0.5162</td>
<td>0.2560-0.3757</td>
<td>&lt;0.2560</td>
<td>-</td>
<td>Yang et al., 2019</td>
</tr>
</tbody>
</table>

- Human activities and climate change induced land cover (quality) change monitoring by using NDVI/vegetation index and net primary production
- Indicators, single Indicator or simple combinations
- Degree definition, manual or automatic (clustering method)
1.2 Degradation monitoring

Different indicators, degradation thresholds and benchmarks, grassland degradation area varies from 10% to 90% (Akiyama T et al., 2007; Wang et al., 2016; Liu et al., 2019; Zhang et al., 2023).

2000 - 2019

- Vegetation coverage
- Theil-Sen median
- Degradation, 10%

2001 - 2013

- NPP
- Linear regression
- Degradation, 40%

- Time series based; Not directly spatial comparison of grassland quality

NDVI, EVI, LAI, NPP, GPP

Theil-Sen median

Degradation, 13%

NDVI, NPP (GDI)

K-means

Degradation, 40%
1.2 Degradation monitoring

- Ecosystem service indicators should be introduced in the monitoring systems for grassland assessment. (Zhang et al., 2016; Bai et al., 2014)
1.3 Objectives

- Ecosystem service indicators were introduced to the grassland degradation assessment.
- Integration of ground survey and remote sensing data by using machine learning method to assess the grassland degradation on the QTP in last 20 years.
➢ Eco-geographical regions: Climatic and topographic factor clustering + vegetation map
➢ Grassland monitoring indicators: FVC, NPP, water retention and soil conservation
➢ Grassland degradation assessment: Field samples + indicators + RF algorithm

Background

Material and method

Eco-geographical regions

Grassland monitoring indicators

Grassland degradation assessment

Future work

2.1 technical route

"roof of the world"
"earth's third pole"
"Asian water tower"

Grassland area, 60%

Machine learning-based assessment of the degradation of alpine grassland on the Qinghai-Tibet Plateau in the past 20 years

Data Collection

Ground Survey
Remote Sensing
Meteorological
Other

NDVI
Elevation
Vegetation-type

Calculation of indicators

Structure Indicator
Function Indicator
Service Indicator

Net primary productivity
Water retention
Soil conservation

Grassland Degradation Assessment System

Ground survey
Assessment of sampling sites
Effective sampling sites
Scene setting
Remote forest
Model compare
Grassland degradation degree assessment from 2000 to 2020

Driving Factors Assessment

Climate
Geographical detector model
Driving factors assessment

Literature
Climate
Human activities
Field samples: July, August in 2019 and 2020. Total 970 samples

- Sample site settings: 1 m × 1 m, 3 replicates, interval >1 km;
- Sample information: location, elevation, coverage, species, rodent etc.

Literature samples: keywords ’QTP’, ‘Grassland degradation’. Total 208 samples

Data sources

<table>
<thead>
<tr>
<th>Category</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS images</td>
<td>MOD13Q1, GEE (<a href="https://code.earthengine.google.com/">https://code.earthengine.google.com/</a>)</td>
</tr>
<tr>
<td>DEM</td>
<td>Earth Resources Data Cloud Platform (<a href="http://www.gis5g.com/">http://www.gis5g.com/</a>)</td>
</tr>
<tr>
<td>Climate</td>
<td>National Qinghai-Tibet Plateau Scientific Data Center (<a href="https://data.tpdc.ac.cn/">https://data.tpdc.ac.cn/</a>)</td>
</tr>
<tr>
<td>Soil</td>
<td>Earth Resources Data Cloud Platform (<a href="http://www.gis5g.com/">http://www.gis5g.com/</a>)</td>
</tr>
<tr>
<td>National eco-geographical division</td>
<td>Geographic remote sensing ecological network scientific data system</td>
</tr>
<tr>
<td>vegetation map</td>
<td>Institute of Geographical Science and Resources, Chinese Academy of Sciences (<a href="https://www.resdc.cn/">https://www.resdc.cn/</a>)</td>
</tr>
</tbody>
</table>
2.3 Eco-geographical regions

Eco-geographical regions for grassland on Qinghai-Tibet Plateau

Flow chart of grassland eco-geographical regions

- **Climate terrain clustering:** temperature, precipitation, ET, elevation
- **Best clustering:** stable NPP, Minimum intra-group variance/inter-group variance;
- **Eco-geographical regions:** Integrated vegetation map
2.4 Grassland monitoring indicators

1 structure, 1 function and 2 ecosystem service indicators

- **FVC**: Structure indicators, pixel dichotomy
- **NPP**: function indicators, LUE model
- **Water retention**: Service indicator, Invest model
- **Soil conservation**: Service indicator, Invest model
2.5 Grassland degradation assessment

Integration of samples and RS data by using ML algorithm

- **Degradation degree**: based on coverage, community composition of samples.
- **Training samples**: field + literature, extract the corresponding indicator values
- **Establishing model**: Random forest with 2 scenarios
- **Degradation assessment**: Grassland degradation on QTP from 2000 to 2020

Flow chat of grassland degradation assessment
3.1 Eco-geographical regions

Based on the clustering results, combined with the mean value of climate and terrain and zonal vegetation, 5 eco-geographical regions were defined.

