

Article

Soil and Water Conservation Vegetation Restoration in Alpine Areas—Taking a Hydropower Station as an Example

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Abstract: High-elevation and cold regions have harsh natural conditions with low temperatures and intense ultraviolet radiation, which impede plant growth and maintenance. Therefore, soil and water conservation vegetation restoration models are of great significance. In this study, a site condition analysis was performed based on three main limiting factors, including climatic and meteorological, soil, and topographic and geomorphological factors, providing a basis for vegetation restoration. The study area was divided into different site types. After investigating the situation of nurseries distributed in places such as Tibet, Qinghai, and Sichuan, trees, shrubs, and grasses with ecological characteristics similar to those of the local vegetation, including strong stress resistance, good soil and water conservation benefits, and well-established artificial cultivation practices, were selected as alternative vegetation for late-stage planting of indigenous tree species. Combining the results of site condition analysis and site type classification, the configuration of trees, shrubs, and grasses for different off-site condition types and the corresponding greening methods are discussed, providing a scientific reference for ecological restoration in high-elevation and low-temperature regions.

Keywords: high-elevation regions; vegetation restoration; soil and water conservation



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1. Introduction

After the 18th CPC National Congress, General Secretary Xi Jinping has incorporated the construction of an ecological civilization into the “five-in-one” overall layout of the socialist cause with Chinese characteristics. In the course of this, he put forward the development concept of ‘green mountains are golden mountains’. The Tibetan Plateau Ecological Protection Law, which came into effect in 2023, raises ecological protection in the Tibetan Plateau region to the legal level and is of great significance in strengthening ecological protection on the Tibetan Plateau, building a national ecological civilization highland, promoting sustainable economic and social development, and realizing a harmonious coexistence between humans and their surrounding natural environment.

Tibet is committed to building a demonstration area for the use of national clean and renewable energy, with the plan to exceed 15 million kilowatts of installed and under-construction hydropower capacity by 2025. However, the development and construction of hydropower plants face inescapable ecological and environmental issues [1,2]. Tibet is a region at high elevation and with a cold climate, characterized by harsh natural conditions, including low temperatures and intense ultraviolet radiation, impeding plant growth and maintenance [3]. Therefore, studying the soil and water conservation and vegetation restoration models for hydropower station construction projects is of great significance [4].

As early as the 1970s, based on succession theory in vegetation science, Miyawaki used seeds of local native tree species for container seedling cultivation, combined with appropriate soil improvement, and established a climax community type suitable for the local climate in a short period of time. This method is called the “Miyawaki method” [5]. Chen et al. [6] employed a restricted cubic spline (RCS) method to examine ecological resilience variables in Hunan Province and proposed an ecological resilience evaluation framework based on ecosystem structure and function. The results indicated that ecological resilience had increased from 2000 to 2020, demonstrating significant spatial heterogeneity among regions. The RCS results revealed a nonlinear relationship between natural and anthropogenic factors and ecological resilience, with thresholds varying over time. Sun et al. [7] took four geomorphological types in the Eastern Loess Plateau (ECLP) as the study area and, based on stable isotope technology, quantitatively studied the water use strategies of typical plants (ecological restoration plants and food crops). The findings showed significant spatiotemporal heterogeneity in regional soil moisture and stable isotopes, with more pronounced fluctuations in soil water isotope values in the rocky mountain region. In China, Chen et al. [8] conducted a grass seeding experiment to study the impact of over-sowing grasses on the aboveground biomass of various economic groups in the high-altitude desertified grasslands of Maqu. The results showed that over-sowing grasses could increase the height and vegetation cover of grass communities in high-altitude desertified grasslands. Over-sowing, as an effective measure to improve natural grasslands, has a positive effect on increasing grass community height, coverage, and enhancing the aboveground biomass of grasslands. In a study of degraded alpine grassland restoration, Peng et al. [9] pointed out that reseeded, fertilization, grassland stocking control, artificial grassland establishment, enclosure and protection, rodent pest control, grazing bans, fallow grazing, and rotational grazing are the main measures for the restoration and management of alpine grasslands; generally, corresponding comprehensive measures are taken according to the degradation level of the alpine grasslands. In a study investigating the habitat characteristics of different types of mobile sand areas in the alpine valleys of Tibet, Li et al. [10] constructed an integrated evaluation model for the potential of vegetation restoration in alpine valley mobile sand areas. The authors stated that, through strong promotion of vegetation restoration measures, the potential for vegetation restoration in alpine valley mobile sand areas can be improved, along with the soil conditions, thereby enhancing the effect of vegetation restoration. Cheng et al. [11], by using ENVI and ArcGIS, corrected and synthesized the vegetation classification map of China by Mr. Zhang Xinsi and the LUCC2015 vegetation classification map to produce a forest distribution map of southeastern Tibet, and compared the forest coverage of various counties in southeastern Tibet, finding that the forest coverage in Nyingchi City reaches over 50%.

