remote sensing

MDPI

Supplementary Material

Mapping seasonal tree canopy cover and leaf area using WorldView-2/3 satellite imagery: A megacity-scale case study in Tokyo urban area

Yutaka Kokubu [1,2,*], Seiichi Hara [3] and Akira Tani [2]

[1] Tokyo Metropolitan Research Institute for Environmental Protection, 1-7-5, Shinsuna, Koto-ku, Tokyo, 136-0075, Japan
[2] Department of Environmental and Life Sciences, University of Shizuoka, 52-1 Yada, Suruga-ku, Shizuoka 422-8526, Japan
[3] NTT Data CCS Corporation, 4-12-1 Higashishinagawa, Shinagawa-ku, Tokyo, 140-0002, Japan
* Correspondence: kokubu-y@tokyokankyo.jp

Table S1. Comparison of the vegetation land cover for each 23 municipalities in Tokyo special wards estimated by aerial photograph interpretation (Tokyo GWC-ratio data), and WorldView-2/3 imagery classification (this study). * The numbers in parentheses show the coverage ratio in the shadow area.

Municipality (Special ward)	Main location Image No. in Figure 2	Area	Land coverage ratio				Difference (%)
			Tokyo GWC-ratio data	WV-2/3 data (Image classification result)			
			(1) Tree canopy	Vegetation*	(2) Tree canopy*	Grass*	(2) – (1)
Nerima-ku	(1) and (2)	48.1 km²	17.3%	23.7 (2.9) %	14.4 (1.8) %	9.3 (1.2) %	−2.9%
Itabashi-ku	(2)	32.1 km²	14.5%	20.0 (2.3) %	10.0 (1.2) %	10.0 (1.2) %	−4.5%
Toshima-ku	(2)	13.0 km²	10.2%	13.0 (1.9) %	8.0 (1.2) %	5.0 (0.7) %	−2.2%
Suginami-ku	(2)	34.1 km²	18.8%	23.7 (3.5) %	15.8 (2.3) %	8.0 (1.2) %	−3.0%
Nakano-ku	(2)	15.6 km²	13.3%	16.3 (2.3) %	10.1 (1.4) %	6.1 (0.9) %	−3.2%
Setagaya-ku	(2)	58.0 km²	18.7%	25.5 (3.2) %	15.2 (1.9) %	10.3 (1.3) %	−3.5%
Kita-ku	(2) and (3)	20.8 km²	12.8%	19.6 (1.9) %	8.6 (0.8) %	11.0 (1.1) %	−4.2%
Adachi-ku	(3)	53.2 km²	11.1%	17.5 (1.8) %	6.4 (0.6) %	11.1 (1.1) %	−4.7%
Arakawa-ku	(3)	10.2 km²	6.4%	10.6 (1.7) %	4.5 (0.7) %	6.1 (1.0) %	−1.9%
Katsushika-ku	(3)	34.8 km²	11.0%	17.6 (1.4) %	6.0 (0.5) %	11.7 (0.9) %	−5.0%
Meguro-ku	(4)	14.6 km²	16.6%	20.9 (2.9) %	17.1 (2.4) %	3.9 (0.5) %	+0.5%
Shinjuku-ku	(4) and (5)	18.2 km²	14.0%	18.2 (2.7) %	15.1 (2.2) %	3.1 (0.5) %	+1.1%
Shibuya-ku	(4) and (5)	15.1 km²	19.3%	23.6 (2.7) %	20.0 (2.3) %	3.6 (0.4) %	+0.7%
Ota-ku	(4) and (5)	60.9 km²	9.6%	20.5 (1.3) %	12.5 (0.8) %	7.9 (0.5) %	+2.9%
Bunkyo-ku	(5)	11.3 km²	17.1%	20.0 (3.0) %	18.0 (2.7) %	2.0 (0.3) %	+0.9%
Taito-ku	(5)	10.1 km²	8.3%	11.7 (1.8) %	9.9 (1.5) %	1.9 (0.3) %	+1.6%
Sumida-ku	(5)	13.9 km²	6.1%	10.5 (1.6) %	7.1 (1.1) %	3.4 (0.5) %	+1.0%
Chiyoda-ku	(5)	11.5 km²	18.7%	24.5 (3.0) %	21.3 (2.6) %	3.2 (0.4) %	+2.6%
Chuo-ku	(5)	10.4 km²	7.4%	9.7 (1.4) %	7.3 (1.1) %	2.4 (0.4) %	−0.1%
Koto-ku	(5)	46.7 km²	10.2%	22.5 (1.6) %	14.6 (1.0) %	7.9 (0.5) %	+4.4%
Minato-ku	(5)	20.6 km²	18.0%	20.9 (2.6) %	17.9 (2.2) %	3.0 (0.4) %	−0.1%
Shinagawa-ku	(5)	22.9 km²	12.3%	15.1 (1.9) %	12.4 (1.6) %	2.7 (0.3) %	+0.1%
Edogawa-ku	(6)	48.8 km²	10.4%	15.0 (1.9) %	9.1 (1.1) %	5.9 (0.7) %	−1.3%
Total	(1)–(6)	625 km²	13.3%	19.6 (2.2) %	12.1 (1.3) %	7.5 (0.8) %	−1.2%

Figure S1. LAI measurement using LAI-2200, Plant Canopy Analyzer. Measurements were made below the tree canopy at the breast height with the sensor facing upward.

