Optical remote sensing of forest carbon budgets in East Siberia and Alaska

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Backgrounds

Larch in Siberia: 7% of the total forest worldwide

Black spruce: 40% of Alaskan forest area

“Important role”: temperature increase, & feedbacks

Geographical distribution of larch forest status

Change ?, Forest fire affects ?

Carbon budget changes:

Year to year, seasonal,

and geographical distribution

Objectives

Geographical distributions:

Optical remote sensing of

for a larch forest in East Siberia

1. LAI & forest floor vegetation cover

   (as indicators of NPP distribution)

2. Fire severity (total burn/wither or surface burn)

for a black spruce forest in interior Alaska

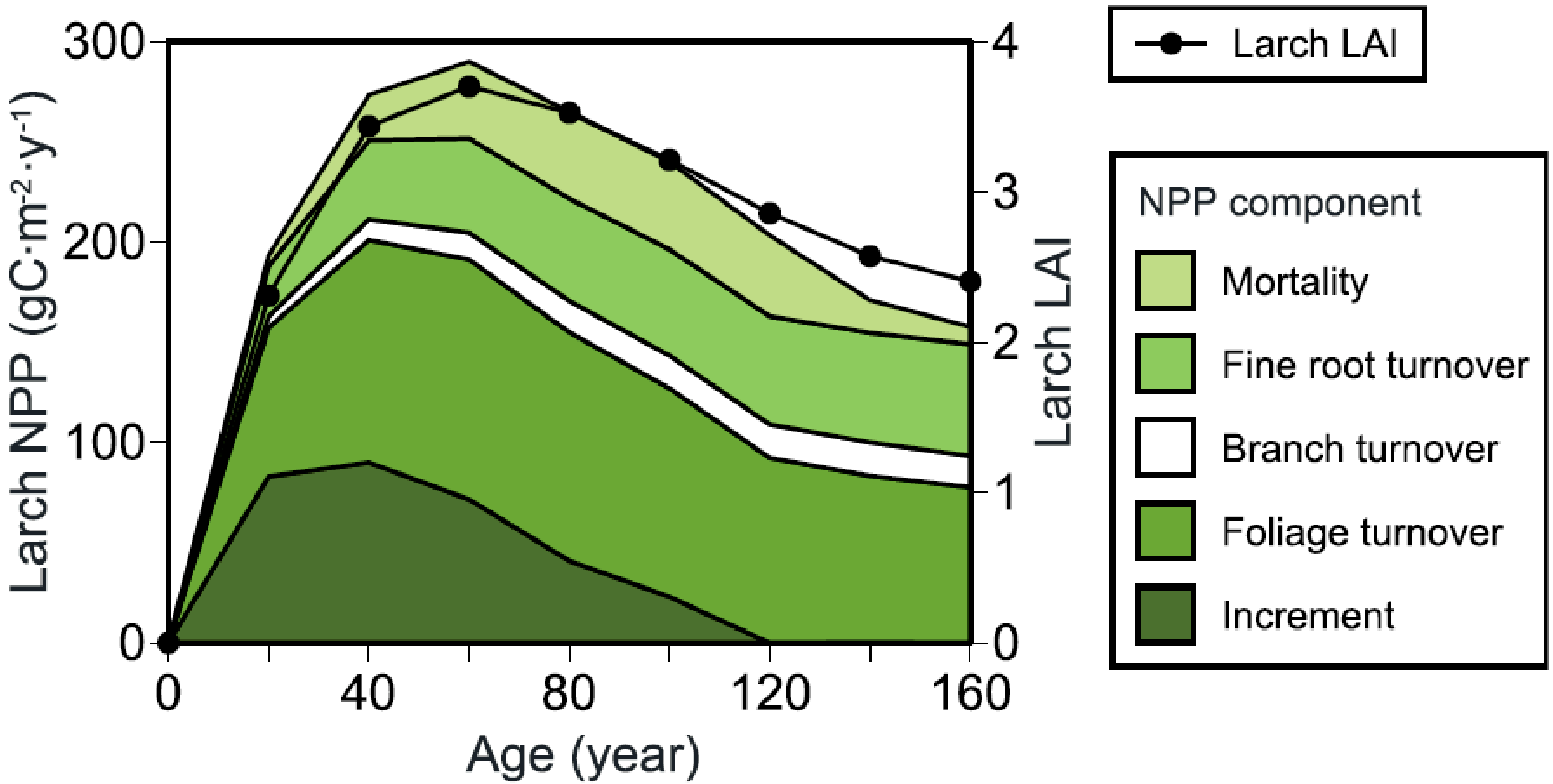
- LAI & forest floor mosses/lichens cover

