Measurement 114 (2018) 132–143

Contents lists available at ScienceDirect

Measurement

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

A non-intrusive image analysis technique for measurement of heterogeneity in grass species around tree vicinity in a green infrastructure

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ARTICLE INFO

Keywords:
Vegetation density
Shoot growth
Image processing
Interactive effects
Non-intrusive

ABSTRACT

Spatial heterogeneity of vegetation growth is important for maintenance of urban green space. It also governs the differential settlement of foundation of buildings and performance of biofiltration units. The objective of this study is to analyse the heterogeneity in vegetation density and shoot growth of a grass around a tree vicinity. A novel non-intrusive image analysis approach was designed and developed for quantifying heterogeneity in vegetation growth. A commercially available unmanned air vehicle (UAV; PHANTOM 3 STANDARD) was utilized to capture images. Vegetation density from these captured images were quantified using a public domain image processing program ImageJ. Atmospheric parameters were monitored by micro-climate monitoring system for interpreting vegetation growth. It is found that, at a given radial distance from stem of tree, vegetation density range is found more heterogenous than shoot growth. The basic assumption of symmetricity around tree vicinity as adopted in previous models for root water uptake is found to be not true. Variation of rainfall is one of the main reason causing heterogeneity in grass growth around tree vicinity. Heterogeneity in vegetation growth more prominent near the tree vicinity than away from it. An increase in vegetation density is found within 2 m radial distance in both sides of tree stem due to presence of shredded leaves from tree during winter.

1. Introduction

Urban green space (i.e., lawns and parks) promotes health, psychological activity and physical well- being of urban residents [1]. Extensive schemes were implemented to increase urban green space and that has been acknowledged as eco system justice issue [1,2]. Suction and hydraulic conductivity are important parameters governing ground water recharge [3] and run off through biofiltration units [4,5], and differential settlement of foundations of the buildings (due to heterogeneous soil moisture uptake) [6]. Vegetation cover change is a vital factor for the maintenance of urban green space [7]. It also has vital implications for a range of complexities, such as suction induced in vegetated soil due to evapotranspiration [8–10] as well as hydraulic conductivity of vegetated soil [11]. Pictorial and schematic view of vegetation cover application in various applications is shown in Fig. 1. This shows the importance of vegetation cover change in land scape and urban planning, ecological, environmental and geotechnical studies.

Vegetation cover change is affected by temperature [12,13], light [14,15] and available water content [16]. Furthermore, vegetation cover change is normally expressed in terms of vegetation density and shoot growth [17]. Vegetation density (m^2/m^2) on a surface is defined as the ratio of area covered by the vegetation to the total surface area [17].

$$\text{Vegetation density} = \frac{\sum_v^A}{A}$$

where:

A_v = Area covered by vegetation on the considered soil surface,

A = Total area of soil surface

The physical meaning of vegetation density is the area of vegetation on ground, which can intercept photo synthetically active radiation (PAR) [18]. However, PAR may not reach the vegetation cover due to shading or presence of shredded leaves on vegetation surface in case of mixed vegetation [19]. Shoot growth rate (mm/month) is the increase in length of shoot per unit time [19]. Previous studies were conducted to determine vegetation density [20–22] and shoot growth in various areas [23–27]. These studies reveal that, vegetation density and shoot growth varies due to seasonal effect and shading. However, rarely any study exist on spatial heterogeneity of vegetation density and shoot growth in the tree vicinity. This limitation of previous studies are

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http://dx.doi.org/10.1016/j.measurement.2017.09.010
Received 11 May 2017; Received in revised form 28 August 2017; Accepted 11 September 2017
Available online 12 September 2017

