UNIVERSITI PUTRA MALAYSIA

ESTIMATION OF VEGETATION DENSITY USING IMAGE ANALYSIS AND ITS EFFECT ON HYDRAULIC CHARACTERISTICS OF AN OPEN CHANNEL

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By

OSELA NOORADIN ABDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2015

DEDICATION

TO

My Father and Mother….

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

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Vegetation density is one of the factors that affect the flow behaviour and resistance in vegetated channels and wetlands. Many approaches have been explored to quantify the vegetation density such as by counting the number of vegetation or determining the area covered by the vegetation per unit area. However, in reality, the aquatic vegetation in the field is diverse in types and has varying properties, and if the vegetation is submerged, the vegetation density estimation becomes even more challenging. The use of remote sensing imagery for vegetation mapping is now gaining popularity due to the rapid development of remote sensing technology and readily available remote sensing imageries from various sources. In this study, the use of satellite image of a PLEIADES is explored to estimate the vegetation density in the Putrajaya Wetlands. Arc Map 10.1 software is used for data entry, image display and output. The vegetation type classification is derived using the Supervised Maximum Likelihood Classification and Support Vector Machine. The environment for Visualizing Images (ENVI) software is used to derive the Normalised Difference Vegetation Index (NDVI) for the selected study area and the area covered by the vegetation for different NDVI. NDVI is the ratio between the maximum absorption of radiation in the red (R) spectral band (0.66 µm) versus the maximum reflection of radiation in the near infrared (NIR) spectral band (~0.83 µm). The percentage area covered by vegetation obtained through ENVI software is then validated with ground truth. In the field survey, areas with different densities are chosen and divided into small cells of 1 m^2. The percentage area covered by vegetation for each cell is estimated by observation. Then, the relationship between the percentage area covered by the vegetation and NDVI is established and it is found that the NDVI has a polynomial relationship with the percentage area covered by vegetation. Also, the relationship between NDVI and hydraulic parameters in the wetland (velocity and resistance coefficient) is derived. The velocity at various locations of different densities in the wetland is measured on site using the Acoustic Doppler Velocitimeter (ADV).

From the image analysis and ground truth validation, a map of vegetation distribution based on types for the selected zone of Putrajaya Wetland has been produced. It has been found that the land cover classes in the study area fall into four classifications; that are the Hanguana Malayana, Phragmites Karka, Scirpus Grossus and water bodies. The accuracy measured using matrix confusion for the overall classification accuracy for Maximum Likelihood is 78.81% and Kappa coefficient is 0.7187% and for Support Vector Machine 81.36% for overall and 0.7512 for kappa coefficient. In addition, the NDVI values representing the vegetation distribution and density have also been generated and the NDVI values for the selected area are found to be in the range of -0.1058 - 0.7825. The velocity at various locations of different densities in the wetland showed that the density of vegetation had a significant effect on the velocity. In addition, it was observed that the flow resistance increases with the increasing in the density, which is also showed in the increasing of NDVI values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