2. Study Area

2.1. Overview of the Study Area

The study area was the construction area of a hydropower station in Tibet, which is located in Bomi County, Linzhi City, Tibet Autonomous Region. The exact location of the study area is shown in Figure 1. The climate is temperate sub-humid plateau monsoon climate, with an average annual precipitation of 850.4 mm, an average annual evaporation of 1088 mm, an average annual temperature of 11.8 °C, a cumulative temperature of ≥ 10 °C of 2269 °C, an average annual wind speed of 0.7 m/s, with the prevailing wind directions being WN (west–northwest) and WS (west–southwest), an annual sunshine duration of 1563 h, a maximum frozen soil depth of 0.6 m, and a frost-free period of 176 days. The main soil type in the study area is black felt-like sandy loam, and the primary vegetation types include the following: alpine cold-temperate coniferous forests, such as *Picea likiangensis* (Franch.) E.Pritz. forest community and *Tsuga dumosa* (D.Don) Eichler forest community; temperate coniferous forests, including *Pinus armandii* (Franch.) forest community and *Pinus densata* (Mast.) forest community; broadleaf forests, including *Populus* (D.Don) forest community, *Betula pendula* (Roth.) community, *Populus longifolia* (Delile) forest community,

Quercus tungmaiensis (Y. T. Chang) forest community, and *Quercus aquifolioides* (Rehd.) forest community; and shrublands, including the *Prunus padus* (L.) forest community, *Berberis thunbergii* (DC.) community, *Cotoneaster microphyllus* (Wall. ex Lindl.) forest community, *Prunus padus* (L.) forest community, *Artemisia mongolica* (Hand.-Mazz.) community, and *Dryopteris championii* (Benth.) Kuntze community. The average vegetation coverage rate of forests and grasslands is approximately 87%.

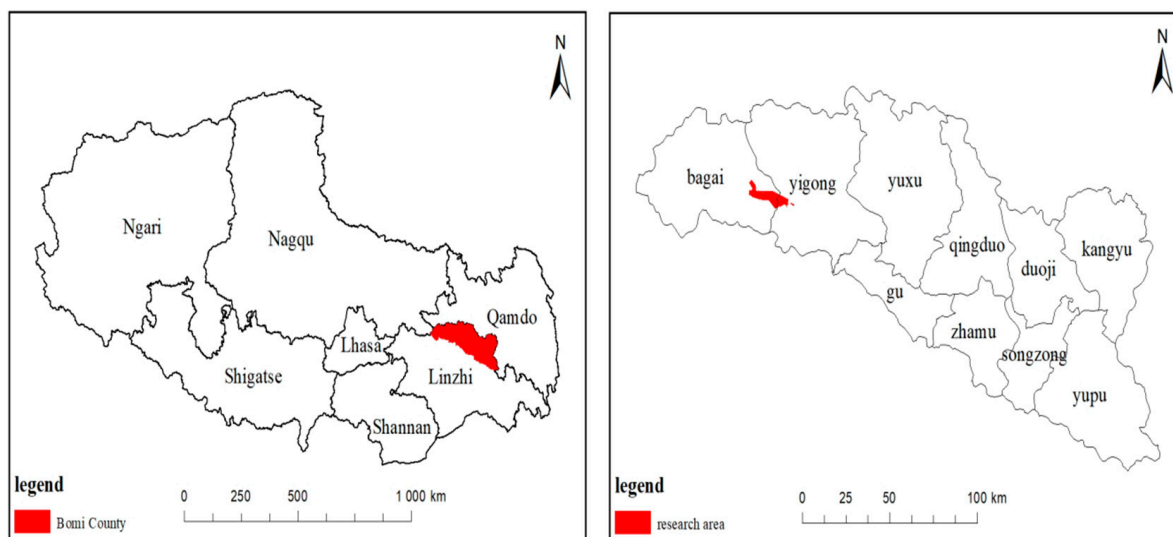


Figure 1. Study Area Location Map.

2.2. Basic Information of the Hydropower Station

The hydropower station involved in this study is located on the main stream of the Yigong Zangbo River. The project is classified as a large second-type project. The installed capacity of the power station is 1000 MW. The hydropower station project mainly includes concrete gravity dam water retaining structure, water discharge structure, and waterpower generation structure.

3. Data and Research Methods

3.1. Data and Data Sources

Remote sensing images were selected from the Landsat-8 OLI satellite series images of the United States Geological Survey (USGS) website (format: <http://earthexplorer.USGS.gov/>, accessed on 4 April 2023). The Landsat-8 satellite, launched by the National Aeronautics and Space Administration (NASA) on 11 February 2013, is the eighth satellite in the Landsat series, equipped with OLI and TIRS sensors. Compared with ETM+, OLI covers nine bands, adding a coastal band and a cirrus band, and adjusting the wavelengths of the remaining bands, mainly reflected in band 5, which eliminates the water vapor absorption characteristics at 0.825 μm while reducing the panchromatic band range, allowing panchromatic images to better distinguish between vegetated and non-vegetated features. In this study, Landsat-8 OLI imagery from 27 October 2022, with cloud cover less than 5%, was used, with a spatial resolution of 30 m. Meteorological data is derived from the Bomi County Meteorological Station. The climatic characteristics of the study area are more similar to those near the Yigong Meteorological Station. However, the data series from the Yigong Meteorological Station is relatively short. Considering that the average temperatures at the Yigong Meteorological Station are quite close to those at the Bomi Meteorological Station and the climatic conditions are similar, the statistical results from the Bomi Meteorological Station, which is more similar in climatic characteristics, are primarily referred to. Meteorological elements, such as temperature and humidity, which have small interannual variations, are referenced from the Yigong Meteorological Station. Soil data were obtained through field surveys and laboratory analysis. Digital elevation

model (DEM) data were acquired from the Geographical Spatial Data Cloud Platform of the Chinese Academy of Sciences Network Information Center (<http://www.gscloud.cn>, accessed on 4 April 2023), with a spatial resolution of 30 m. Since the majority of the trees in the study area are distributed in steep and inaccessible terrain, high-resolution remote sensing data were used for the inversion of vegetation coverage to obtain the coverage of arbor vegetation, and unmanned aerial vehicle (UAV) aerial images were applied for vegetation coverage monitoring.