  (as indicators of NPP distribution)

4. Fire severity

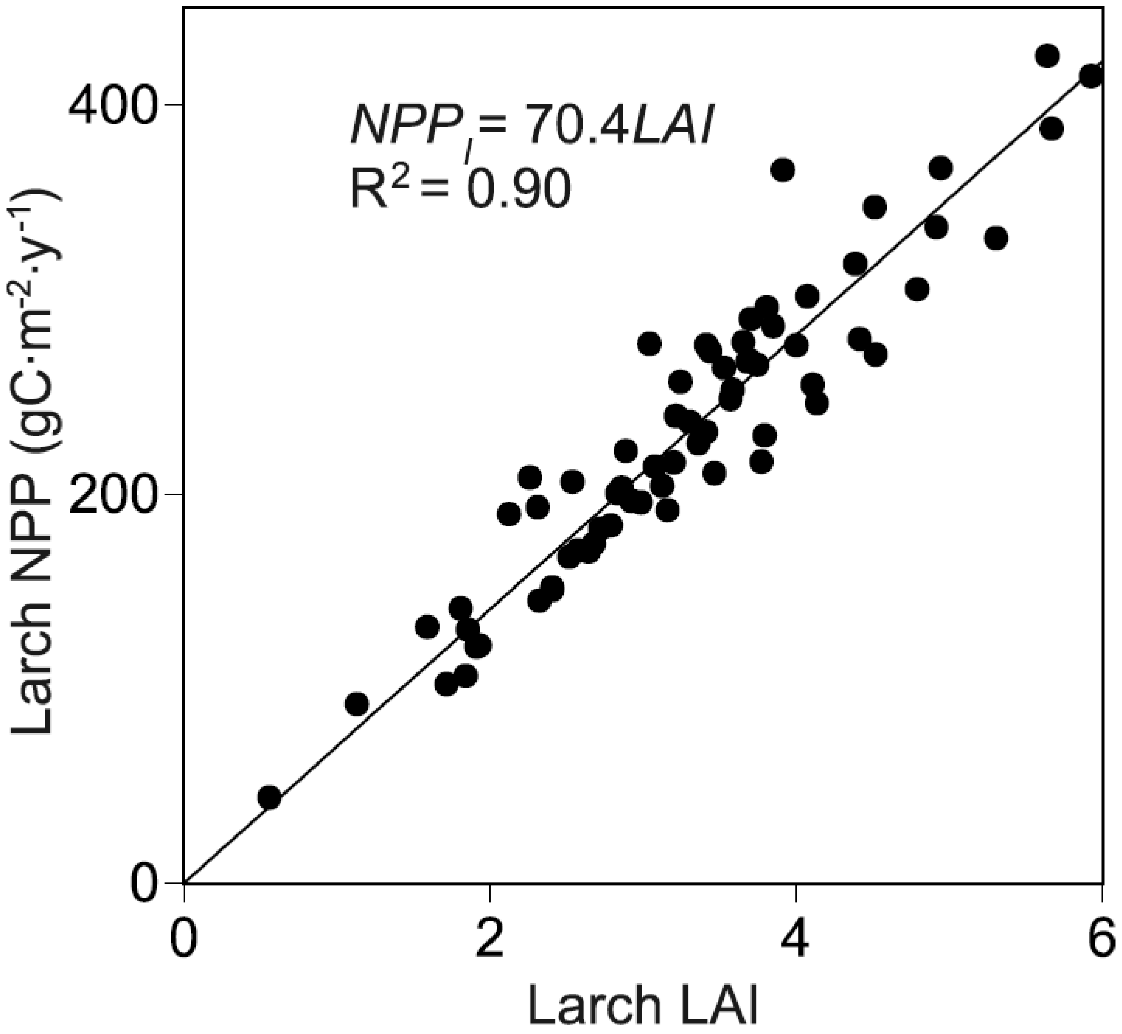
   (burn ratio of forest floor sphagnum mosses)

Foliage (leaf) turnover contributes much to larch NPP.
Foliage turnover correlated with LAI because of deciduous.



Kushida, K., Isaev, A.P., Maximov, T.C., Takao, G., & Fukuda, M. (2007) Remote sensing of upper canopy leaf area index and forest floor vegetation cover as indicators of net primary productivity in a Siberian larch forest. Journal of Geophysical Research - Biogeosciences, 112, G02003, doi:10.1029/2006JG000269.