ANGGARAN KETUMPATAN TUMBUHAN MENGGUNAKAN ANALISIS IMEJ DAN KESANNYA TERHADAP CIRI-CIRI HIDRAULIK SALURAN TERBUKA

Oleh

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Ketumpatan tumbuhan adalah salah satu faktor yang diambil kira dalam kelakuan aliran dan rintangan dalam saluran tumbuhan dan tanah bencah. Banyak pendekatan telah diterokai untuk mengukur ketumpatan tumbuhan seperti dengan mengira bilangan tumbuhan atau dengan menentukan kawasan yang diliputi oleh tumbuhan kawasan per unit. Walau bagaimanapun, pada hakikatnya, tumbuhan akuatik di lapangan terdiri daripada pelbagai jenis tumbuhan dan mempunyai ciri-ciri yang berbeza, dan tambahan pula, jika tumbuhan itu tenggelam, anggaran ketumpatan tumbuhan akan menjadi lebih mencabar. Penggunaan imej penderiaan jauh untuk pemetaan tumbuhan kini menjadi semakin popular disebabkan oleh perkembangan pesat teknologi penderiaan jauh dan imejan penderiaan jauh yang diperoleh daripada pelbagai sumber. Dalam kajian ini, penggunaan imej satelit dari jenis PLEIADES digunakan untuk menganggar ketumpatan tumbuhan di Tanah Bencah Putrajaya. Perisian Arc Map 10.1 digunakan untuk memasukkan data petunjuk, pemprosesan pengelasan jenis tumbuhan, paparan imej dan output. Pengelasan jenis tumbuhan diperoleh dengan menggunakan Pengelasan Kemungkinan Diselia *(Maximum Likelihood Classification)* dan Mesin Vektor Super *(Super Vector Machine)* . Perisian *Environment for envisage Images* (ENVI) digunakan untuk memperoleh Indeks Perbezaan Pernormalan Tumbuhan (NDVI) bagi kawasan kajian yang dipilih dan kawasan yang diliputi oleh tumbuhan untuk NDVI berbeza. NDVI adalah nisbah di antara penyerapan maksimum radiasi dalam jalur spektrum (0.66 µm) merah (R) berbanding dengan pantulan maksimum radiasi dalam jalur spektrum dekat (~ 0.83 µm) inframerah (NIR). Peratusan kawasan yang diliputi oleh tumbuhan diperolehi melalui perisian ENVI kemudiannya disahkan dengan kesahihan lapangan. Dalam tinjauan lapangan, kawasan yang mempunyai ketumpatan yang berbeza dipilih dan dibahagikan ke dalam sel kecil iaitu 1 m^2. Peratusan kawasan yang diliputi oleh tumbuhan

untuk setiap sel dianggarkan melalui pemerhatian. Kemudian, hubungan antara peratusan kawasan yang diliputi oleh tumbuhan dan NDVI diwujudkan dan didapati NDVI mempunyai hubungan polinomial dengan luas kawasan yang diliputi tumbuhan. Juga, hubungan antara NDVI dan parameter hidraulik dalam tanah bencah (halaju dan pekali rintangan) diperoleh. Halaju di pelbagai lokasi ketumpatan yang berbeza dalam tanah bencah diukur di lokasi dengan menggunakan meter Halaju Doppler Akustik (ADV).

Dari analisis imej dan pengesahan kesahihan lapangan, peta taburan tumbuhan berdasarkan jenis untuk zon Tanah Bencah Putrajaya yang dipilih telah dihasilkan. Kajian mendapati bahawa kelas litupan tanah di kawasan kajian terbahagi kepada empat kelas, iaitu *Hanguana Malayana*, *Phragmites Karka*, *Scirpus Grossus* dan air. Ketepatan diukur menggunakan matriks kekeliruan teknik confusion matrix, dan untuk ketepatan pengelasan keseluruhan yang diperoleh adalah 78.81% % dan pekali Kappa adalah 0.7187 untuk *Maximum Likelihood*, dan untuk *Vector Super Machine* ketepatan keseluruhan yang diperoleh adalah 81.36% dan pekali Kappa adalah 0.7512. Di samping itu, nilai-nilai NDVI mewakili taburan tumbuhan dan ketumpatan juga boleh dihasilkan dan nilai NDVI bagi kawasan yang dipilih didapati adalah dalam julat -0.1058 hingga 0.7825. Halaju di pelbagai lokasi ketumpatan yang berbeza dalam tanah bencah itu menunjukkan bahawa ketumpatan tumbuhan mempunyai kesan yang besar ke atas halaju aliran. Di samping itu, analisis menunjukkan bahawa peningkatan rintangan aliran adalah seiring dengan peningkatan ketumpatan, yang juga menunjukkan peningkatan dalam nilai NDVI.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ADV	Acoustic doppler velocitimeter
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible Infrared Image Spectrometer
ASTER	The Advanced Spaceborne Thermal Emission and Reflection Radiometer
CIR	Colour Infrared imagery
D	Stem diameter
ENVI	Environment for envisage Images
ETM	Enhanced Thematic Mapper
G	Acceleration due to gravity
GIS	Geographic Information Systems
GLO	General Land Office
H	Flow depth
HNWR	Havasu National Wildlife Refuge
L	Wetted stem length
l*	Submergence ratio
MODIS	Moderate Resolution Images Spectroradiomerter
MSS	Multispectral Scanner System
N	Number of stems per unit bed area
NASA	National Aeronautics and Space Administration
NDVI	Normalised Difference Vegetation Index
n_d	Manning's roughness coefficient
NIR	Near infrared
Q	Channel discharge
R	Red spectral band
R*	Convection coefficient
RBV	Return Beam Vidicon
Re	Reynold's number
ROI	Region of interest
S	Total friction slope or slope of the channel
S_b	Portion of friction slope attributable to bed shear
*S*n	Portion of friction slope attributable to stem drag
S	Stem spacing