3.2. Research Methods

3.2.1. High-Resolution Image Processing Method

Landsat series data require preprocessing steps, such as radiometric calibration [12] and atmospheric correction [13,14], before they can be used. Radiometric calibration is the preparatory work before atmospheric correction. In this study, the radiometric calibration tool (Radiometric Calibration) within the ENVI software suite was employed to perform radiometric calibration on remote sensing imagery, which involves converting the image brightness grayscale values into absolute radiance values.

Atmospheric correction is the process of converting the radiance values, post radiometric calibration, into surface reflectance values. The aim is to eliminate the impact of atmospheric elements, such as water vapor, oxygen, carbon dioxide, methane, and ozone, on the reflection of terrestrial objects and to correct for the effects of atmospheric molecules and aerosol scattering to obtain accurate reflectance data of the terrain. Atmospheric correction allows for the acquisition of more precise spectral characteristics of plant communities, which is fundamental for their classification and identification. Currently, the most commonly applied method of atmospheric correction is based on the radiative transfer equation. In this study, the FLAASH model provided by ENVI was used to complete atmospheric correction.

3.2.2. UAV Image Processing

UAV imagery data were used for monitoring vegetation coverage. To strictly control the resolution, the flight altitude of UAV was set to within 100 m. UAV aerial photography was processed using Pix4Dmapper software, which involves steps such as image selection, color balancing, feature point matching, point cloud computation, and image stitching. This process generates a visible light orthophoto map [15] (DOM, digital orthophoto map) of the photographed area for monitoring and comparison of vegetation coverage.

3.2.3. DEM Data Processing

ArcGIS software was employed for data processing [16]. After obtaining DEM data, the first step is to perform image stitching to acquire a complete set of DEM data. Subsequently, by incorporating vector data and conducting a mask extraction, the data for the required study area are obtained.

3.2.4. Vegetation Cover Inversion

The vegetation coverage of herbaceous plants was obtained through field surveys. Since most of the arbor trees in the study area were distributed in steep and inaccessible terrain, high-resolution remote sensing images were used for the inversion of vegetation coverage to obtain the coverage of arbor vegetation. After loading the imagery into the ArcGIS software, the coverage range of the arbor trees was obtained through visual interpretation, and the vegetation coverage of the trees was calculated.

4. Results and Analysis

4.1. Site Condition Analysis

Site condition analysis is conducted based on three main limiting factors, including climatic and meteorological, soil, and topographic and geomorphological factors, providing a foundation for vegetation restoration [17].

4.1.1. Climate

The study area has a high total precipitation, a large number of precipitation days, low rainfall intensity, and frequent night-time rainfall. The winter temperatures are low, with large temperature differences. The average annual temperature is 9.1 °C, with the highest monthly average temperature in July and the lowest in January. The average annual precipitation is 850.4 mm, and the rainy season lasts from May to September, with concentrated rainfall accounting for over 70% of the total annual precipitation. From October to the following April, the precipitation accounts for only 10% to 20% of the annual total. The average wind speed is 1.4 m/s.

4.1.2. Soil

The soil in the project area shows a distinct vertical distribution with increasing elevation, and the soil type is predominantly black felt-like sandy soil, which is slightly acidic. Based on the survey results, the surface soil in the engineering area is mainly found in forest–grassland and cultivated land with a flat terrain and low gravel content. Soil pH ranged from 5.88 to 6.88, and the organic matter content was between 23.09 and 63.85 g/kg, classifying the soil as weakly acidic soil. The soil in the construction area contained large amounts of total potassium and phosphorus, with the vast majority being third-grade soil and a minority being second-grade soil. Overall, the soil in the project area was rich in organic matter and total nutrients, with an adequate amount of available nutrients, indicating a good overall soil quality.

The steep riverbank slopes and the exposed rocky surfaces are low in soil moisture, which is one of the key factors affecting plant growth [18]. Soil samples from 10 plots were taken using aluminum boxes, and the soil moisture content was obtained via oven-drying; the results are shown in Table 1. The soil moisture content in the study area ranged from 5.27% to 51.85%, with an average of 27.80%. Shi [19] explored the physiological characteristics of flag leaves of different barley varieties (lines) at different elevations in Linzhi City, Tibet; according to the author, the growth conditions are better at a soil moisture content between 10% and 30%. Through a hybrid model that combined the apparent thermal inertia (ATI) and the temperature vegetation dryness index (TVDI), Yang and Guo [20] inverted the soil moisture of the national grassland ecosystem in 2016 and found that the average soil moisture content in the Tibet area reached 20% to 30%. Within this range, the soil moisture can meet the growth and development needs of plants, which is instructive for vegetation selection.

Table 1. Soil moisture levels at the different sampling plots.

