INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
10–331/DWXI/2010/12–6–921–925
http://www.fspublishers.org

Full Length Article

Discriminating Between Canopies of Natural Forest and *Acacia* Plantation Plots in a Google Earth Image to Evaluate Forest Land Rehabilitation by *Acacia* Species

RYOICHI DOI[1] AND S.L. RANAMUKHAARACHCHI
AFE Building, School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani 12120, Thailand
[1]Corresponding author's e-mail: roird@aeiou.pt; frtbmb@hotmail.com

ABSTRACT

A Google Earth image was used to examine if canopies of *Acacia* plantation plots for land rehabilitation and natural evergreen forest can be discriminated through the multivariate color profiling of the canopies in the image. Among canopies of 19-or 20-years-old *Acacia* plantation plots and the natural evergreen forest of Sakaerat, Thailand, 83% of the *Acacia* canopies and 80% of the evergreen forest canopies were correctly classified by discriminant analysis, indicating incomplete restoration of the ecosystem after the rehabilitation period. The rehabilitative effects were recognized as demonstrating no significant differences between the *Acacia* and the evergreen forest canopies for some single color variables. The discriminatory power was nearly comparable to that of established remote-sensing technologies and to the abiotic discrimination of forest soils. The use of Google Earth images in land rehabilitation as well as the relevance of *Acacia* plantation for the rehabilitation of degraded lands in the region is discussed.

Key Words: *Acacia auriculiformis*; Color profiling; Google Earth image; Land degradation and rehabilitation; Multivariate analysis

INTRODUCTION

Deforestation has emerged as a challenge to socio-economic development in Thailand (Anonymous, 2006), as in many other countries. Reforestation was one of the rehabilitation measures taken by the Thai government (Sharp & Nakagoshi, 2006). Because native tree species are prone to fail to survive due to the degraded soil conditions, exotic plant species are often introduced as a part of the reforestation strategy to rehabilitate the degraded lands, which have harsh soil conditions (Ashton *et al*., 2001). This strategy is often criticized however, because the introduced exotic species may result in biological deserts (Wuethrich, 2007). Also, exotic tree species may escape to adjacent areas and threaten native species (Hartley, 2002). Given this, we examine whether or not the introduction of exotic tree species is truly rehabilitative.

Some evidence of the rehabilitative effects of reforestation has been shown as soil physicochemical (Doi & Ranamukhaarachhi, 2007) and biotic changes (Doi & Ranamukhaarachhi, 2009a) and as plant species community structure (Kamo *et al*., 2002). Following the plantation of exotic tree species, as succession proceeds, native tree species may return. The appearance of the canopy should then resemble that of the original natural forest. If so, the reforestation could confidently be considered rehabilitative. To evaluate the rehabilitative effects of reforestation by comparing with the original natural canopy, a method is needed to detect differences between canopies of forests with different tree species compositions. Forest canopies can be discriminated by a variety of aspects (Parker & Brown, 2000). However, no studies have been carried out to discriminate between canopies of forests. Even examples of discriminating between agricultural crop canopies are very rare (Shibayama & Akita, 2002). It is thus evident that discriminating between canopies that consist of various tree species is difficult.

However, a single forest canopy can be profiled using multivariate color profiling of the canopy image. Google Earth is one of the most commonly available tools for profiling forest canopies. In some areas, the resolution is good enough to show detailed textures of forest canopies. Canopy images can be color-profiled using photo-editing software. Values of red-green-blue (RGB) and other color variables can yield multivariate profiles of canopies. Human activities, mainly slash-and-burn cultivation, have deforested some parts of Sakaerat, Thailand that were originally covered by dry evergreen forest. Some degraded areas were rehabilitated by planting exotic tree species, including *Acacia auriculiformis* (Fig. 1; Doi & Ranamkhaarachchi,

To cite this paper: Doi, R. and S.L. Ranamukhaarachchi, 2010. Discriminating between canopies of natural forest and *Acacia* plantation plots in a Google Earth image to evaluate forest land rehabilitation by *Acacia* species. *Int. J. Agric. Biol.*, 12: 921–925

2009a). In this study, we used Adobe Photoshop to discriminate between forest canopies in Sakaerat, Thailand (Doi & Ranamukhaarachchi, 2007). The first objective of this study was to investigate if the color profiling of canopies can discriminate between the *Acacia* plantation plots and the evergreen forest in a Google Earth image. The second objective was to evaluate the rehabilitative effects of the *Acacia* plantation through the color profile of the canopy.