SP	Centre to centre distance between plants
V	Apparent channel velocity
V'	Averaged velocity
V*	Friction velocity
V_p	Vegetation porosity
TM	Thematic Mapper
UN	Upper North Wetland Arm in Taman Wetland

CHAPTER 1

INTRODUCTION

1.1 Motivation

Many types of researches in hydraulic, hydrology and geomorphology of river environments have neglected the effects of instream vegetation, even though aquatic vegetation plays an important part in the flow attribute of the waterways. By changing the mean velocity and turbulent flow characteristics, aquatic vegetation changes the predestination and transport, of sediment and causes contamination. It is, therefore, important to know the characteristics of the flow over the vegetation in order to manage vegetated waterways.

The researchers have realized the significant environmental benefits that vegetation brings to an aquatic ecosystem. Submerged canopies can have an affirmative influence on water quality by taking off nutrients and producing oxygen in the remaining region. Vegetation also can increase habitat varieties, and thus types of varieties, by introducing the locative heterogeneity to the velocity field. Some researchers now are supporting the wide spread replanting and ecological based management of channel vegetation (Shields Jr & Rigby, 2005).

Vegetation has the effects on the velocity and flows resistances, sediment transport, shear stress, turbulence properties and these effects are much dependent on the aquatic vegetation characteristics and flow regime (Afzalimehr, Najfabadi, et al., 2010; Badronnisa Yusuf, 2009; Wang et al., 2009). Among the most important vegetation characteristics is vegetation density or porosity. Vegetation density affects the flow behaviour and resistance in the vegetated channel (Järvelä, 2004). The stem and foliage concentration, length and diameter impact the flow resistance.

A study on the vegetation density is very important in the hydraulic analysis of vegetated channel. Vegetation population density is a very important aspect for estimating flow resistance, channel velocity and channel roughness (Stone & Shen, 2002). However, knowledge on vegetation density estimation is still lacking (Järvelä, 2005).

A lot of researches have been done to find an accurate representation of the flow behaviour by studying the velocity and the roughness coefficient and their relation to the vegetation density in different ways. (Huai et al., 2009) observed through experimental and field work and found that the hydraulic parameters change with different vegetation density; while (Li & Zeng, 2009) used numerical modelling to show how the density of the vegetation can control flow diversion.

Satellite and digital imagery play important roles to measure and record information on the land studies from a distance. It is due to the increasing availability and the rapid advancement of remote sensing, satellite and digital imagery technology with high-resolution satellite images such as Landsat, Spot (Satellite Pour l'Observation de la Terre, lit. "Satellite for observation of Earth"), Moderate Resolution Images Spectroradiometer (MODIS), Advanced Very High-Resolution Radiometer (AVHRR), IKONOS name from the Greek term eikōn for image, QuickBird, The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Airborne Visible Infrared Image Spectrometer (AVIRIS). Mapping vegetation through digital image involves various considerations, processes and techniques. This technology is a practical and economical means to study vegetation cover changes, particularly over large areas (Langley et al., 2001), not only can it be utilized to map vegetation that covers over land areas; but also for underwater areas in mapping submerged aquatic vegetation (Wolter et al., 2005).

Colour Infrared (CIR) imagery has great value in the analysis of vegetation classification types and submerged vegetation mapping. This is done when the chlorophyll absorption scatters the spectrum so that the vegetation indexes capture this contrast through the combinations of broadband red/ near-infrared reflectance. For example, CIR reflection changes throughout the year as with the agriculture crops during their growing season as shown in Figure 1.1 (Myneni et al., 1995).

