International Journal of Sediment Research 30 (2015) 131–141

Contents lists available at ScienceDirect

International Journal of Sediment Research

journal homepage: www.elsevier.com/locate/ijsrc

Original Research

The effects of plant density of *Melastoma malabathricum* on the erosion rate of slope soil at different slope orientations

Aimee Halim*, Osman Normaniza

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 10 December 2013
Received in revised form
17 September 2014
Accepted 12 March 2015
Available online 9 June 2015

Keywords:
Melastoma malabathricum
Erosion rate
Plant density
Physiology
Slope orientations
Soil saturation level

ABSTRACT

Malaysia's cut slopes, especially for road lines accommodation, are prone to erosions and landslides. These problems mainly occur due to lack of vegetation cover and strong erosive forces. In addition, the topography factors have also become a major factor affecting soil degradation. Thus, this study is aimed at determining the effects of planting density of a selected species, namely *Melastoma malabathricum*; one, two, and three seedlings per box, on the erosion rate at selected slopes of different orientation (morning and evening sun) at the Guthrie Corridor Expressway, Selangor. In six months of observation, treatment with three seedlings/box on the morning sun slope showed a lower erosion rate by 69.2% than those with the same treatment on the evening sun slope. In addition, the treatment of the three seedlings recorded at month six (final observation) had the highest reduction of soil saturation level (STL), by 23.6%. Furthermore, the physiological values of the species studied, grown on the morning sun slope, were higher in terms of stomatal conductance and photosynthetic rate by 12.1% and15.8% (three seedlings/box), respectively. The overall results showed that plant density was inversely related to the STL and erosion rate on the slope. In conclusion, a planting density of three seedlings/box and morning sun orientation gave positive effects on the plant's physiological performance of the slope, reducing the STL, as well as alleviating the erosion rate of slope soils.

1. Introduction

Malaysia's climate is described as tropical with warm, high rainfall intensity as well as humidity throughout the year. As it experiences high precipitation ranging from 2000 mm to 2500 mm per annum, the highland areas, especially sloped areas, are prone to landslides. In addition, a study by Mafian et al. (2009) showed that a number of failures reported due to slope were caused by improper human practices. Generally, the process of erosion includes rainsplash, rilling and gullying, sheetwash, and dry ravel (Menashe, 1993). These contribute to soil productivity and water quality degradation, causing sedimentation as well as increasing the probability of flood (Zhou et al., 2008). Thus, the requirements for maintenance of risky areas need to be seriously considered. Gyssels et al. (2005) also revealed that the intrinsic properties of soil such as aggregate stability, infiltration capacity, soil bulk density, soil texture, organic and chemical content, and shear strength are the most important determinants of erosion.

Apart from using engineering techniques for landslide prevention, bioengineering is one approach which uses plant materials, either dead or alive, to alleviate environmental problems, include eroding slopes. This bioengineering approach also known as a “soft approach” provides many advantages, including high biodiversity, low maintenance, and most importantly, self-sustainability (Normaniza & Barakbah, 2006; Norris & Greenwood, 2006). The living approach includes conventional direct planting of grasses, shrubs or trees, and techniques that use the stems or branches of living plants to reinforce the soil, while the latter includes live stakes, live fascines, brushlayers, hedgelayers, and branchpacking. Numerous studies have shown the success of the bioengineering approach on slope (Ekanayake et al., 2007; Genet et al., 2010; Li et al., 2005; Normaniza & Barakbah, 2011). Nonetheless, those studies differ in practice and vary among regions. They also depend on slope geometry, climatic condition, and soil types, and must be specifically tailored. For example, in the semi-arid Mediterranean region, most experimental studies on the influence of natural vegetation on erosion have quantified soil loss and

* Corresponding author.
E-mail addresses: aimeehalim12@gmail.com (A. Halim), normaniza@um.edu.my (O. Normaniza).

http://dx.doi.org/10.1016/j.ijsrc.2015.03.003
1001-6279/

runoff under woodlands or shrublands comprising a mixture of plant species (Dunjó et al., 2004; Romero-Díaz et al., 1999). These studies concluded that typical Mediterranean shrubland vegetation is very efficient in reducing water erosion, even under extreme torrential simulated rainfalls (González-Hidalgo et al., 2004). GarcíaFayos et al. (2000) reported that short-lived water availability and high salinity of the regolith seem to be key factors limiting colonization of vegetation on badlands slopes in Southwest Spain. Thus, the inclusion of specific annual colonizer species in seed mixes specific to each slope type and aspect could be an alternate strategy.