MATERIALS AND METHODS

Site description: In a Google Earth image, canopies of dry evergreen forest and the *Acacia* plantation in addition to bare ground surface were color-profiled. The vegetation types were randomly distributed. Thus, the vegetation mosaic was regarded as having a completely randomized design (Doi *et al*., 2009). The number of replications was 5, 6 and 3 for dry evergreen forest, *Acacia* plantation and bare ground, respectively. All sampling points were on slight slopes (<10°). The dry evergreen forest is the natural vegetation type of Sakaerat and is primarily dominated by *Hopea ferrea* and *Shorea* spp. that form the upper storey 20 to 40 m above ground (Kanzaki *et al*., 1995). The *Acacia auriculiformis* plantation plots were established in 1986 and 1987 after the original evergreen forest was subjected to slash-and-burn shifting cultivation (Kaeoniam *et al*., 1976), became bare and was then abandoned. The bare ground has been intensively deprived of soil nutrients and has the poorest fertility in Sakaerat, as reported elsewhere (Doi & Ranamukhaarachchi, 2009b). These vegetation types represent a land degradation–rehabilitation gradient, as shown by the soil fertility index (Doi & Sakurai, 2004) and other soil characteristics.

Google Earth image and color profiling: We obtained a Google Earth image for 3 April 2006. An altitude of 1000 m above ground was chosen when copying the image of the soil sampling point from where the soil sample was collected on 27/28 Feb 2006 (Doi & Ranamukhaarachchi, 2009c). The resolution enabled us to recognize a single tree canopy with a diameter of 5 m or smaller. The image was used for the multivariate color profiling of the canopy using Adobe Photoshop (Fig. 2). Around the soil sampling point, we set three square-shaped grids on the image to obtain approximately 1500 pixels/grid. For the bare ground, 12 to 20 pixels/grid were chosen, because the areas were relatively small. We chose the "Image" menu and then the "Mode" menu to show the image in RGB, cyan-magenta-yellow-key black (CMYK) or International Comission on Illumination-defined L*a*b* color mode (Doi *et al*., in press). After choosing a color mode, we chose "Image" then "Histogram" to show the histogram window (Fig. 2). In the window, values of R, G, B and other color variables were indicated. RGB and L*a*b* values were directly used, whereas the CMYK values were converted to percentages using the following equation:

$$\text{Percentage} = (255 - \text{Raw value}) \times 100 / 255 \quad (1).$$

In the histogram window (Fig. 2), a CMYK color is expressed by four numbers between 0 and 255. When all CMYK values are 255, the color is white with no color intensity at all. The conversion gives a positive correlation between the color intensity of a CMYK variable and the converted percentage. The conversion thus facilitates an intuitive understanding of how intensive the CMYK color is.

Data analyses: To examine the significance of vegetation type, as a source of variation of the color or the soil variable, analysis of variance was performed using the statistical software, SPSS 10.0.1 (SPSS Inc.). A least significant difference test was performed to examine the significant differences between means. In analyses of variations of the color variables, raw values for the three grid replications for each sampling point were directly used for the grid replications as a covariable. We performed discriminant analysis to obtain Wilk's lambda statistic and its significance using the SPSS software. Wilk's lambda is the most widely used statistic in determining the difference between multivariate profiles of compared sample groups (Zar, 1999). In this study, if the means among compared groups for each color variable are equal, Wilk's lambda becomes 1. More different the multivariate color profiles, closer Wilk's lambda gets to 0.

