

基于模拟强降雨的不同草种人工边坡水土保持功能研究

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摘要: 人工边坡与自然边坡相比具有稳定性差、坡度较大等特征, 而小雨强对坡面侵蚀的效果并不明显, 80%的坡面水土流失来自于短时间的强降雨侵蚀, 植物覆盖措施作为常用的人工边坡修复措施, 常用于公路边坡、矿山修复等工程中。为研究不同草种在强降雨情况中对人工边坡的水土保持功能, 我们探讨了在两极端降雨强度(70mm/h、100mm/h)、不同坡度(30°、45°、60°)和不同植物覆盖措施下: 白三叶(*Trifolium repens* L.)、高羊茅(*Festuca arundinacea* Schreb.)、狗牙根(*Cynodon dactylon*(Linn.) Pers.)的坡面产流、产沙和降雨入渗量特征和减流减沙效益。评估了不同因素对坡面侵蚀的动态影响。研究的主要结果如下:

(1) 地表径流量随降雨强度和坡度的增加而显著增加, 植物覆盖措施可以有效减少坡面的产流量。在同一坡度和降雨强度条件下, 裸坡组的产流量最高, 狗牙根的产流量最低, 狗牙根对降低地表径流量的效果显著。随着坡度的增加, 坡面的产流量也均有增加。但在较陡坡面中, 有植物覆盖措施的坡面减流效果更加显著。对比不同条件下不同植物覆盖坡面相对裸坡组的减流效益来看, 植物覆盖措施均能显著提高坡面的减流效益随着坡度的增加, 减流效益整体呈现增大的趋势, 这表明在较陡的坡面中, 植物覆盖措施下的减流效益更显著。总体来看, 三组草本植物减流效益从大到小依次为狗牙根>高羊茅>白三叶。

(2) 总体产沙特征为随着降雨历时的增加呈现先增加, 随后稳定产沙。随着坡度的增加, 产沙量增加显著, 在裸坡组中较为明显。随着降雨强度的增加, 产沙量也显著增加。随着坡度的增加, 坡面的减沙效益也随着更加显著。在较陡坡面上三组坡面均表现出显著的减沙效益。总体来看, 三组草本植物减沙效益从大到小依次为高羊茅>狗牙根>白三叶。降雨强度和坡度的增加对坡面侵蚀速率影响较为显著, 而植物覆盖措施可以有效减少坡面侵蚀速率。在高陡边坡中, 过大的降雨强度可能会导致坡面崩塌, 在防治过程中需要配合一定的排水措施。

(3) 降雨入渗的产流时间随坡度的增加而缩短, 随降雨强度的增加而缩短。降雨入渗量随地表产流量和产沙量的增加而减少, 随降雨强度和坡度的增加而增加。各组植物覆盖措施的坡面由于表现出良好的入渗能力, 导致初始产流时间与裸坡组相比均有不同程度的缩短。降雨入渗量随降雨历时的增加而增加, 到达一定程度开始稳定入渗。与白三叶相比, 高羊茅和狗牙根对坡面土壤表现出较好的降雨入渗能力。

(4) 总体来看, 坡面产流量与产沙量呈正相关, 与降雨入渗量呈负相关。三者均随降雨强度和坡度的增加而增大。三种草本植物均可以有效抑制产流产沙和增加降雨入渗。

Research on the Soil and Water Conservation Function of Artificial Slopes with Different Grass Species Based on Simulated Heavy Rainfall

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Abstract: The stability of artificial slopes is generally poorer and steeper compared to natural slopes, and the effect of light rainfall intensity on slope erosion is not significant. Eighty percent of the soil and water loss on slopes is caused by erosion from short periods of intense rainfall. Plant cover measures, as commonly used artificial slope restoration methods, are often applied in highway slope and mine reclamation projects. To study the soil and water conservation function of different grass species on artificial slopes under strong rainfall conditions, we explored the characteristics and benefits of runoff, sediment production, and infiltration under two extreme rainfall intensities (70mm/h and 100mm/h), different slopes (30° , 45° , 60°), and various plant cover measures: white clover (*Trifolium repens* L.), tall fescue (*Festuca arundinacea* Schreb.), and Bermuda grass (*Cynodon dactylon* (Linn.) Pers.). The dynamic impact of different factors on slope erosion was assessed. The main findings of the study are as follows:

(1) Surface runoff increases significantly with increasing rainfall intensity and slope gradient. Plant cover measures can effectively reduce the amount of runoff on slopes. Under the same slope and rainfall intensity conditions, the bare slope group had the highest runoff, while Bermuda grass had the lowest, with a significant effect on reducing surface runoff. As the slope gradient increases, the runoff on slopes also increases. However, on steeper slopes, the runoff reduction effect of slopes with plant cover measures is more pronounced. When comparing the runoff reduction benefits of different plant-covered slopes relative to the bare slope group under various conditions, plant cover measures can significantly improve the runoff reduction benefits of slopes. The overall trend of runoff reduction benefits increases with the increase in slope gradient, indicating that the runoff reduction effect of plant cover measures is more significant on steeper slopes. Overall, the runoff reduction benefits of the three groups of herbaceous plants decrease in the following order: Bermuda grass > tall fescue > white clover.

(2) The overall sediment production characteristics show an initial increase followed by a stable production of sediment with the increase in rainfall duration. With an increase in slope gradient, the sediment production increases significantly, especially in the bare slope group. As the rainfall intensity increases, sediment production also increases significantly. With an increase in slope gradient, the sediment reduction effect on slopes becomes more pronounced. On steeper slopes, all three groups of slopes show significant sediment reduction benefits. Overall, the sediment reduction benefits of the three groups of herbaceous plants decrease in the following order: tall fescue > Bermuda grass > white clover. An increase in rainfall intensity and slope gradient has a significant impact on the erosion rate of the slope, and plant cover measures can effectively reduce the erosion rate of the slope. On high and steep slopes, excessive rainfall intensity may lead to slope collapse, and it is necessary to coordinate with certain

drainage measures in the prevention process.

(3)The time required for rainfall infiltration to produce runoff decreases with an increase in slope gradient and with an increase in rainfall intensity. The amount of rainfall infiltration decreases with an increase in surface runoff and sediment production but increases with an increase in rainfall intensity and slope gradient. The slopes with various plant cover measures exhibit good infiltration ability, resulting in a reduction of the initial runoff time compared to the bare slope group to varying degrees. The amount of rainfall infiltration increases with the increase in rainfall duration and begins to stabilize after reaching a certain level. Compared to white clover, tall fescue and Bermuda grass show better infiltration ability for slope soil.

(4)In general, there is a positive correlation between slope runoff and sediment production, and a negative correlation with rainfall infiltration. All three increase with the increase in rainfall intensity and slope gradient. The three types of herbaceous plants can effectively suppress runoff and sediment production and increase rainfall infiltration.