In general, vegetation contributes by initiating the process of slope stabilization either via mechanical or hydrological processes (Saifuddin & Normaniza, 2014a, 2014b). It is well known that vegetation cover reduces soil erosion (Bochet & García-Fayos, 2004; Elwell & Stocking, 1976; Francis & Thornes, 1990) by decreasing soil erodibility, effective precipitation, and kinetic energy of runoff and raindrops (Domingo et al., 1998; Martínez-Mena et al., 2000). Vegetation reduces water-induced soil erosion by intercepting rainfall, increasing water infiltration on associated soil-fertility islands, intercepting runoff at the soil surface level, and stabilizing the soil by roots (Gyssels et al., 2005).This results in greater energy needed to detach soil particles (Bochet & García-Fayos, 2004) and acts as a roughness element, causing flow retardance (Styczen & Morgan, 1995). Normaniza and Barakbah (2006) also discovered that vegetation type and coverage indirectly enhance water extraction from soil to the atmosphere and directly enhance slope shear strength, ultimately influencing the stability of the slope. Moreover, increasing plant coverage can significantly reduce the sediment yield and effectively control soil erosion (Cerdá, 1999; Elwell & Stocking, 1976; Morgan et al., 1997). Snelder and Bryan (1995) investigated the relationship between plant coverage and soil loss under simulated rainstorms, and results showed that soil loss was maximum for plant coverage at less than 25%, and that a minimum of 55% plant coverage was required to achieve satisfactory soil erosion control. In addition, cover crops fulfill several functions including nitrogen fixation (Parkin et al., 2006), carbon sequestration (Reicosky & Forcella, 1998), soil aggregation influencing soil hydrology, and prevention of wind and water erosion (Battany & Grismer, 2000). The use of vegetation has also been proven to restore the ecosystem itself, accelerating the natural succession process (Normaniza & Barakbah, 2011).

The presence of an initial plant cover will be markedly important in beginning the process of stabilization and accumulation of organic material (Bradshaw, 2000; Parrotta & Knowles, 2001). In this study, *Melastoma malabathricum* was chosen due to its outstanding capacity to survive in extreme soil conditions, and it is widely known as an aluminum accumulating plant (Watanabe et al., 2008). In Rohailah (2010), *M. malabathricum* was described as having the best physiological performance on slope in terms of stomatal conductance and photosynthetic and transpiration rates, as well as high Water Use Efficiency (WUE), which attributed to high growth rate. Therefore, it exhibited the best potential for a slope species.

Apart from that, topography factors have also become major factors affecting soil degradation. Understanding slope orientations is a critical part of knowing the intensity, amount, and direction of sunlight essential for plant growth. It is known that different slope orientations relative to the sun vary the amount of solar radiation received by the ground. The differences in light intensity on a slope may result in different responses of seedlings to plant biochemical, physiological, and structural changes. The impact of solar radiation from the sun on plant growth could be ascribed to its effect on photosynthetic CO_2 assimilation, the main process for production of biomass (Papadopoulos & Pararajasingham, 1997).

Hence, this study is aimed at determining the influence of slope orientations in regard to sunlight directions; morning sun with evening shade slopes (the plant received morning sun) and evening sun with morning shade slopes (the plant did not receive morning sun) on the erosion rate and physiological performances of *M. malabathricum* at different planting densities. It is anticipated that the results of this study will produce a viable approach to increasing slope stability in a non-destructive method.

2. Materials and methods

2.1. Plant materials

Seeds of *M. malabathricum* were germinated in a Petri dish containing wet cotton with a surrounding temperature of 30 °C. After three weeks of germination, seedlings were then transferred to Polyvinylchloride (PVC) pipes (size of 0.1 m in diameter and 0.3 m in height) filled with sandy loam and placed in a greenhouse (temperature 25–32 °C, maximum PAR 2100 μE m^{-2} $s^{-1,}$ and relative humidity of 60–90%) at the Institute of Biological Sciences, Faculty of Science, University of Malaya. The bottom of the pipes were tied with plastic net and perforated to allow drainage. After reaching the average height of 1 m, seedlings of *M. malabathricum* were transferred onto a slope.

2.2. Planting density treatment

A planting density is defined by the vertically projected limits of the plant canopy on the soil surface. According to Bochet et al. (2006), by using shrubs with the average height of 1 m, the suitable erosion box size chosen was 0.25 m^2 (modified Gerlach-type microplots). Hence, a preliminary experiment was conducted to determine the planting density per 0.25 m^2. Based on the plant canopy sizes, the results showed the density of three seedlings per box was the maximum planting density appropriate to fully cover the box size chosen (Table 1). This assumption is based on the idea that the percentage of canopy coverage of the species studied was low in the initial study period and would be increased with time. Thus, one, two, and three seedlings per box were set up as an experimental treatment with a bare box as a control.

2.3. Experimental set up

2.3.1. Site description

Two slopes were selected along Guthrie Corridor Expressway, Selangor; one which received morning sun with evening shade (the latitude and longitude is N 3°1′5.0109″ and East 101°5′2.3556″, respectively) and another slope which received evening sun with morning shade (the latitude and longitude is N 3°1′ 5.8769″ and East 101°5′14.8556″, respectively). A similar slope angle and berm

Table 1
Preliminary experiment of planting density treatment.

Plant density (no. of seedlings/0.25 m^2)	Average of leaf area index (LAI)	Estimation of the canopy covers relative to the box size (%)
1	0.09	25
2	0.14	50
3	0.19	75
4	0.24	100
5	0.29	100
6	0.34	100