Thus, larch LAI correlated with larch NPP.



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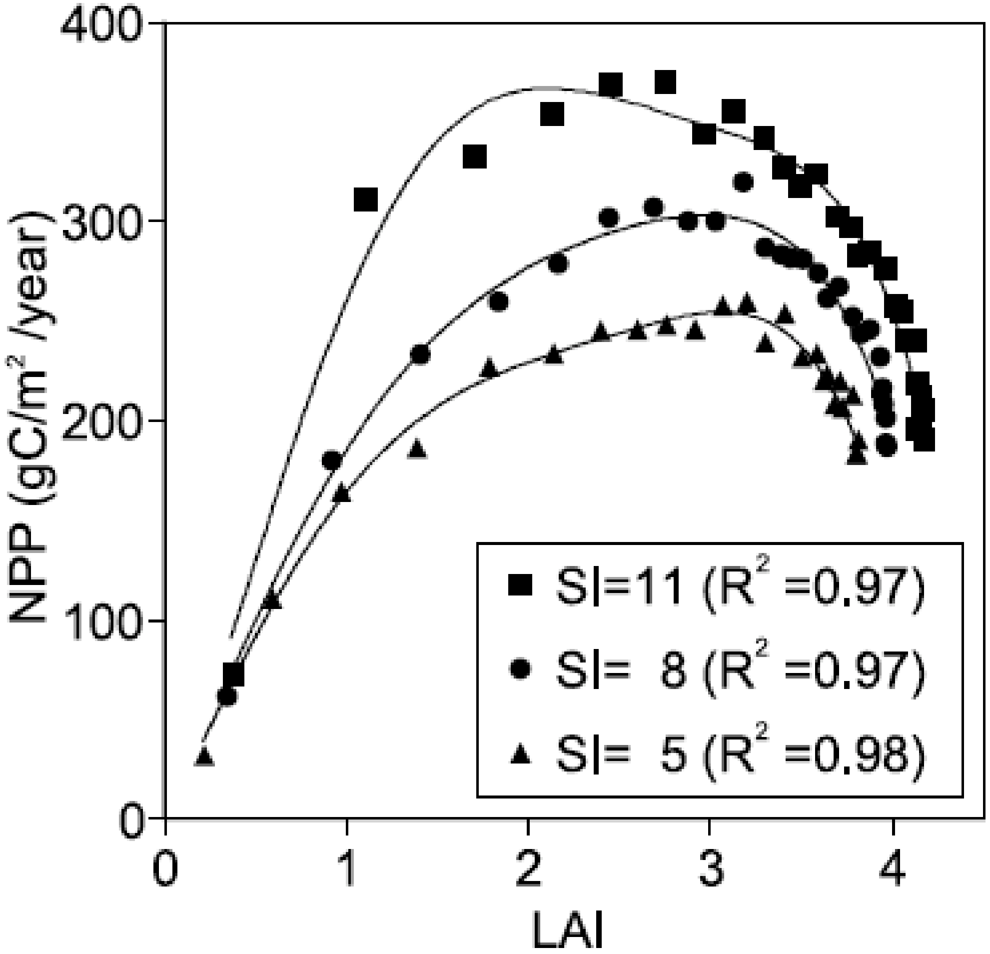
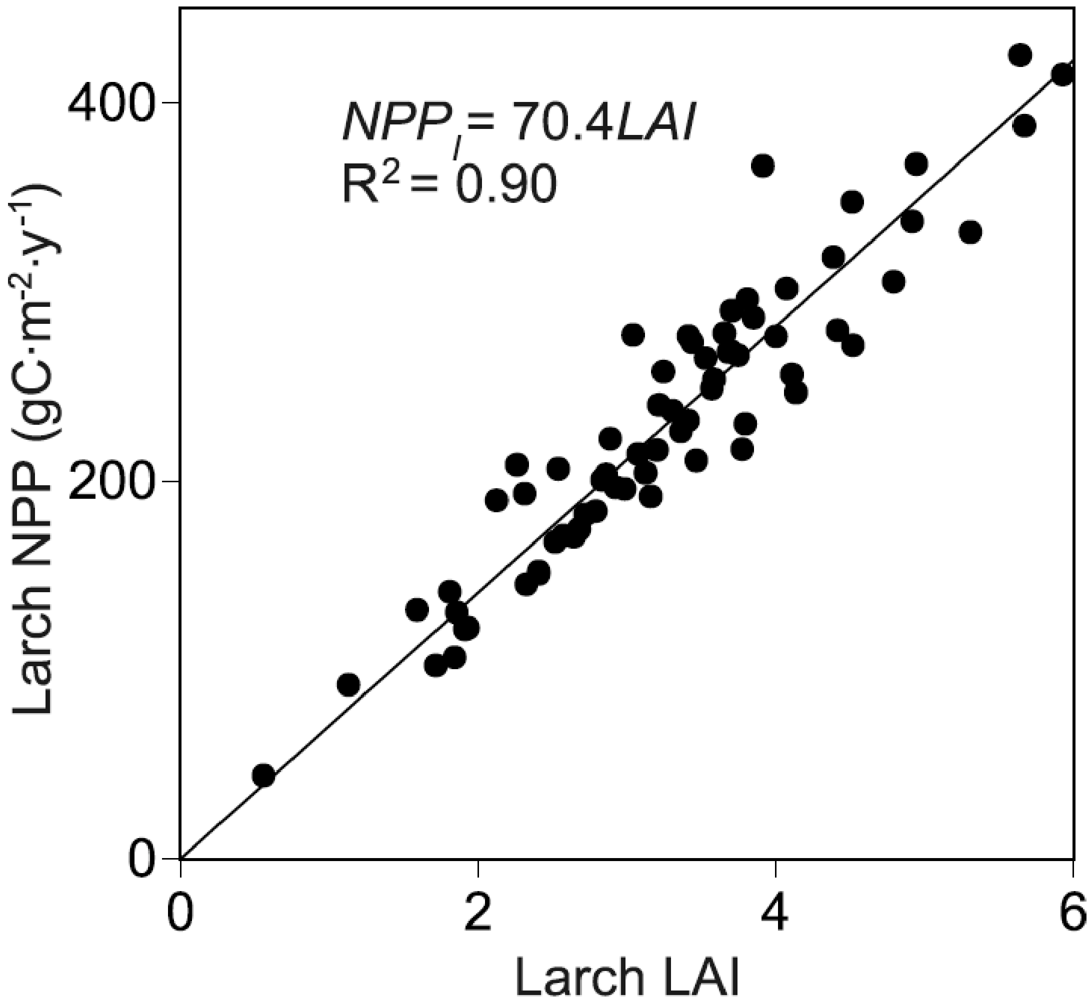
For evergreen forest, not correlated…..

