

恢复方式和地形对晋西黄土区退耕林分物种多样性的影响

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摘要 运用样带样方调查法,对比不同恢复方式和地形条件下退耕林分的物种多样性,以期为晋西黄土区植被恢复效果评价和经营管理提供参考。结果表明:恢复方式对退耕林分物种多样性具有显著影响。自然恢复林物种数为刺槐人工林的1.6倍,Shannon指数大于刺槐人工林,Pielou指数小于刺槐人工林。物种多样性受坡位影响显著,各指数均表现为沟底>沟坡>梁峁坡>梁峁顶;坡向对退耕林分物种多样性影响不显著,各指数均表现为阴坡>阳坡。物种多样性受地形和恢复方式综合作用影响显著,在自然恢复林阴坡沟底处最高,物种均匀度在刺槐人工林阴坡沟底处最高。从提高物种多样性角度,黄土区植被恢复在遵循适地适树原则的同时,应参照自然恢复林分,在不同地形部位采用不同的造林设计。

关键词 恢复方式;坡位;坡向;物种多样性

Effects of revegetation approach and terrain on plant species diversity as a result of converting croplands to forests in the Loess region of western Shanxi Province, China. WU Wen-juan¹, ZHA Tong-gang^{1,2*}, ZHANG Zhi-qiang² (¹*School of Soil and Water Conservation, Beijing Forestry University, Beijing 100083, China*; ²*Ministry of Education Engineering Research Center of Forestry Ecological Engineering, Beijing 100083, China*).

Abstract: The plant species diversity of stands converted from croplands as affected by revegetation approaches and terrains was studied using the transect line plot sampling. The goal of the study was to provide reference for evaluation reforestation effects and forest management in the Loess region of western Shanxi Province. The results showed that revegetation approach had a great influence on plant species diversity in stands. The number of species in the natural restoration forest (NF) was 1.6 times of that of *Robinia pseudoacacia* plantation (RP), the Shannon index of NF was higher, and the Pielou index of NF was lower. Slope position had significant effect on the species diversity, and the three species diversity indices were all in order of bottom of loess gully > middle slope of loess gully > slope of loess hill > top of loess hill. The species diversity indices on the shady slope were higher than those on the sunny slope, while the difference was not significant. Integrated effects of terrain and revegetation approach had significant influences on species diversity. The species diversity was highest at the bottom of shady slope of NF, and the species evenness was highest at the bottom of shady slope of RP. For improving the species diversity, the afforestation design in the Loess area must consider terrain position and the natural forest recovery process following the principle of ‘selecting suitable tree species for the right site’.

Key words: revegetation approach; slope position; slope aspect; species diversity.

森林群落物种多样性是基于群落的物种数和个体数及其分布均匀程度的统计量,是衡量森林群落

物种丰富及分布均匀的一项重要指标^[1-2]。物种多样性可体现群落的层次类型、组织水平、稳定程度和生境差异,是植被恢复的重要目标和评价指标之一^[3-4]。黄土区具有黄土堆积深厚、土质疏松、降雨集中、植被稀疏、坡面土壤侵蚀和沟道侵蚀严重等特点,一直是我国植被恢复建设的重点区域^[5-7]。有研

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究表明,以退耕还林为主的植被恢复措施实施以来,黄土高原大部分地区在植被覆盖度上升、林(草)地面积增加的同时,植物群落盖度、高度、多样性及稳定性等也有明显提高^[8-9].然而,部分地区退耕林分存在林木生长不良、林分结构单一、功能低下、物种多样性偏低的现象^[10-11],其原因是脆弱的区域生态环境,同时不合理的植被恢复方式与经营管理活动也是重要原因之一^[12-13].

传统植被恢复中往往以坡面为单元进行林草物种选择和造林模式设计^[14-15].但在地形破碎化程度很高的黄土沟壑区,坡向、坡位等地形因子通过对物质和能量的再分配,改变光照、温度、水分和土壤养分等生态环境因子,从而对群落结构和生产力以及生态系统功能等产生重要影响^[14,16-17].因此,同一坡面不同地形条件下的林分物种多样性研究,可为坡面尺度更合理的植被配置设计提供理论支撑^[18].本文以山西吉县蔡家川小流域退耕还林地的自然恢复林分和刺槐(*Robinia pseudoacacia*)人工林分为研究对象,以坡面为单元对比不同地形条件下的植被结构层次、群落物种组成和物种多样性,研究地形和恢复方式对退耕林分物种多样性的影响,以期为黄土区的退耕林地坡面尺度植被恢复状况评价和经营管理提供参考.