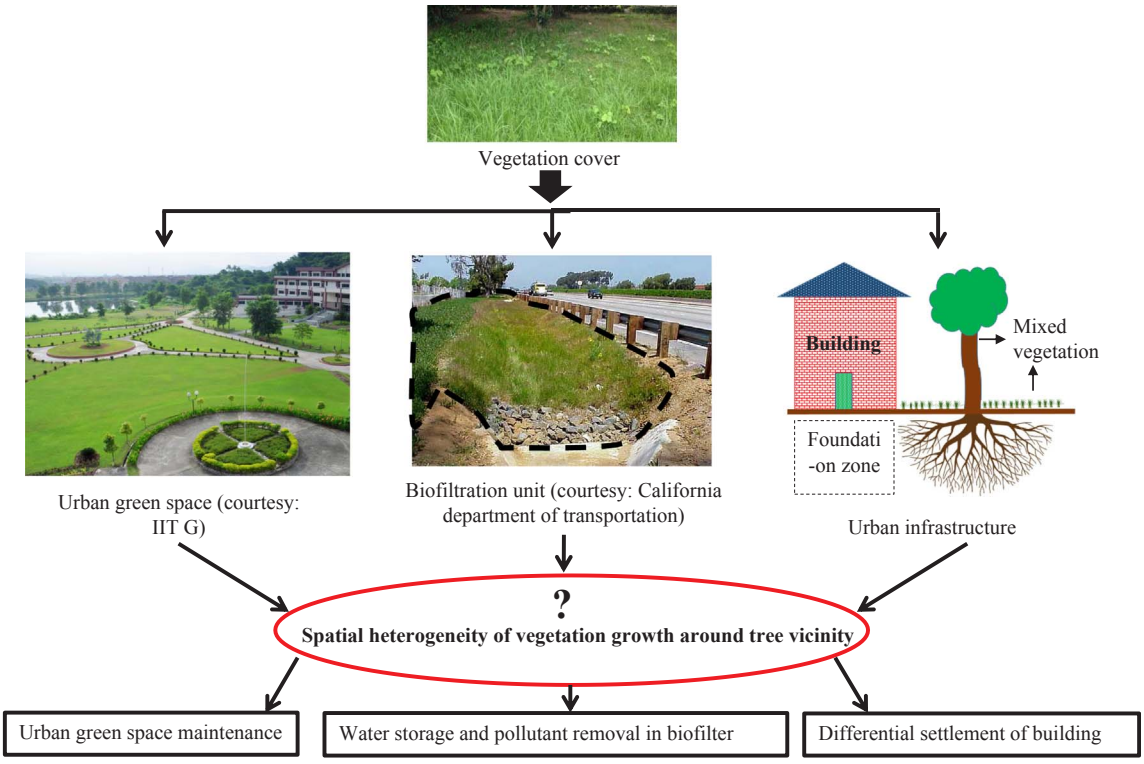

Fig. 1. Importance of spatial heterogeneity of vegetation growth in various infrastructures.

shown in Fig. 1 (with question mark).

Study on the heterogeneity of vegetation density and shoot growth in the tree vicinity is highly needed due to the wide spread existence of tree vicinities in urban areas. One reason for such wide spread existence of tree vicinities is, strategic plantation of in the urban areas for land scape maintenance and to reduce air temperature [28–32]. It is evident from previous studies that, difference between hydraulic conductivity or suction induced in soil surface covered with higher and lower vegetation areas could be up to 450% [8,11]. Furthermore, such higher difference would also occur at various points within a small area due to spatial heterogeneity of vegetation cover in a tree vicinity. Hence, spatial heterogeneity of vegetation cover is essential to understand spatial variation of hydraulic conductivity and suction (i.e., run-off and ground water recharge through biofiltration units and differential settlement of foundation of buildings) in addition to maintenance of green space. The importance of spatial heterogeneity of vegetation cover in the context of urban green space maintenance, biofiltration units and urban infrastructure is pointed Fig. 1.

The objective of this study is to investigate the vegetation cover in the vicinity of a *Pongamia pinnata* tree. Three different species, i.e., *Poacea*, *Cyperus* and *Bauhinia purpurea* with distinct root systems were found in the tree vicinity. Field monitoring was conducted for a period of around six months, during which the vegetation density was quantified and shoot growth was measured. Spatial variations in vegetation density and shoot growth rate were compared and interpreted with atmospheric parameters.

2. Materials and methods

2.1. Site description

Figs. 2 and 3 show the location (at Indian Institute of Technology Guwahati, India) and overview, respectively of a selected testing site (after Gadi et al. [10]). The site consist of a *Pongamia pinnata* tree. The tree vicinity consists of *Poacea*, *Cyperus* and *Bauhinia purpurea* species on a flat ground. In this study, field monitoring was conducted on vegetation in the tree vicinity. This field monitoring is designed to improve understanding of the spatial variation of vegetation density and shoot growth rate.

2.2. Soil properties

In order to determine in situ dry density, disturbed soil samples were collected from four different locations. Among these four samples, two samples are collected within 2.5 m radial distance from tree stem and remaining two are collected in between 2.5 m and 5 m radial distances from tree stem. It was found that, in situ dry densities of the four samples vary between 1324 kg/m^3 and 1372 kg/m^3, with an average value of 1348 kg/m^3. The average in situ dry density was approximately equal to 76.8% of the maximum dry density. The average contents of gravel (particle size $D_0 \geq 2$ mm), sand (particle size 0.063 mm $\geq D_0 \leq 2$ mm), silt and clay (particle size $D_0 \leq 0.063$ mm) were found to be 0%, 98.6% and 1.4%, respectively. Based on the measure particle size distribution, the soil in the vicinity of tree is classified as poorly graded sand (SP) [33], according to the unified soil classification system (USCS).

2.3. Overview of tree vicinity

Poacea, Cyperus and *Bauhinia purpurea grass were selected* for present study. *Poacea* is widely considered to be the ornamental or fodder crop or lawn grass [34,35]. *Cyperus* and *Bauhunia pupuria* are widely used to cure several diseases. *Cyperus* is used in medicine systems to cure fever, pain, diarrhea and dysentery [36]. Whereas, *Bauhunia Purpurea* is used as antidiabetic, anti-inflammatory, anti-bacterial and thyroid hormone regulating agent [37]. Furthermore, these three species are grown widely in subtropical regions [38–40] and are drought tolerant [41–46]. It is important to understand the growth variations of *Poacea, Cyperus* and *Bauhinia purpurea* in an urban green infrastructure. Fig. 3 shows the overview of vicinity of a tree. It can be seen that the front side of tree vicinity was divided into five concentrated half circles. Radii of these semicircles are 1 m, 2 m, 3 m, 4 m and 5 m, respectively.