Sampling Plot	Fresh Soil Weight (g)	Soil Weight After Drying (g)	Soil Moisture Content (%)
1	25.89	17.05	51.85
2	24.29	17.8	36.46
3	42.83	31.14	37.54
4	68.54	62.62	9.45
5	32.17	22.45	43.30
6	45.07	37.99	18.64
7	51.21	44.52	15.03
8	44.44	39.44	12.68
9	62.7	59.56	5.27
10	42.47	28.73	47.82
Average soil moisture content in the study area			27.80

4.1.3. Topographic and Geomorphological Factors

The topography and geomorphology of the study area are complex and closely related to the main factors affecting vegetation growth, such as light, temperature, and soil moisture. Investigating and analyzing the characteristics of topography and geomorphology are crucial to assessing the site conditions and selecting adequate vegetation restoration

techniques. Therefore, combining DEM and field survey data, a quantitative analysis of the overall topography and geomorphology of the study area and the current status of each control area, including elevation, slope, and aspect, was conducted. Elevation was divided into five levels: I: <2400 m; II: 2400–2700 m; III: 2700–2900 m; IV: 2900–3200 m; V: ≥ 3200 m. The results are presented in Table 2 and Figure 2. Slope was partitioned into four levels: gentle slope (0–5 degrees), moderate slope (6–15 degrees), steep slope (16–25 degrees), very steep slope (>25 degrees). Aspect was divided into nine categories: flat, north-facing, northeast-facing, east-facing, southeast-facing, south-facing, southwest-facing, west-facing, northwest-facing.

Table 2. Project area elevation classification and area statistics.

Statistical Projects		Area (km ²)	Proportion (%)
Grading height	<2400 m	9.09	11.5
	2400–2700 m	29.83	37.73
	2700–2900 m	13.49	17.07
	2900–3200 m	15.76	19.94
	≥ 3200 m	10.88	13.76

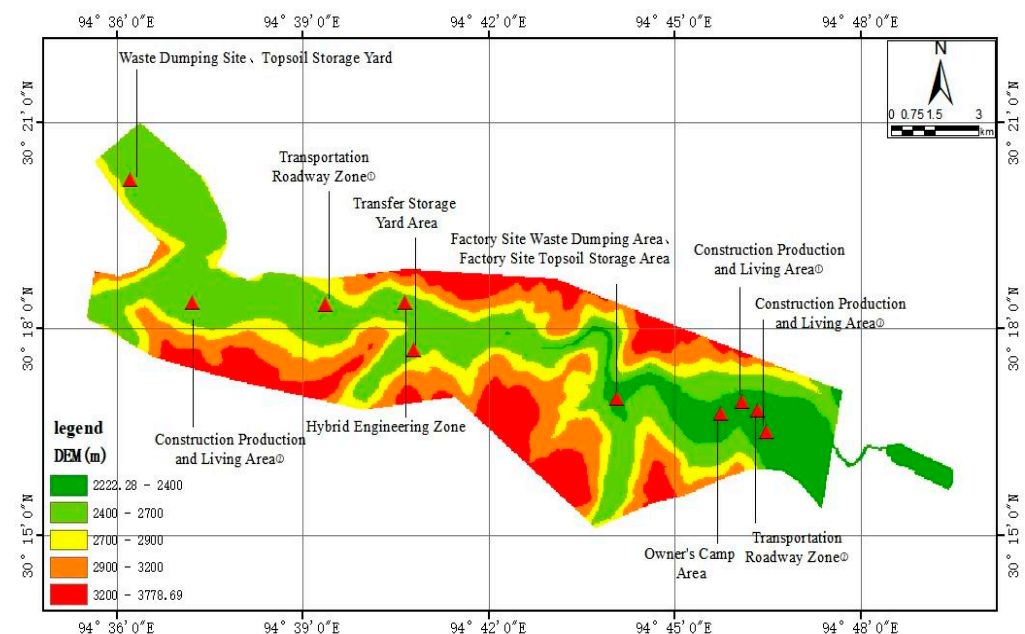


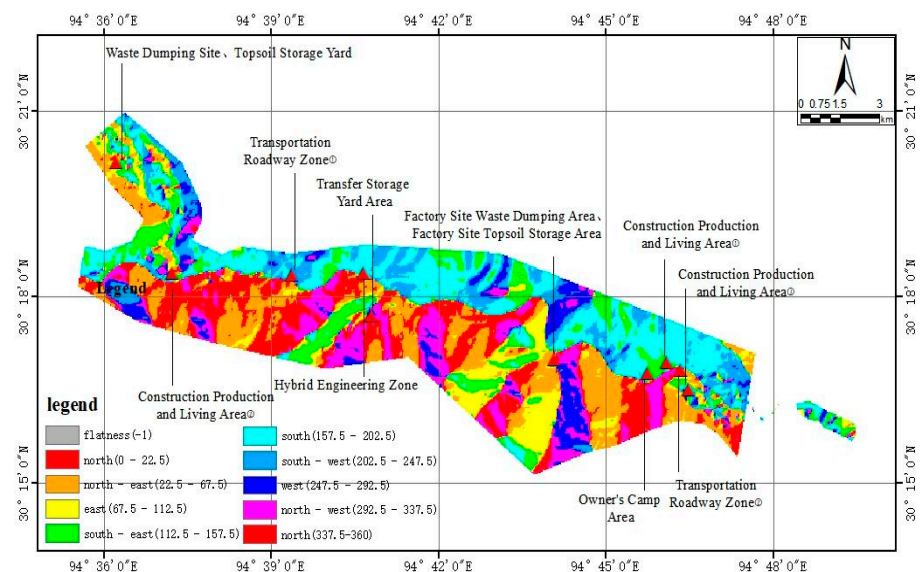
Figure 2. Digital elevation model map of the study area. The legend in the figure, from bottom to top (red–dark green), represents the elevation ranges of 3200–3778.69 m, 2900–3200 m, 2700–2900 m, 2400–2700 m, and 2222.28–2400 m, respectively.