1 研究地区与研究方法

1.1 研究区概况

山西吉县蔡家川流域(36°40' N,110°37' E)位于由暖温带褐土阔叶落叶林向森林草原的过渡地带,年均降雨量为 579.3 mm,最大年降雨量为 828.6 mm,最小年降雨量为 365.1 mm,其中 7—9 月的降雨量占全年降雨量的 59.5%.年均蒸发量为 1723.9 mm,4—7 月蒸发量最大,占全年蒸发量的 54%.流域大体呈西向东走向,长约 12.15 km,面积 38 km²,主沟道及其部分支沟具有常流水.流域内主要为 20 世纪 90 年代初退耕还林工程后,自然恢复形成了以山杨(*Populus davidiana*)、白桦(*Betula platyphylla*)落叶阔叶林和人工种植形成的刺槐、油松(*Pinus tabulaeformis*)、侧柏(*Platycladus orientalis*)等树种为主的纯林和混交林,林下灌草以沙棘(*Hippophae rhamnoides*)、黄刺梅(*Rosa xanthina*)、白蒿(*Acroptilon repens*)、羊胡子草(*Carex rigescens*)等为主.

1.2 样地设置

在蔡家川柳沟小流域内选取自然恢复林分,蔡家川井沟小流域内选取刺槐人工林分.在两种林分

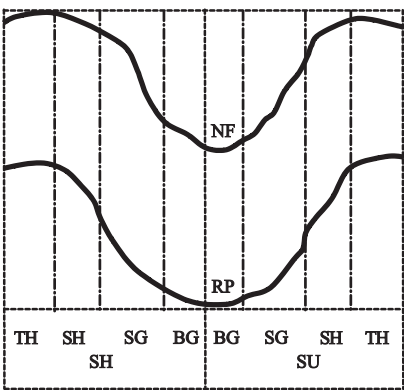


图1 不同林分地形位置
Fig.1 Terrain position of different forests.

RP: 刺槐人工林 *Robinia pseudoacacia* plantation; NF: 自然恢复林 Natural restoration forest. SU: 阳坡 Sunny slope; SH: 阴坡 Shady slope. TH: 梁峁顶 Top of loess hill; SH: 梁峁坡 Slope of loess hill; SG: 沟坡 Slope of loess gully; BG: 沟底 Bottom of loess gully. 下同 The same below.

内在林分阴、阳坡分别布设样带.按照黄土区典型地形地貌特征,把每条样带从上到下依次划分为梁峁顶、梁峁坡、沟坡、沟底 4 个坡位(图 1).每个坡位设置 1 个 20 m×20 m 乔木样方,在每个乔木样方内用对角线法设置 3 个 5 m×5 m 灌木样方,在灌木样方内用对角线法设置 5 个 2 m×2 m 草本调查样方开展植被调查.

1.3 数据处理

物种重要值(RW)^[19]:

$$RW = (RD + RDE + RF) / 3$$
 (1)

式中:RD 为相对密度;RDE 为相对盖度;RF 为相对频度.

多样性 Shannon 指数(H)^[20]:

$$H = - \sum P_i \ln P_i$$
 (2)

均匀度 Pielou 指数(J_{sw})^[20]:

$$J_{sw} = H / \ln S$$
 (3)

式中:S 为样方内所有物种数; $P_i = N_i / N$, N_i 为物种 i 的重要值, N 为样方中所有物种重要值之和.

采用 Excel 2007 软件对数据进行统计分析.采用 Bartlett test 方法进行方差齐性检验,用 Tukey HSD 方法对不同恢复方式、坡向、坡位及综合作用下,不同样带植被物种多样性做差异显著性分析($\alpha=0.05$).采用 Word 2007 和 Origin 9.0 软件作图.