Figure S2. Bi-modal histograms used to obtain the threshold values for image classification (leaf-on season). The histograms are normalized with the total number of each classification category for each satellite imagery.

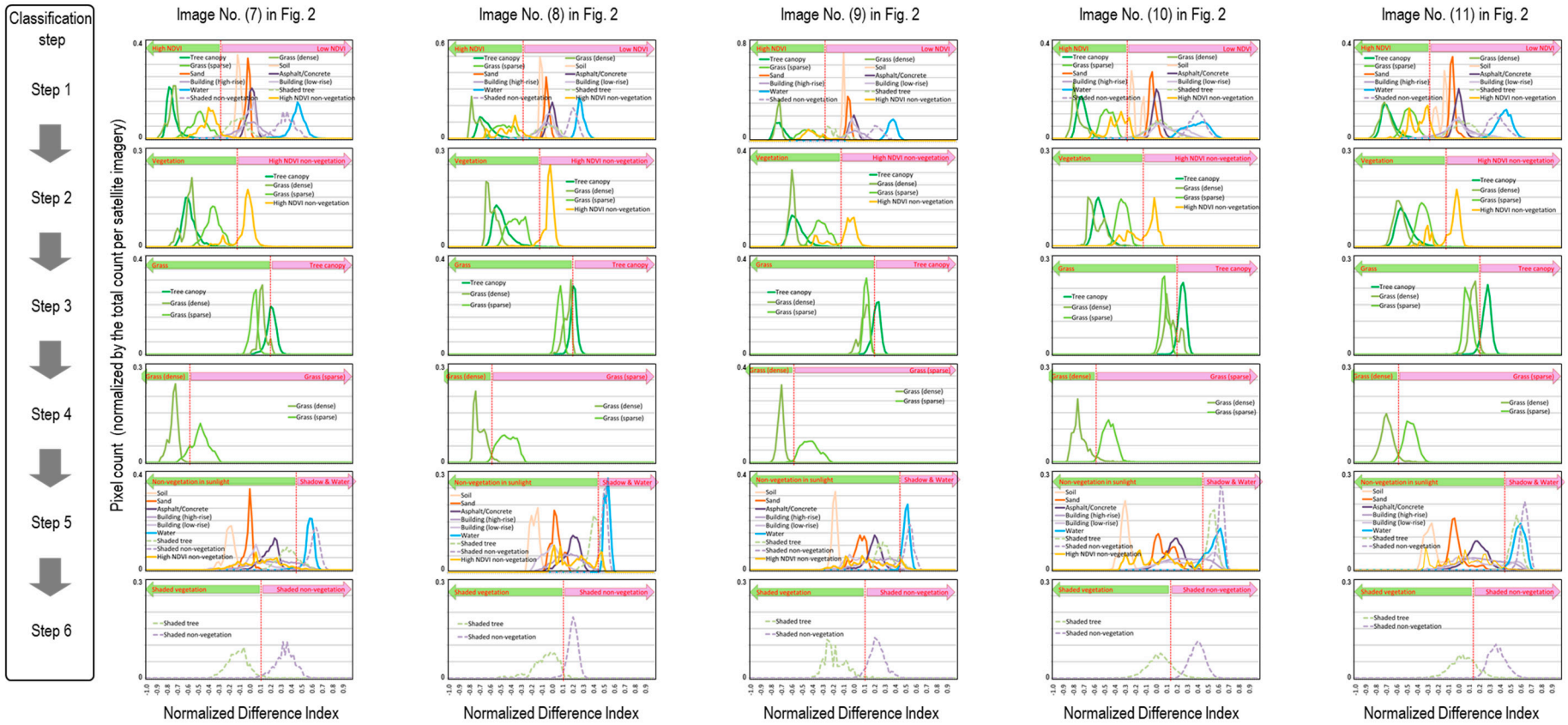

Figure S3. Bi-modal histograms used to obtain the threshold values for image classification (leaf-off season). The histograms are normalized with the total number of each classification category for each satellite imagery.