RESULTS AND DISCUSSION

Table I presents color profiles of the forest canopies and the bare ground in the Google Earth image. Vegetation type was a significant source of variations of all color variables ($P < 0.05$). Most variables showed that, in the Google Earth image, the bare ground was easily discriminated from the canopies. The greater values of R, G, B and L* as well as the smaller values of C, M, Y and K for the bare ground indicate its lighter color in comparison with the forest canopies. Greater value of a* indicates that the bare ground surface was reddish, while the canopies were greenish (Fig. 1, 2). The bare ground also had a greater value of b* than the forest canopies, indicating its brownish surface; the canopies were more bluish. Significant differences between the canopies were also detected for M, Y, a* and b*, indicating that the evergreen forest canopy was more purple, yellowish, reddish and brownish, respectively, than the *Acacia* canopy. The greenness of the evergreen forest canopy drops in the dry season and is not completely restored in April; it was still low when the image was obtained (Huete *et al*., 2008). This could aid in the discrimination of the evergreen forest canopy from the *Acacia* canopy, which was more greenish, as shown by a*. In this study, the rehabilitative effects were shown as no significant differences in R, G, B, C, K and L* between the canopies of the *Acacia* plantation plot and the evergreen forest. In other words, the canopies had been increasing their proximity over the last 19 or 20 years due to the rehabilitative succession in the *Acacia* plantation plots.

Table I: Color profiles of bare ground, canopies of *Acacia* plantation plot and dry evergreen forest of Sakaerat in the Google Earth image on 3 April 2006

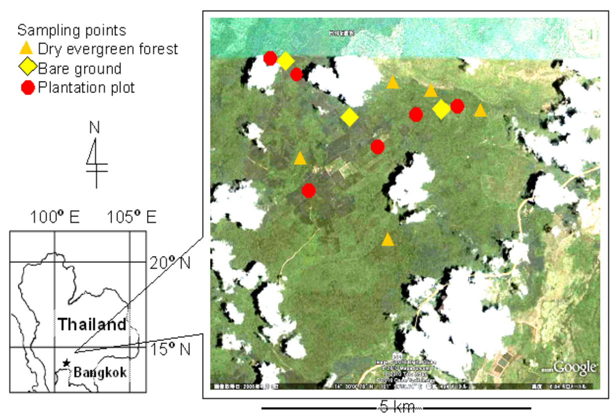
Canopy color variable	Separation of means for vegetation types						Significance of vegetation type as source of variation (*P* value)
	Bare ground		Acacia plantation plot		Dry evergreen forest		
	Mean	SD**	Mean	SD	Mean	SD	
R	92.4^{a*}	13.9	53.4^{b}	3.48	53.4^{b}	2.67	<0.001
G	84.1^{a}	12.8	58.2^{b}	4.77	59.9^{b}	3.56	<0.001
B	70.7^{a}	12.8	46.9^{b}	3.67	45.9^{b}	4.20	<0.001
C (%)	56.1^{b}	0.56	68.1^{a}	0.39	68.3^{a}	0.42	<0.001
M (%)	55.0^{b}	0.60	56.8^{a}	0.41	54.7^{b}	0.44	0.004
Y (%)	66.6^{c}	0.82	69.8^{b}	0.57	73.4^{a}	0.61	<0.001
K (%)	37.2^{b}	1.64	56.4^{a}	1.13	55.9^{a}	1.21	<0.001
L*	92.2^{a}	13.2	59.3^{b}	4.96	61.8^{b}	3.75	<0.001
a*	130^{a}	1.69	124^{b}	1.19	123^{c}	0.72	<0.001
b*	137^{a}	2.29	134^{c}	1.14	136^{b}	1.33	<0.001

*For each color variable, the means indexed by the same letter do not differ significantly at $P < 0.05$ according to the least significant difference
**Standard deviation

However, the *Acacia* plantation plots were still moving towards full recovery to evergreen forest, as indicated by discriminant analysis of the color profiles (Fig. 3), in which most of the canopies were correctly discriminated. Thus, in the *Acacia* plantation plots, the tree community structure was significantly different from the evergreen forest, enabling discrimination of the canopies. In Fig. 3, among all 33 grids in the evergreen forest and the *Acacia* plantation plots, six grids were misclassified and three were *Acacia* grids. The bare ground grids were clearly separated from the forest grids. Therefore, 83% of the *Acacia* grids and 80% of the evergreen forest grids were correctly classified. The discriminatory power was demonstrated to be nearly comparable to that of established remote-sensing technologies (Roberts *et al*., 2007) that discriminated different forests with up to 90% accuracy. The *Acacia* plantation plot and the evergreen forest were discriminated as well as they were by soil color and physicochemical characteristics (Doi & Ranamukhaarachchi, 2007). However, the discrimination was less successful compared with the physiological profiling of soil bacterial communities (Doi & Ranamukhaarachchi, 2009a), suggesting that there exist different rates of rehabilitation for the soil and the plant community (Singh *et al*., 2001).