I. Arid alpine steppe
II. Semiarid alpine steppe
III. Semiarid alpine meadow
IV. Semiarid temperate mountain meadow
V. Semiarid temperate mountain steppe
3.2.1 Fractional vegetation coverage

Spatial:
Decrease from SE to NW

Temporal:
0.06 % a⁻¹ ↑
Increase: 42.1 %
Significant increase: 14.4 %
Decrease: 37.7 %
Significant decrease: 5.7 %
3.2.2 Net primary productivity

Temporal:
0.15 g C m\(^{-2}\) a\(^{-1}\)

Increase: 29.7 %
Significant increase: 39.4 %
Decrease: 29.5 %
Significant decrease: 1.4 %

Spatial:
Decrease from SE to NW
3.2.3 Water retention

**WR of 2000**

**WR of 2010**

**WR of 2020**

**Change trends of WR from 2000 to 2020**

**Spatial distribution of WR**

**Spatial:**
Decrease from SE to NW

**Temporal:**
- Increase: 31.5 %
- Significant increase: 6.5 %
- Decrease: 59.1 %
- Significant decrease: 2.9 %

**Annual WR trends (00-20):**

- Temporal: 0.47 mm·m$^{-2}$·a$^{-1}$

**Stem:**
- WR of 2000
- WR of 2010
- WR of 2020
- Change trends of WR from 2000 to 2020
3.2.4 Soil conservation

Temporal:
-0.04 t·hm⁻² a⁻¹

Increase: 46.3 %
Significant increase: 6.6 %
Decrease: 44.8 %
Significant decrease: 2.3 %

Spatial:
Decrease from SE to NW
**3.3.1 Field samples**

**Grassland field samples on the QTP**

**Amount of samples**

<table>
<thead>
<tr>
<th>Total</th>
<th>Effective samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1208</td>
<td>838 (field 630, literature 208) 30 (sample migrating)</td>
</tr>
</tbody>
</table>

**Standard for degradation degree definition of grassland sample sites**

<table>
<thead>
<tr>
<th>Degradation degree</th>
<th>Coverage reduction (%)</th>
<th>Species composition</th>
<th>Populations of rodent</th>
</tr>
</thead>
<tbody>
<tr>
<td>None degradation (ND)</td>
<td>0-10</td>
<td>No significant change in the dominant species</td>
<td>No or less distribution</td>
</tr>
<tr>
<td>Light degradation (LD)</td>
<td>11-20</td>
<td>Number of dominant species has decreased, while the number of poisonous weeds has obvious increased</td>
<td>Obvious increase</td>
</tr>
<tr>
<td>Moderate degradation (MD)</td>
<td>21-30</td>
<td>Obvious reduction in dominant species and widespread distribution of poisonous weeds</td>
<td>A large number of rodent</td>
</tr>
<tr>
<td>Heavy degradation (HD)</td>
<td>&gt;30</td>
<td>The dominant species are mostly replaced by poisonous weeds</td>
<td>Rodent caused disasters</td>
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**Eco-geographical regions**

<table>
<thead>
<tr>
<th>Eco-geographical region</th>
<th>Sampling sites</th>
<th>ND</th>
<th>LD</th>
<th>MD</th>
<th>HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Arid alpine steppe</td>
<td>93</td>
<td>30</td>
<td>29</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>II Semiarid alpine steppe</td>
<td>307</td>
<td>20</td>
<td>53</td>
<td>85</td>
<td>149</td>
</tr>
<tr>
<td>III Semiarid alpine meadow</td>
<td>242</td>
<td>11</td>
<td>56</td>
<td>69</td>
<td>106</td>
</tr>
<tr>
<td>IV Semiarid temperate mountain meadow</td>
<td>87</td>
<td>20</td>
<td>27</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>V Semiarid temperate mountain steppe</td>
<td>139</td>
<td>39</td>
<td>28</td>
<td>42</td>
<td>30</td>
</tr>
</tbody>
</table>

**Grassland degradation assessment**

**Populations of rodent**

<table>
<thead>
<tr>
<th>Degradation degree</th>
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3.3.2 ML models

Model 1: whole QTP + 8 factors
Model 2: eco-geo regions + 4 factors

Importance of input variables:
- \( FVC \), \( NPP \) (79%)
- \( WR \), \( SC \) (21%)

Accuracy:
- Model 2 (0.86) > Model 1 (0.59)
- Best performance in heavy degradation
3.3.3 Grassland degradation assessment

- 55.3% grassland on QTP were at degree of moderate and heavy degradation in 2020.
- Generally stable (75%), 17% degraded grassland was restored, only 8% got worse from 2000 to 2020.
3.3.3 Grassland degradation assessment

Stable: II (79%) > IV > III > I > V (73%)
Worsen: I (12%) > IV > III > V > II (2%)
Recovery: V (24%) > III > II > IV > I (14%)
Driving forces of grassland degradation on QTP

- Climatic (temperature, precipitation, induced rodent disaster etc.)
- Anthropogenic (population, GDP, grazing intensity etc.)
Thanks for your attention!