By overlaying the scope of each control area with DEM data and high-resolution satellite imagery, and using ArcGIS to extract the site conditions of each control area, it could be determined that the study area was mainly distributed below an elevation of 3000 m.

The horizontal distribution is shown in Figure 2, where the red triangles represent the approximate locations of the sample plots in the figure. The vegetation in the study area is mainly influenced by factors such as topography, lighting conditions, and human activities in its horizontal distribution. The River runs in a nearly east–west direction, and the mountains along the river form shaded and sunny slopes which significantly differ in terms of vegetation (Table 3 and Figure 3).

Table 3. Aspect division and area values of the study area.

Statistical Projects		Area (km ²)	Proportion (%)
Classified aspect	Flatness	0.07	0.10
	North slope	12.88	16.75
	North-east slope	13.75	17.89
	East slope	6.71	8.72
	South-east slope	8.27	10.75
	South slope	14.50	18.85
	South-west slope	7.67	9.98
	West slope	5.27	6.86
	North-west slope	7.77	10.11

**Figure 3.** Slope orientation map of the study area.

Analysis of the slope indicated that the area was predominantly characterized by steep and moderate slopes, with slopes of less than 15° accounting for 23.59% of the total area (Table 4 and Figure 4).

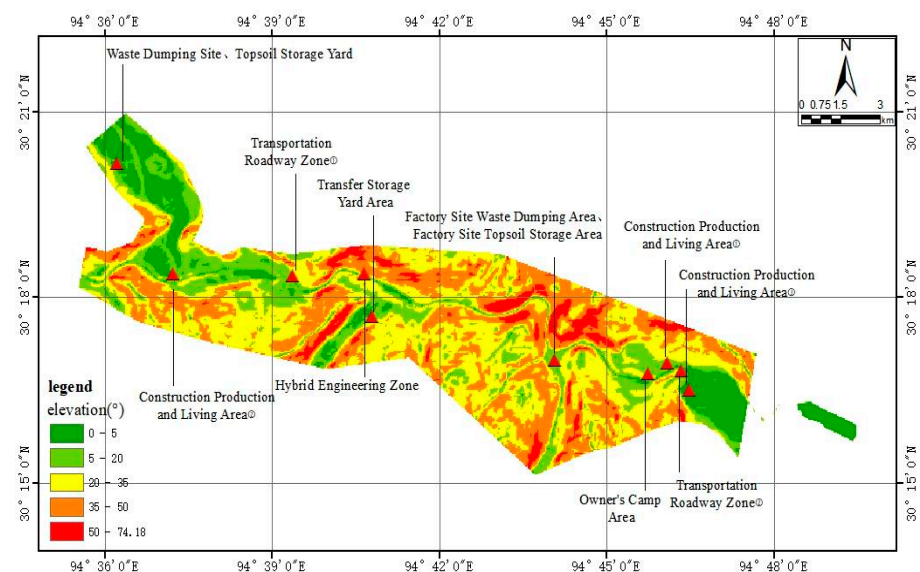
**Figure 4.** Slope map of the study area. The legend in the figure, from bottom to top (red to dark green), represents the slope gradients as follows: 25.01–74.18°, 15.01–25°, 5.01–15°, and 0–5°.

Table 4. Slope gradient division and area values of the study area.

Statistical Projects		Area (km ²)	Proportion (%)
Graded slope gradient	Flat slope (0–5)	8.64	11.23
	Gently sloping (6–15)	9.43	12.26
	Incline (16–25)	12.13	15.78
	Steep slopes (>25)	46.70	60.73

4.2. Site Classification

According to the “Practical Manual for Soil and Water Conservation Plant Measures in Construction Projects” [21], the project area is located in Bomi County, which is part of the Yarlung Zangbo River Valley and the Southern Tibetan Plateau Subregion (VIII-1). The area is divided into two site type sub-districts, five site type groups, and seven site types. The classification results are shown in Table 5.

Table 5. Site type classification results.