In the southern Yucatan peninsula of Mexico, under similar climatic conditions, 40-60 years was estimated for recovery of total above-ground biomass following shifting cultivation based on the most optimistic estimate (Chazdon, 2003). Thus, the *A. auriculiformis* plantation ecosystem was likely to be in succession toward the climax. In the savanna region, *A. auriculiformis* plantation looks suitable to invest for the environment thus, in turn the society and the economy, because the species rehabilitates the harsh bare ground on which the native tree species can not survive (Doi & Ranamukhaarachchi, 2009a). Self-thinning (Ashton *et al*., 2001) could enrich plant community structure and many native plant species came back 10 years after the plantation (Kamo *et al*., 2002). This perceivable progress in succession was thought to contribute to the relative proximity of the *Acacia* plantation canopy to the evergreen forest canopy.

Fig. 1: Map of the research area, Sakaerat, Thailand. Brightness and contrast were increased from the original values for clarification. Red spots are *Acacia* plantation plots



More variables are available for profiling forest canopies if the land surface is observed using satellites. Various satellites carry sensors that utilize visible and invisible light (Im & Jensen, 2008), whereas for forestry studies, the commonly used sensor bands include X (2.4–3.8 cm), C (3.9–7.5 cm), L (15.0–30.0 cm) and P (30.0–100 cm, Roberts *et al*., 2007). Some of these bands are expected to be useful in discriminating between canopies of different forests, though this precise application, such as the discrimination between canopies, has not yet been reported. Instead, most satellite data have been used in discriminating between more clearly different forests (Conway, 1997) or in the estimation of land cover percentages by discriminating among agricultural field, forest and urban areas (Islam *et al*., 2008). Utilizing satellite-based variables could be effective in evaluating the rehabilitative effects of plantation on degraded lands and would thus be worth investigating, as suggested by Boyd and Danson (2005). The usefulness of Google Earth images is however, attractive as it is commonly available through personal computers, Internet access and Adobe Photoshop or similar software. Today,

Fig. 2: Procedures of color profiling of forest canopy in Google Earth image using Adobe Photoshop. Value of G (greenness) and other color variables for the square-shaped area defined by the dotted lines were read as shown in the "histogram" window

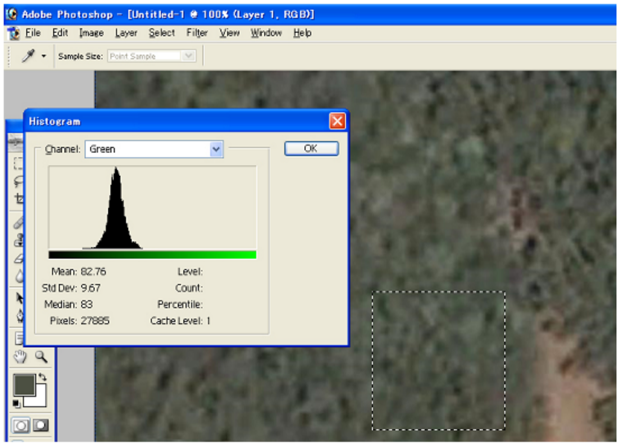
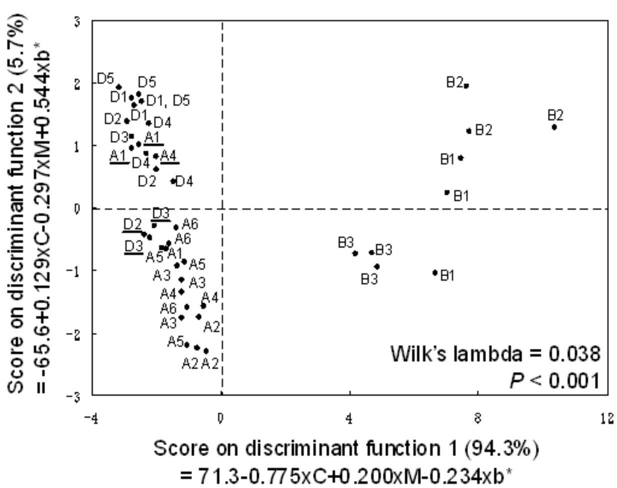