2 结果与分析

2.1 恢复方式对植被恢复的影响

2.1.1 林分物种组成 经过 20 多年的恢复,刺槐人工林分共有 19 种植物(表 1).其中,乔木层仅有人

表 1 不同林分物种组成及分布
Table 1 Species composition and distribution in different stands

植被类型 Vegetation type		物种数 Number of species	优势种(物种重要值, %) Dominant species (species importance, %)	科分类数 Number of families	属分类数 Number of genus
刺槐人工林分 <i>Robinia pseudoacacia</i> plantation	乔木 Arbor	1	刺槐 <i>Robinia pseudoacacia</i> (100)	1	1
	灌木 Shrub	4	绣线菊 <i>Spiraea salicifolia</i> (24.2)	4	4
	草本 Herb	14	白蒿 <i>Acroptilon repens</i> (18.77)、柴胡 <i>Bupleurum chinense</i> (11.39)	7	13
自然恢复林分 Natural restoration forest	乔木 Arbor	5	山杨 <i>Populus davidiana</i> (56.8)、白桦 <i>Betula platyphylla</i> (39.5)	5	5
	灌木 Shrub	6	荆条 <i>Vitex negundo</i> (31.3)、黄刺梅 <i>Rosa xanthina</i> (20.2)	5	6
	草本 Herb	20	羊胡子草 <i>Carex rigescens</i> (22.7)、铁杆蒿 <i>Heteropappus al-ticus</i> (19.3)、苜蓿草 <i>Medicago sativa</i> (15.1)	9	20

工种植的刺槐 1 种;灌木层 4 种,分属不同的科和属;草本层 14 种,物种重要值为 3.1%~18.8%。自然恢复林分内共有植物 31 种,其中乔木层 5 种,为山杨、白桦、侧柏、臭椿 (*Ailanthus altissima*) 和栎树 (*Koelreuteria paniculata*),前两种植物重要值远大于其他物种成为优势种;灌木层 6 种,分属 5 科 6 属,物种重要值较高的荆条 (*Vitex negundo*) 和黄刺梅 (*Rosa xanthina*) 相差 11.1%;草本层 20 种,物种数最丰富。同一林分物种数均为草本层>灌木层>乔木

层,不同林分相同植被层均为自然恢复林分物种数大于刺槐人工林分。总体上,自然恢复林分物种数为刺槐人工林分的 1.6 倍。

2.1.2 不同恢复方式下物种多样性 恢复方式对退耕林分物种多样性具有影响,不同指标衡量结果存在一定差异(图 2)。自然恢复林灌、草层物种数均显著大于刺槐人工林灌、草层;自然恢复林灌、草层 Shannon 指数均大于刺槐人工林灌、草层,但差异不显著;自然恢复林灌木层 Pielou 指数小于刺槐人工