Slope Gradient	Site Type Group	Site Type	Site Type Code
Flat area (VIII-1-1)	Beautification area (A)	Office beautification area (a)	VIII-1-1-A-a
		Lifestyle beautification area (b)	VIII-1-1-A-b
	Functional area (B)	Dust/noise prevention area (a/c)	VIII-1-1-B-a/c
	Restoration area (C)	General restoration area (a)	VIII-1-1-C-a
Slope area (VIII-1-2)	Rocky slope (F)	Gentle slope (a)	VIII-1-2-F-a
		Steep slope (b)	VIII-1-2-F-b
	Soil slope (D)	Steep slope (b)	VIII-1-2-D-b

4.3. Soil and Water Conservation Vegetation Restoration Model

4.3.1. Plant Species Selection

Based on the conditions of nurseries distributed in Lhasa, Nyingchi, Bomi County, and other areas within the Tibet Autonomous Region, as well as the vegetation at elevations from 2200 to 3700 m on the Qinghai–Tibet Plateau outside the Tibet Autonomous Region, such as in Sichuan and Qinghai, a preliminary screening was conducted. This led to the selection of arbor, shrub, and grass species with characteristics similar to those of the local vegetation, strong stress resistance, good soil and water conservation benefits, and mature cultivation methods. These species are considered potential candidates for local tree selection in the later stages, as seen in Table 6 [22]. The satellite imagery of vegetation in the study area and the distribution map of vegetation types are shown in Figures 5 and 6, respectively.

Table 6. Candidate vegetation restoration plant species.

ID Number	Species	Origin of the Species	Biological Form	Altitudinal (Beltsm)
1	<i>Pinus densata</i> (Mast.)	Alpine region of western China	Evergreen tree	1500–4500
2	<i>Populus szechuanica</i> Schneid. var. <i>tibetica</i> (C. K. Schneid.)	Mountainous areas of the Qinghai–Tibet Plateau	Deciduous tree	2000–4500
3	<i>Picea likiangensis</i>	Southeastern Tibet, northwestern Yunnan, southwestern Sichuan	Evergreen tree	2900–3700
4	<i>Quercus aquifolioides</i> (Rehd. et Wils.)	Southwest Alpine Region	Evergreen small tree, shrub	2000–4500
5	<i>Rosa xanthina</i> Lindl.	Northern China	Shrub	200–2400
6	<i>Cotoneaster microphyllus</i> (Wall. ex Lindl.)	Tibet	Shrub	2500–4100

Table 6. Cont.

ID Number	Species	Origin of the Species	Biological Form	Altitudinal (Beltsm)
7	<i>Potentilla parvifolia</i> Fisch. var. <i>parvifolia</i>	Heilongjiang, Inner Mongolia, Gansu, Qinghai, Sichuan, Tibet	Shrub	900–5000
8	<i>Berberis hemsleyana</i> (Ahrendt)	Tibet	Shrub	3660–4400
9	<i>Elymus dahuricus</i> (Turcz.)	Northeastern Qinghai-Tibet Plateau	Perennial herb	450–4500
10	<i>Festuca elata</i> (Keng ex E. B. Alexeev)	Southern Europe, North Africa, and the mountainous regions of East Africa	Perennial herb	500–1500
11	<i>Potentilla chinensis</i> (Ser.)	China, Russia, Korea, Japan	Perennial herb	400–3200
12	<i>Oxalis corniculata</i> (L.)	Tropical America and Southern Africa	Perennial herb	800–3000
13	<i>Cosmos bipinnatus</i> (Cav.)	Mexico	Annual or perennial herb	<2700

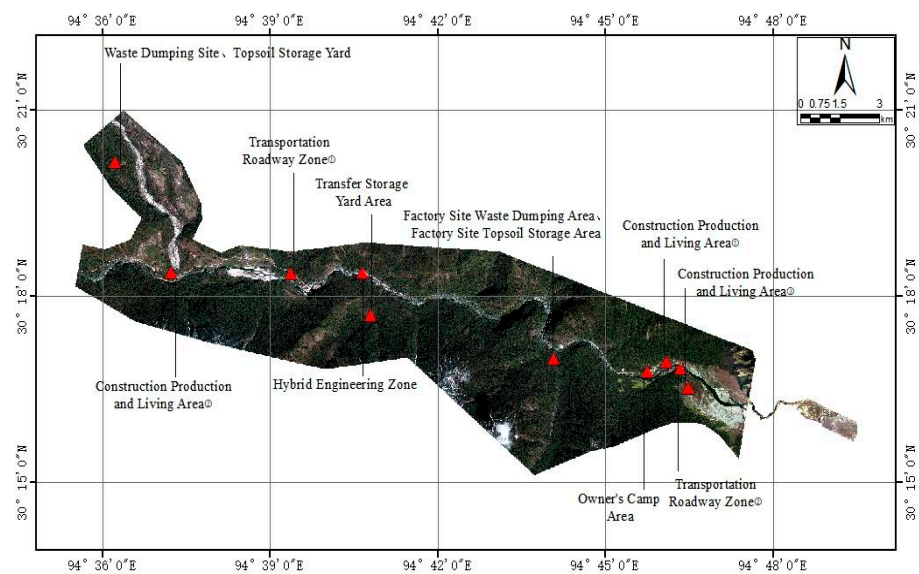


Figure 5. Satellite image of vegetation in the study area.