Fig. 3: Discriminant score plots indicating discriminant scores for the canopy and the bare ground grids in the Google Earth image on 3 April 2006. The symbols indexed by A, B and D denote *Acacia* plot, bare ground and dry evergreen forest, respectively. The numbers following A, B or D are the replication numbers. The percentage in parentheses indicates the variation explained by the function. The formula indicates the discriminant formula to separate the sample groups



various freeware such as MouseZoom is available for RGB and other color profiling of canopies. Using the freeware, profiling single pixels, averaging the raw values for the pixels and utilizing the data is also possible (Doi *et al*., in press). In this study, M, Y, a* and b* more sensitively showed the differences between the canopies of the *Acacia* plantation plot and the evergreen forest when the R, G and B did not show any significant differences. In addition to R, G and B, various freewares offer additional color variables to enable discrimination among various objects that are similar to one another. The complementary relationship among the color variables was an unexpected and favorable advantage of the current method based on Google Earth. As suggested by Cuozzo *et al*. (2004), the feasible and cost-effective method examined in this study would be worth considering, testing, improving and developing in various related activities, including agricultural management, land development and land rehabilitation/conservation. For example, if we found a relationship between the color profile of vegetation cover and a plant disease, then conditions to minimize the disease could be empirically extracted.

CONCLUSION

A Google Earth image enabled to discriminate between forest canopies and to evaluate the rehabilitative effects of *Acacia* plantation in Sakaerat through the multivariate color profiling of the canopies. The color profiles revealed *Acacia* plantation plots moving towards full recovery to evergreen forest, as shown by previous comparisons of the soils. Further examination and development of the method examined in this study will be useful, because of the cost effectiveness, public availability and discriminatory power of the method.

REFERENCES

Anonymous, 2006. *The Tenth National Economic and Social Development Plan (2007–2011)*. National Economic and Social Development Board of Thailand, Offce of the Prime Minister, Bangkok, Thailand

Ashton, M.S., C.V.S. Gunatilleke, B.M.P. Singhakumara and I.A.U.N. Gunatilleke, 2001. Restoration pathways for rain forest in southwest Sri Lanka: A review of concepts and models. *For. Ecol. Manage*., 154: 409–430

Boyd, D.S. and F.M. Danson, 2005. Satellite remote sensing of forest resources: Three decades of research development. *Prog. Phys. Geog.*, 29: 1–26

Chazdon, R.L., 2003. Tropical forest recovery: Legacies of human impact and natural disturbances. *Perspect. Plant Ecol. Evol. Syst.*, 6: 51–71

Conway, J., 1997. Evaluating ERS-1 SAR data for the discrimination of tropical forest from other tropical vegetation types in Papua New Guinea. *Int. J. Remote Sens.*, 18: 2967–2984

Cuozzo, G., C. D'Elia and V. Puzzolo, 2004. A method based on tree-structured Markov random field for forest area classification. *Proc. the IEEE International Geoscience and Remote Sensing Symposium*, pp: 2352–2354. 20-24 September, 2004, Anchorage, Alaska

Doi, R. and S.L. Ranamukhaarachchi, 2007. Soil color designation using adobe PhotoshopTM in estimating soil fertility restoration by *Acacia auriculiformis* plantation on degraded land. *Curr. Sci.*, 92: 1605–1610

Doi, R. and S.L. Ranamukhaarachchi, 2009a. Community-level physiological profiling in monitoring rehabilitative effects of *Acacia auriculiformis* plantation on degraded land in sakaerat, Thailand. *Silva Fennici*, 43: 739–754