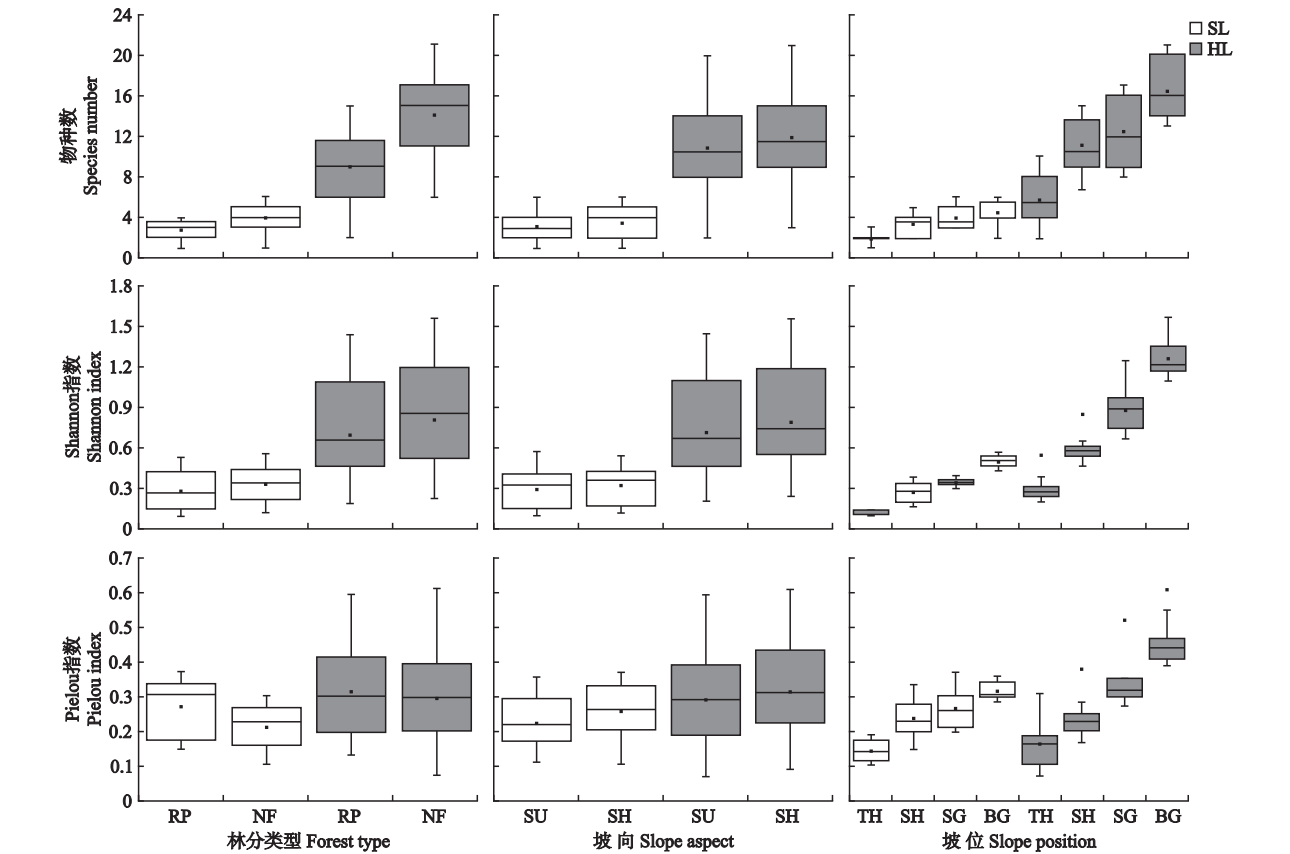


图 2 不同林分、坡向、坡位灌木层和草本层的物种多样性
Fig.2 Species diversity at shrub and herb layers in different stands, slope aspect and slope position.
SL: 灌木层 Shrub layer; HL: 草本层 Herb layer. 下同 The same below.