Relationship between spruce LAI and upper canopy NPP



Kushida, K., Y. Kim, N. Tanaka, and M. Fukuda (2004), Remote sensing of net ecosystem productivity based on component spectrum and soil respiration observation in a boreal forest, interior Alaska, J. Geophys. Res. - Atmospheres, 109, D06108, doi:10.1029/2003JD003858.

Larch LAI - NPP is simple.



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$$NPP = NPP_l + NPP_u \quad (1)$$

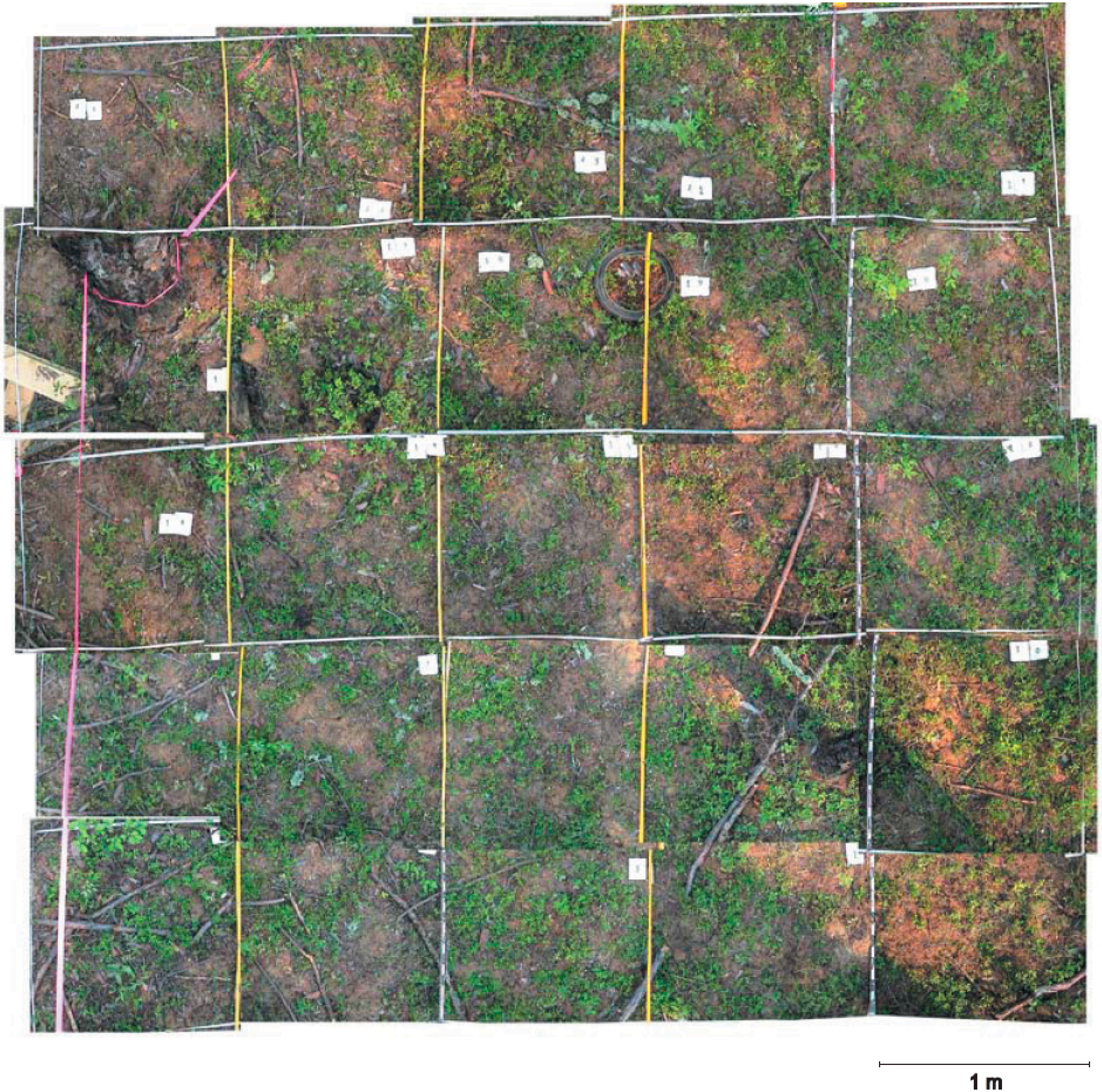
$$NEP = NPP_l + NPP_u - SHR, \quad (2)$$

where,

NPP [gC.m^{-2}.y^{-1}]: net primary productivity

NEP [gC.m^{-2}.y^{-1}]: net ecosystem productivity

NPP_l [gC.m^{-2}.y^{-1}]: NPP of the upper canopy (larch)
NPP_u [gC.m^{-2}.y^{-1}]: NPP of understory
SHR [gC.m^{-2}.y^{-1}] : Soil heterotrophic respiration .



30m×30m

Photo mosaicing for forest floor vegetation mapping

$$NPP = 70.4 LAI_l + 1.10 FVC + D \ [\mathrm{gC.m^{-2}.y^{-1}}],$$

where,

LAI_l [$m^2.m^{-2}$]: upper canopy (larch trees) LAI ,

FVC [%]: forest floor vegetation cover ratio

D [$gC.m^{-2}.y^{-1}$]: unknown factors .