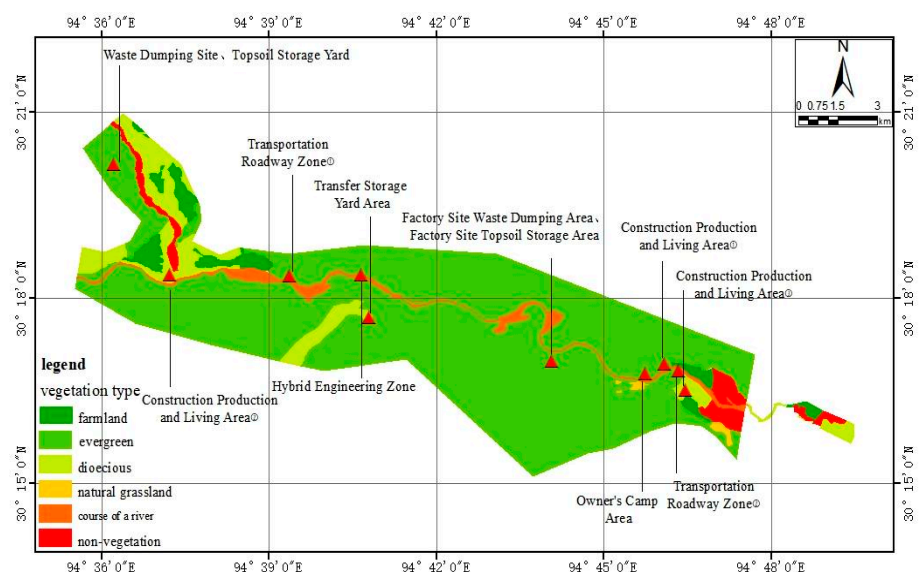


Figure 6. Distribution of vegetation types in the study area. The legend in the figure, from bottom to top (red to dark green), represents the following types of vegetation: non-vegetated areas, river channels, natural grasslands, shrubs, trees, and cultivated land.

In the table, *Pinus densata* is an arboreal species, reaching up to 30 m in height, also known as Sichuan oil pine, and is a unique tree species in the high mountain areas of western China. It is widely distributed in the high mountain regions of western Sichuan, southern Qinghai, eastern Tibet, and northwestern Yunnan, at altitudes of 1500 m to 4500 m, often growing in river valleys, slopes, forests, valleys, and sunny slopes; it has been artificially cultivated. It is a light-loving, deep-rooted tree species that can grow in arid and barren environments. It can be used as a tree species for afforestation in the high mountain areas of western Sichuan and eastern Tibet. *Populus szechuanica* Schneid. var. *tibetica* prefers a cool and humid climate, is relatively shade-tolerant, and is not particular about soil requirements, growing poorly in open and dry environments. It is distributed in high mountain areas or high-latitude regions with an average annual temperature of 4–12 °C and a relative humidity of over 60%. *Picea likiangensis* is an arboreal species, mainly distributed in southeastern Tibet, northwestern Yunnan, and southwestern Sichuan, growing at altitudes of 2900–3700 m. In Tibet, it is mainly found in Linzhi, Milin, Bomi, and other places. It often forms mixed coniferous and broadleaf forests with *Pinus armandii*, *Pinus densata*, and *Tsuga dumosa*, with excellent wood quality and rapid growth, making it a tree species for forest regeneration and afforestation in its distribution area. *Quercus aquifolioides* et Wils. is a tree or shrub, up to 20 m tall, growing on sunny slopes or under *Pinus densata* forests at altitudes of 2000 m to 4500 m. It is a major tree species forming the hard-leaved evergreen broad-leaved oak forests in the southwestern high mountain areas, often mixed with other high mountain oak species. It is light-loving, drought-resistant, and well-suited to a warm and humid climate, with a wide adaptability to various ecological factors and strong resistance to environmental disturbances, possessing a vigorous sprouting ability. Common in the steep areas of the upper reaches of rivers and streams, it is an excellent soil and water conservation forest and water source protection forest. *Rosa xanthina* is a shrub, 2–3 m tall. It prefers light, tolerates some shade, has strong cold resistance, and does not tolerate waterlogging. It is not particular about soil requirements, endures drought and barrenness, and thrives best in loose, fertile soil. It has a strong root system, strong sprouting ability, and few diseases and pests. It often grows on sunny slopes or in shrub thickets. *Cotoneaster microphyllus* is an evergreen low-growing shrub, up to 1 m tall. It commonly grows on rocky slopes and in shrub thickets at altitudes of 2500–4100 m. It prefers light but tolerates some shade, prefers a moist air environment, endures soil drought and barrenness, and is relatively cold-resistant, but does not tolerate waterlogging. *Potentilla parvifolia* is a shrub, 0.3–1.5 m tall, growing on dry slopes, rock crevices, forest edges, and forests at altitudes of 900–5000 m. It forms its own communities or becomes an accompanying and dominant species in the sparse forests of gray elm, juniper, and alpine shrublands. It is a plant with a wide ecological range, cold-resistant, barren-resistant, and drought-resistant. *Berberis hemsleyana* is a deciduous shrub reaching a height of 2 m and distributed in Tibet, China, at elevations of 3660–4400 m. It is commonly found in rock crevices, field edges, shrublands, or grassy slopes. This species has high adaptation ability, is drought- and shade-tolerant, and does not require specific water and light conditions. *Elymus dahuricus* is a perennial tufted herbaceous plant. The stems are sparsely clustered, upright, and 70–140 cm tall, with a knee-like bend at the base. It is drought-resistant, cold-resistant, alkali-resistant, and wind–sand resistant, with a wide adaptability and well-developed root system capable of absorbing water from deep soil layers. *Festuca elata* is a perennial bunchgrass. The stems are round, erect, and robust. This species grows along roadsides, on hillsides, and in the understory of forests. It prefers a cold and humid, warm climate and does not tolerate high temperatures. It is light-demanding but tolerates semi-shade and can tolerate high soil moisture, stress, acidity, poor soils, and diseases. *Potentilla chinensis* is a perennial herb reaching a height of 20–70 cm. It grows in meadows, on hillsides, valleys, forest edges, shrub lands, or under sparse forests at elevations from 400 to 3200 m. It prefers sunlight, tolerates semi-shade, is cold- and drought-resistant, and can grow in poor soil. It has strong soil adaptability and is suitable for moist and fertile sandy loam soil. *Oxalis corniculata* is a perennial herb without