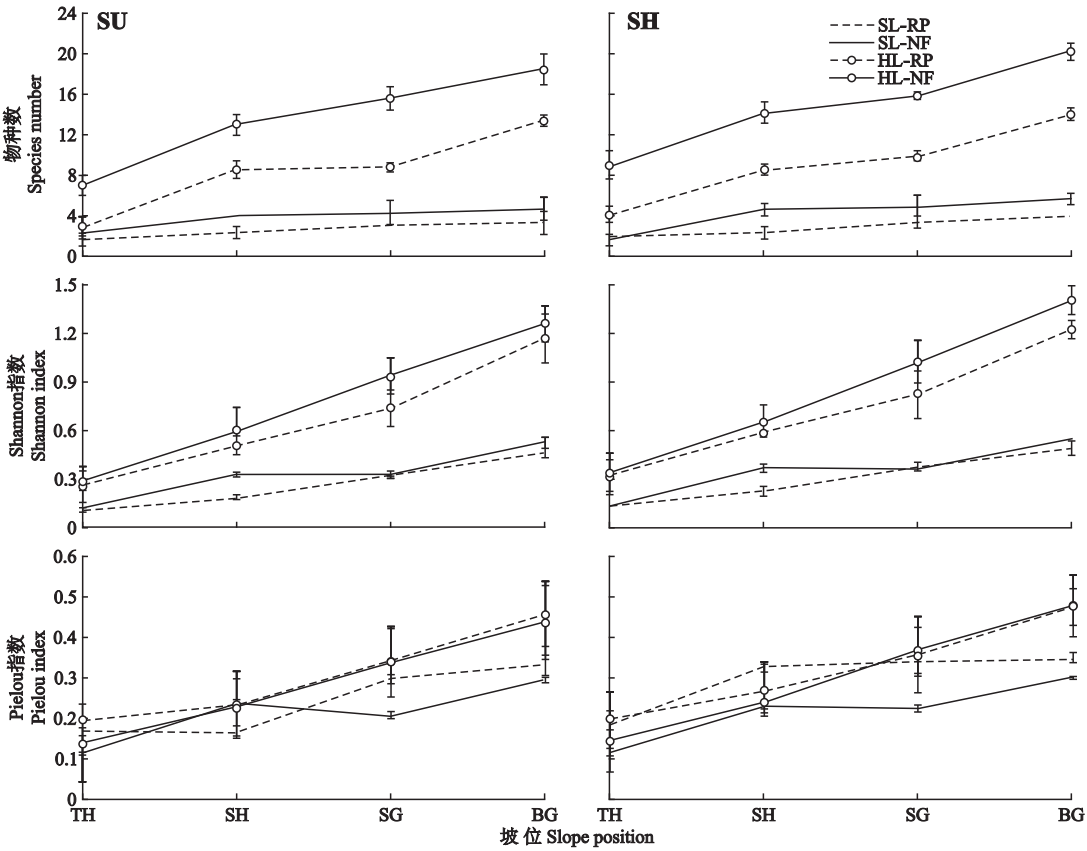


图3 不同地形条件下刺槐人工林分和自然恢复林分的物种多样性
Fig.3 Species diversity of *Robinia pseudoacacia* plantation and natural restoration forest under different terrains.

林,草本层 Pielou 指数与刺槐人工林差别不明显.物种数和 Shannon 指数表征物种丰富度,Pielou 指数表征物种均匀度.因此比较而言自然恢复林物种丰富度较高,刺槐人工林物种均匀度较高.

2.2 地形对物种多样性的影响

2.2.1 坡向 坡向对退耕林分物种多样性影响不显著(图2).物种数、Shannon 指数和 Pielou 指数均表现为阴坡草本层>阴坡灌木层>阳坡草本层>阳坡灌木层.阳坡灌、草层 Shannon 指数分别为阴坡灌、草层的 91.9%、91.0%,表明灌、草层物种多样性在阴坡更高.灌木层不同坡向间 Pielou 指数差异大于草本层不同坡向间差异,表明灌木层物种多样性受坡向的影响更敏感.

2.2.2 坡位 坡位对退耕林分物种多样性影响显著,灌木层和草本层的各多样性指数均随坡位下降呈现上升的趋势(图2).草本层物种数和 Shannon 指数随坡位下降而增大的幅度均高于灌木层,说明坡位对草本层物种多样性影响更大.Pielou 指数在灌木层和草本层随坡位的变化幅度差别不明显,表明坡位对灌木层和草本层的物种分布影响接近.

2.3 地形与恢复方式对退耕林分物种多样性的综合影响

地形和恢复方式综合作用对退耕林分物种多样性影响显著.灌木层物种数在自然恢复林阴坡梁峁顶和刺槐人工林阳坡梁峁顶最小,在自然恢复林阴坡沟底最大(图3);草本层物种数在刺槐人工林阳坡梁峁顶最小,在自然恢复林阴坡沟底最大.Shannon 指数在刺槐人工林阳坡梁峁顶灌木层最小,分别达到了梁峁坡、沟坡、沟底的 61.1%、33.3%、23.9%;在自然恢复林阴坡沟底草本层最大,分别是沟坡、梁峁坡、梁峁顶的 1.4、2.2、4.2 倍;说明随坡位降低物种丰富度逐渐增大.灌木层 Pielou 指数在自然恢复林阴坡梁峁顶处最小,在刺槐人工林阴坡沟底处最大;草本层 Pielou 指数在自然恢复林梁峁顶最小,在自然恢复林和刺槐人工林阴坡沟底最大.总体上,在地形和恢复方式的综合影响下,退耕林分物种多样性在自然恢复林阴坡沟底处最高,在刺槐人工林阳坡梁峁顶处最低;物种均匀度在刺槐人工林阴坡沟底处最高,在自然恢复林梁峁顶处最低.