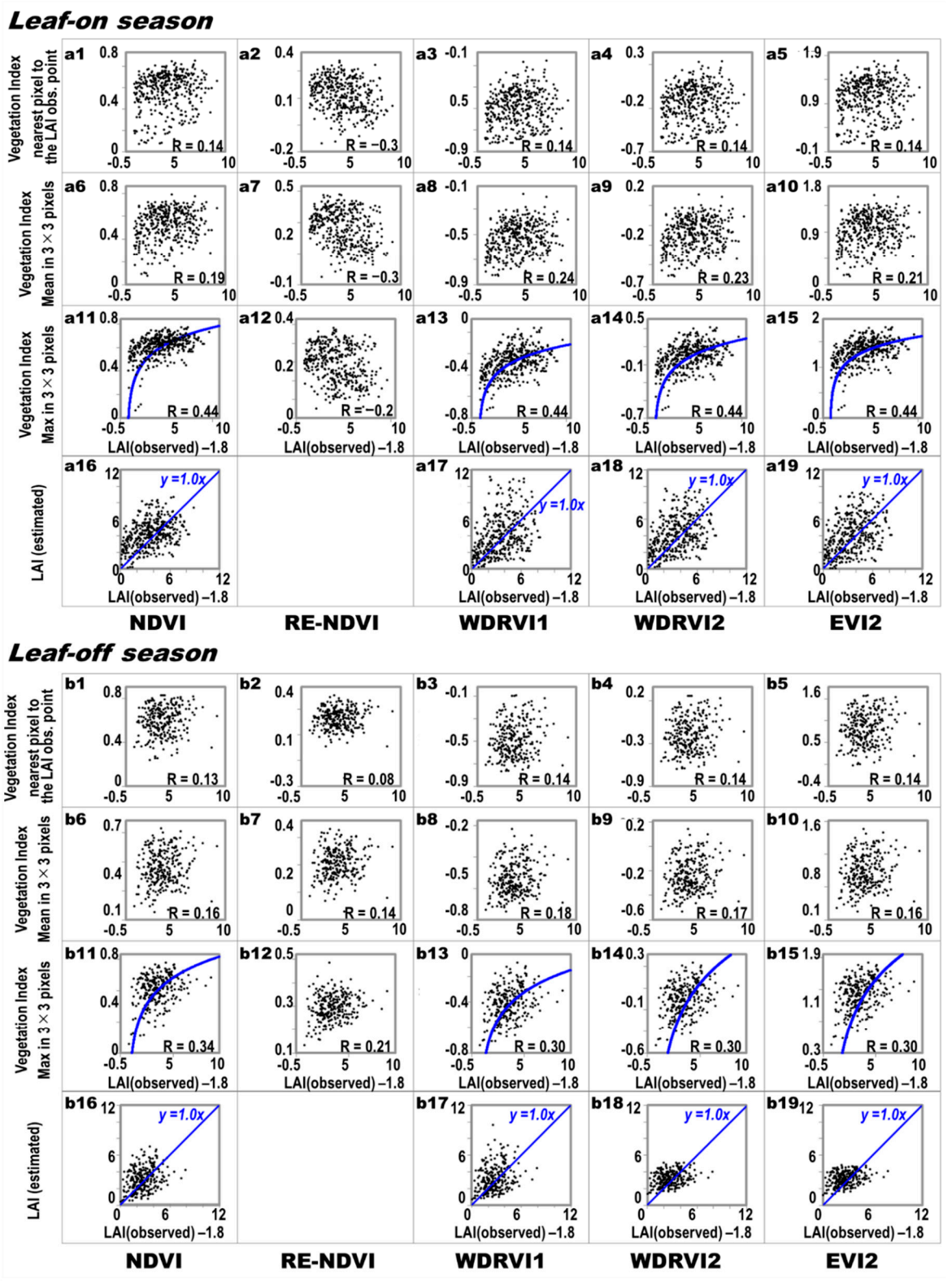

Figure S4. Relationships between the VI and the observed/estimated LAI for the leaf-on season (upper panels: **a**) and the leaf-off season (lower panels: **b**). Columns (**1**–**5**), (**6**–**10**), and (**11**–**15**) are the relationship between the VI obtained with different extraction methods and the observed LAI, respectively. The blue line in columns **11**, **13**, **14**, **15** represents LAI–VI approximate model derived from the maximum VI and observed LAI data. Columns **16**, **17**, **18**, and **19** are performances of the LAI–VI approximate model developed herein. The y = 1.0x line is fitted.

Table S2. The obtained LAI–VI approximate models.

Vegetation Indices	Approximate Models, and RMSEs	
	Leaf-on season	Leaf-off season
NDVI	$LAI = 0.1e^{NDVI/0.179}$ (NDVI range: 0–0.8) RMSE = 2.11	$LAI = 0.1e^{NDVI/0.188}$ (NDVI range: 0–0.8) RMSE = 2.41
WDRVI1	$LAI = 27.5e^{WDRVI1/0.167}$ (WDRVI1 range: < −0.15) RMSE = 2.54	$LAI = 13.7e^{WDRVI1/0.240}$ (WDRVI1 range: < −0.15) RMSE = 2.30
WDRVI2	$LAI = 4.0e^{WDRVI2/0.217}$ (WDRVI2 range: < 0.2) RMSE = 2.35	$LAI = 3.5e^{WDRVI2/0.500}$ (WDRVI2 range: < 0.2) RMSE = 1.93
EVI2	$LAI = 0.05e^{EVI2/0.307}$ (EVI2 range: 0–1.6) RMSE = 2.34	$LAI = 0.71e^{EVI2/0.833}$ (EVI2 range: 0–1.6) RMSE = 1.86