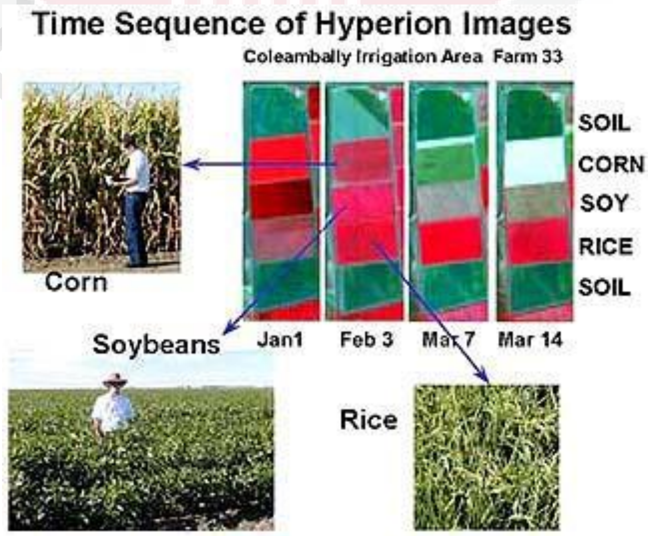

Figure 1.1 CIR satellite image showing three crop fields (corn, soybean, and rice) and two fields of bare soil at four dates during the growing season at the Coleambally agriculture test area in Australia. source: (http://landsat.gsfc.nasa.gov/)

Geographic Information Systems (GIS) is used to convert the remote sensing imagery into tangible information by processing and analysing the image pixel by pixel to delineate readily usable objects from imagery at the same time as combining the image processing and GIS functionalities in order to utilise the spectral and related information in an integrative way (Blaschke, 2010). The image pixel is used to find the index value in terms of NDVI to represent the density of the vegetation. The highest NDVI that corresponds to the vegetated area has the highest density (Gonzalez, 2011).

1.2 Statement of Problem

There is lack in the studies on the effect of the vegetation density on the waterway through satellite image. Most of them focused on counting the number of vegetation through experimental and field work to find the density of the vegetation. (Montakhab et al., 2012; Righetti, 2008)

Remote Sensors Images can be used to study perhaps other major wetland types (Turpie et al., 2015) as well as in mapping wetland aquatic vegetation (White & Lewis, 2011).

However, most studies focus on the use of the satellite image for classifying the in land vegetation but not on the aquatic vegetation classification and vegetation density estimation.

Furthermore, the relationship between the density of the aquatic vegetation and hydraulic parameters of waterway such as velocity and flow resistance are still under research. So far based on the literature review there has been no study carried out on the vegetation distribution in the Putrajaya wet land.

1.3 Objectives

The primary aim of this research is to investigate the suitability of image analysis method for vegetation density estimation in an open channel. This involves the determination of the signature and classification of various aquatic vegetation characteristics by using digital image analysis and its relation to vegetation density in the open channel. This is achieved by acquiring and analysing the PLEIADES satellite image of the Putrajaya wetland which is a habitat for many types of aquatic vegetation. The specific objectives for this research are

1. To classify various aquatic vegetation characteristics in the Putrajaya wetland through PLEIADES satellite image mapping and digital image analysis.
2. To estimate the vegetation density in an open channel by using the image analysis and verify the results with field observations.

3. To develop the relationship between vegetation density and hydraulic parameters (resistance coefficient, velocity) in an open channel (Putrajaya Wetland).

1.4 Thesis Organization

This thesis has five chapters. Chapter one consists of the introduction and the objectives of the thesis with explanation on the research gaps and problem statement. Chapter two presents the previous studies on the effects of the vegetation on the hydraulic of waterways, which were carried out through laboratory, numerical modelling, field work and remote sensing. The types of the satellite images and their applications for analysing the different kinds and characteristics of the vegetation through different kinds of software are also discussed in this chapter.

Chapter Three describes the methodology which consists of two parts: the first part presents the PLEIADES satellite image analysis to determine the classification and the density of aquatic vegetation. The second part describes the field work. Chapter Four discusses the results of the image analysis for vegetation density estimation as well as the relationship between the vegetation density and hydraulic parameters. In the last chapter, a conclusion of the study with the suggestions for future work is presented.

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