3 讨 论

3.1 恢复方式对植被恢复的影响

植被恢复一般有自然恢复和人工恢复两种方式^[21-22].自然恢复有利于生物多样性的提高,形成稳定的多物种群落,但恢复速度比较缓慢^[23-25];人工恢复加快了植被恢复的进程^[26],但存在植被存活率低、造林树种单一、群落稳定性差等问题^[27].不同恢复方式林分的物种组成不同,林分植被存在差异^[28-29].本研究表明,退耕 20 年的自然恢复林分物种数是刺槐人工林分的 1.6 倍,这与黄土丘陵区退耕 10 年后的人工恢复林分物种数高于自然恢复林分^[30]的研究结果不同.这种差异可能与恢复年限有关,在恢复初期,自然恢复林分对环境的适应能力较弱,因此相比同时期的人工林分物种数要少;随着恢复年限的增长,自然恢复林内植被对环境的适应能力不断提高,植被群落在与立地条件相互适应的过程中促进了植物种类的增加^[31-32],相比同时期人工林分的物种数要多.林分各层的物种多样性均表现为自然恢复林分大于刺槐人工林分,原因可能是人工种植的刺槐占据了乔木层的生存空间,抑制了林内其他乔木种的更新繁殖,同时规格一致的乔木造成林内较低的生态环境异质性,不利于其下灌木草本物种的生长繁殖^[33],而自然恢复林分内生态环境异质性高,为植被生长提供了广阔的生态位,更适宜多物种的生长繁殖^[24].

恢复方式对退耕林分物种多样性具有影响,不同指标衡量结果存在一定差异^[30].本研究中,自然恢复林分物种数、Shannon 指数大于刺槐人工林,这与大多研究^[33-34]结果一致;而 Pielou 指数在自然恢复林分小于刺槐人工林,这可能是因为刺槐人工林均一的乔木层造成林内生境均匀度较大,导致灌木、草本层物种分布均匀度较高;而自然恢复林分内植被多为林分原有植被,参差不齐的植被高度造成了较高的生境异质性,有利于形成稀疏各异的灌、草层植被,导致植被均匀度低于刺槐人工林.

3.2 地形对植被恢复的影响

复杂的地形条件对土壤厚度、水分等土壤条件以及光照分布等存在不同程度的影响,进而影响植被物种多样性的表达^[14,18,35].坡向对土壤水分分布和光照条件差异影响显著^[36-37],阳坡较高的太阳辐射促进了土壤水分的蒸发,而阴坡背向的光照条件使得土壤水分状况优于阳坡^[38-39].本研究表明,物种数、Shannon 指数、Pielou 指数均为阴坡>阳坡,这

与其他学者^[18,23]在黄土丘陵沟壑区的研究结论一致.

坡位的差异会引起光照、温度、水分、土壤条件及其空间组合的差异,进而影响群落植被的结构特征及物种多样性的表达^[40].地势高的梁峁顶、梁峁坡坡度较为缓和,呈凸形变化,光照强烈,土壤条件差、水分蒸发强烈;地势低的沟坡、沟底坡度变化较大,呈凹形、直线形变化,受光度显著减弱,能够集流、水分条件好,土壤条件好^[41].土壤水分受径流的叠加作用,随坡位降低呈现出逐渐增大的趋势^[37].在最为陡峭的沟坡坡位,水土流失虽较梁峁坡严重,但其土壤条件却优于梁峁坡.此外沟坡处复杂多样的地形条件生境环境异质性高^[35],为不同植被的生长发育提供了良好的条件.本研究显示,物种数、Shannon 指数、Pielou 指数在不同坡位均表现为沟底>沟坡>梁峁坡>梁峁顶.在黄土丘陵区织坊沟流域的研究也表明坡位对植被存在显著的影响^[40].

3.3 恢复方式和地形对植被恢复的影响

大量研究表明,物种多样性因植被恢复方式和地形因子形成的小生境不同而有所差异^[42].本文也得出相同的结果:经过 20 多年的植被恢复后,晋西黄土区不同恢复林分物种多样性在不同地形条件下差异显著,在阳坡梁峁顶处人工刺槐林分内最低,阴坡沟底处自然恢复林分内最高.传统上坡面尺度的统一造林设计,高均质性的人工林在不同地形条件下,存在植被生长需求与水分、能量和养分供给的异质性^[43],因而表现出较低的物种多样性和较高的物种均匀度.

黄土区不同恢复方式、不同地形部位林分的生境条件不同,物种多样性差异显著.因此,该区域植被恢复过程中,在遵循适地适树原则的前提下,应参照自然恢复林分,在坡面尺度上区分地形部位采取不同的造林设计.如参照自然恢复林分选择造林树种和混交比例,随坡位上升适当增大造林密度和灌、草种的比例等.

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