Doi, R., and S.L. Ranamukhaarachchi, 2009b. Correlations between soil microbial and physicochemical variations in a rice paddy: Implications for assessing soil health. *J. Biosci.*, 34: 969–976

Doi, R. and S.L. Ranamukhaarachchi, 2009c. Soil dehydrogenase in a land degradation-rehabilitation gradient: Observations from a savanna site with a wet/dry seasonal cycle. *Rev. Biol. Trop.*, 57: 223–234

Doi, R., P. Sahunalu, C. Wachrinrat, S. Teejuntuk and K. Sakurai, 2009. Antibiotic resistance profiles of soil bacterial communities over a land degradation gradient. *Community Ecol.,* 10: 173–181

Doi, R. and K. Sakurai, 2004. Principal components derived from soil physico-chemical data explained a land degradation gradient and suggested the applicability of new indexes for estimation of soil productivity in the Sakaerat environmental research station, Thailand. *Int. J. Sustain. Dev. World Ecol.,* 11: 298–311

Doi, R., C. Wachrinrat, S. Teejuntuk, K. Sakurai and P. Sahunalu, 2010. Semiquantitative color profiling of soils over a land degradation gradient in Sakaerat, Thailand. *Environ. Monit. Assess.,* in press

Hartley, M.J., 2002. Rationale and methods for conserving biodiversity in plantation forests. *For. Ecol. Manage*., 155: 81–95

Huete, A.R., N. Restrepo-Coupe, P. Ratana, K. Didan, S.R. Saleska, K. Ichii, S. Panuthai and M. Gamo, 2008. Multiple site tower flux and remote sensing comparisons of tropical forest dynamics in monsoon Asia. *Agric. For. Meteorol.,* 148: 748–760

Im, J. and J.R. Jensen, 2008. Hyperspectral remote sensing of vegetation. *Geography Compass,* 2: 1943–1961

Islam, Md. A., P.S. Thenkabail, R.W. Kulawardhana, R. Alankara, S. Gunasinghe, C. Edussriya and A. Gunawardana, 2008. Semi-automated methods for mapping wetlands using landsat ETM + and SRTM data. *Int. J. Remote Sens.,* 29: 7077–7106

Kaeoniam, P., P. Khoorat, W. Sunthornsan, M. Issareeya, C. Cherdchun and W. Buachum, 1976. *A Study of Illegal Deforestation in the Reserved Forest Area at the Sakaerat Environmental Research Station.* Environmental and Ecological Research Department, Applied Scientific Research Corporation of Thailand, Bangkok

Kamo, K., T. Vacharangkura, S. Tiyanon, C. Viriyabuncha, S. Nimpilas and B. Doangsrisen, 2002. Plant species diversity in tropical planted forests and implication for restoration of forest ecosystems in Sakaerat, northeastern Thailand. *JARQ,* 36: 111–118

Parker, G.G. and M.J. Brown, 2000. Forest canopy stratification-Is it useful? *American Nat*., 155: 473–484

Roberts, J.W., S. Tesfamichael, M. Gebreslasie, J. Van Aardt and F.B. Ahmed, 2007. Forest structural assessment using remote sensing technologies: An overview of the current state of the art. *Southern Hemisphere For. J.,* 69: 183–203

Sharp, A. and N. Nakagoshi, 2006. Rehabilitation of degraded forests in Thailand: Policy and practice. *Landsc. Ecol. Eng.,* 2: 139–146

Shibayama, M. and S. Akita, 2002. A portable spectropolarimeter for field crop canopies: Distinguishing species and cultivars of fully developed canopies by polarized light. *Plant Prod. Sci.,* 5: 311–319

Singh, K.P., T.N. Mandal and S.K. Tripathi, 2001. Patterns of restoration of soil physicochemical properties and microbial biomass in different landslide sites in the sal forest ecosystem of Nepal Himalaya. *Ecol. Eng.,* 17: 385–401

Wuethrich, B., 2007. Reconstrusting Brazil's atlantic rainforest. *Science,* 315: 1070–1072

Zar, J.H., 1999. *Biostatistical Analysis*. Prentice-Hall, New Jersey

(Received 28 June 2010; Accepted 23 August 2010)