aboveground stems that reaches a height of 5–10 cm. The leaves are clustered at the base and palmately compound. It often grows in forests, shrublands, and along the banks of streams in mountainous areas. It is also cultivated in courtyard lawns and prefers a warm, moist, and semi-shaded environment. It is cold-, drought-, and semi-shade-tolerant and thrives in fertile but not barren soil. *Cosmos bipinnatus* is an annual or perennial herbaceous species that prefers sunlight and can tolerate infertile soil. It does not grow in waterlogged soil and cold climates.

4.3.2. Vegetation Restoration Model

Combining the site conditions and site type classification results, different tree, shrub, and grass configurations are proposed for flat and sloped areas, along with the corresponding greening methods. The details of the vegetation configuration model are shown in Table 7.

Table 7. Engineering vegetation configuration chart.

Slope Gradient	Site Type Group	Site Type	Site Type Code	Plant Configuration			Greening Methods
				Tree	Shrub	Herb	
Flat	Beautification area	Office beautification area	VIII-1-1-A-a	<i>Picea likiangensis</i>	<i>Quercus aquifolioides</i> + <i>Berberis hemsleyana</i> + <i>Cotoneaster microphyllus</i>	<i>Festuca elata</i> + <i>Oxalis corniculata</i> + <i>Cosmos bipinnatus</i>	Landscape greening, grass greening
Flat	Restoration area	General restoration area	VIII-1-1-C-a	<i>Picea likiangensis</i> + <i>Pinus densata</i>	<i>Quercus aquifolioides</i> + <i>Rosa xanthina</i>	<i>Elymus dahuricus</i> + <i>Festuca elata</i>	Tree, shrub, and grass greening,
Sloped	Soil slope	Steep slope	VIII-1-2-D-b	/	<i>Rosa xanthina</i> + <i>Cotoneaster microphyllus</i>	<i>Elymus dahuricus</i> + <i>Festuca elata</i>	Gabion shrub and grass greening

For the restoration method with the code VIII-1-1-A-a, the selection of trees involves transplanting local native trees; for shrubs, seedlings with a length of about 30–40 cm and a crown diameter of about 20 cm should be planted; and grass seeds should be plump with a germination rate of $\geq 95\%$. The land preparation method involves using native soil or soil transplantation, complete land preparation, fertilization, and irrigation. The planting density is determined as follows: the spacing for street tree transplantation is 2–3 m, the spacing for site tree transplantation is between 2 m $\times$ 2 m and 3 m $\times$ 3 m, and the spacing for shrub planting is 1–2 m; the sowing amount for lawn grass is 15–20 g/m².

For the restoration method with the code VIII-1-1-C-a, shrubs are selected with seedlings that are about 30–40 cm in length and have a crown diameter of about 20 cm. Grass seeds should be plump with a germination rate of $\geq 95\%$. The land preparation method involves using native soil or soil transplantation, with either complete land preparation or regular pit arrangement, fertilization, and irrigation. The planting density involves intercropping of shrubs with row and plant spacing between 1 m $\times$ 1 m and 2 m $\times$ 2 m, and the gaps are filled with grass seed for greening at a rate of 15–20 g/m².

For the restoration method with the code VIII-1-2-D-b, shrubs are selected with seedlings that are about 30–40 cm in length and have a crown diameter of about 20 cm. Grass seeds should be plump with a germination rate of $\geq 95\%$. The land preparation method involves using native soil or soil transplantation, with comprehensive land preparation using fish-scale pits, horizontal trenches, or terraces, fertilization, and irrigation. The planting density involves intercropping of shrubs with row and plant spacing between 1 m $\times$ 1 m and 2 m $\times$ 2 m, and the gaps are filled with grass seed for greening at a rate of 15–20 g/m².

5. Conclusions

In this study, a site condition analysis was conducted based on three main limiting factors, including climatic and meteorological, soil, and topographic and geomorphological factors, dividing the study area into several three-dimensional types. After investigating the situation of nurseries distributed in Tibet, Qinghai, Sichuan, and other places, trees, shrubs, and grasses with ecological characteristics similar to those of the local vegetation, such as high stress resistance, soil and water conservation benefits, and established cultivation methods, were selected. Combining the results of site condition analysis and site type classification, the configuration of trees, shrubs, and grasses for different off-site condition types and the corresponding greening methods are discussed, with the following conclusions:

- (1) Suitable plant species are *Pinus densata*, *Populus szechuanica*, *Picea likiangensis*, *Quercus aquifolioides*, *Rosa xanthina*, and *Cotoneaster microphyllus*.
- (2) Based on the site conditions and dominant plant species, plant configurations and greening methods for different site condition types are proposed. The research results can provide good technical support for vegetation restoration in the Qinghai–Tibet Plateau and have a good reference for vegetation restoration of construction projects.

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