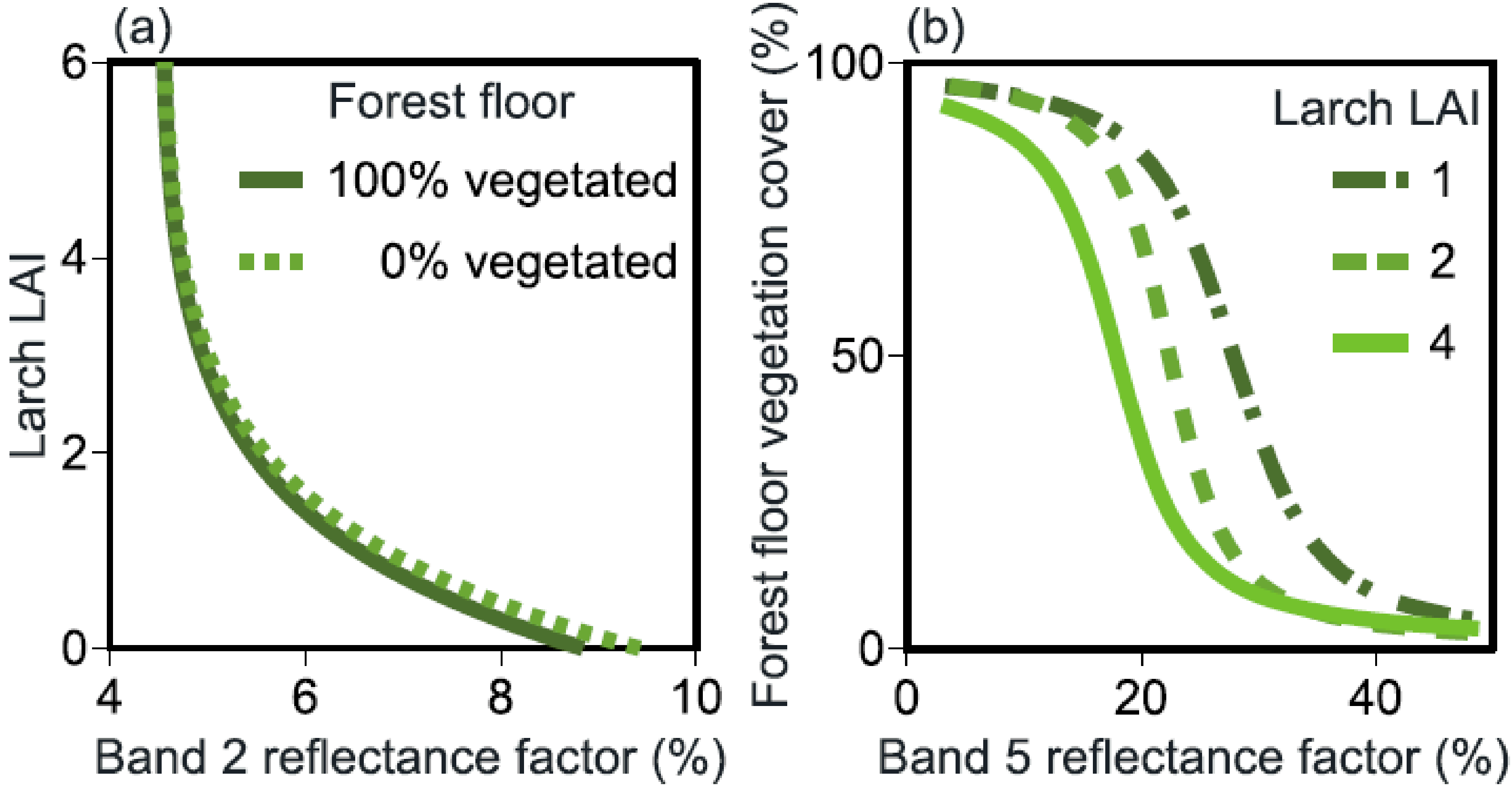
Spectral measurement

GER-2600 spectrometer
350 - 2500 nm

Table 2. Spectral characteristics of forest floor components and leaves of the larch forest in Landsat ETM+ bands (average ± standard deviation, unit: %). The number of samples is 10 for forest floor reflectance and 14 for leaf reflectance and transmittance.

Band	Wavelength	*V. vitis-idaea*	Fallen leaves	Leaf reflectance	Leaf transmittance
1	0.45–0.52 μm	3.2 ± 0.5	4.9 ± 0.6	6.1 ± 0.8	2.1 ± 0.9
2	0.53–0.61 μm	8.8 ± 1.1	9.4 ± 1.1	13.2 ± 1.8	7.7 ± 0.9
3	0.63–0.69 μm	4.9 ± 0.9	11.2 ± 1.7	6.3 ± 1.1	1.2 ± 0.1
4	0.75–0.90 μm	41.3 ± 3.8	24.1 ± 3.2	48.8 ± 5.1	38.8 ± 3.7
5	1.55–1.75 μm	27.3 ± 4.7	41.6 ± 6.9	32.4 ± 3.0	24.6 ± 3.4
7	2.09–2.35 μm	25.0 ± 10.9	47.5 ± 9.8	58.6 ± 10.2	22.8 ± 14.7

From field spectral measurements….
Leaf absorbs 80 % of incident beam in green band (band 2).
LAI ↑ →Band 2 ↓
Fallen leaves were brighter than vegetation around 1.5 μm (band 5).
FVC ↑ →Band 5 ↓



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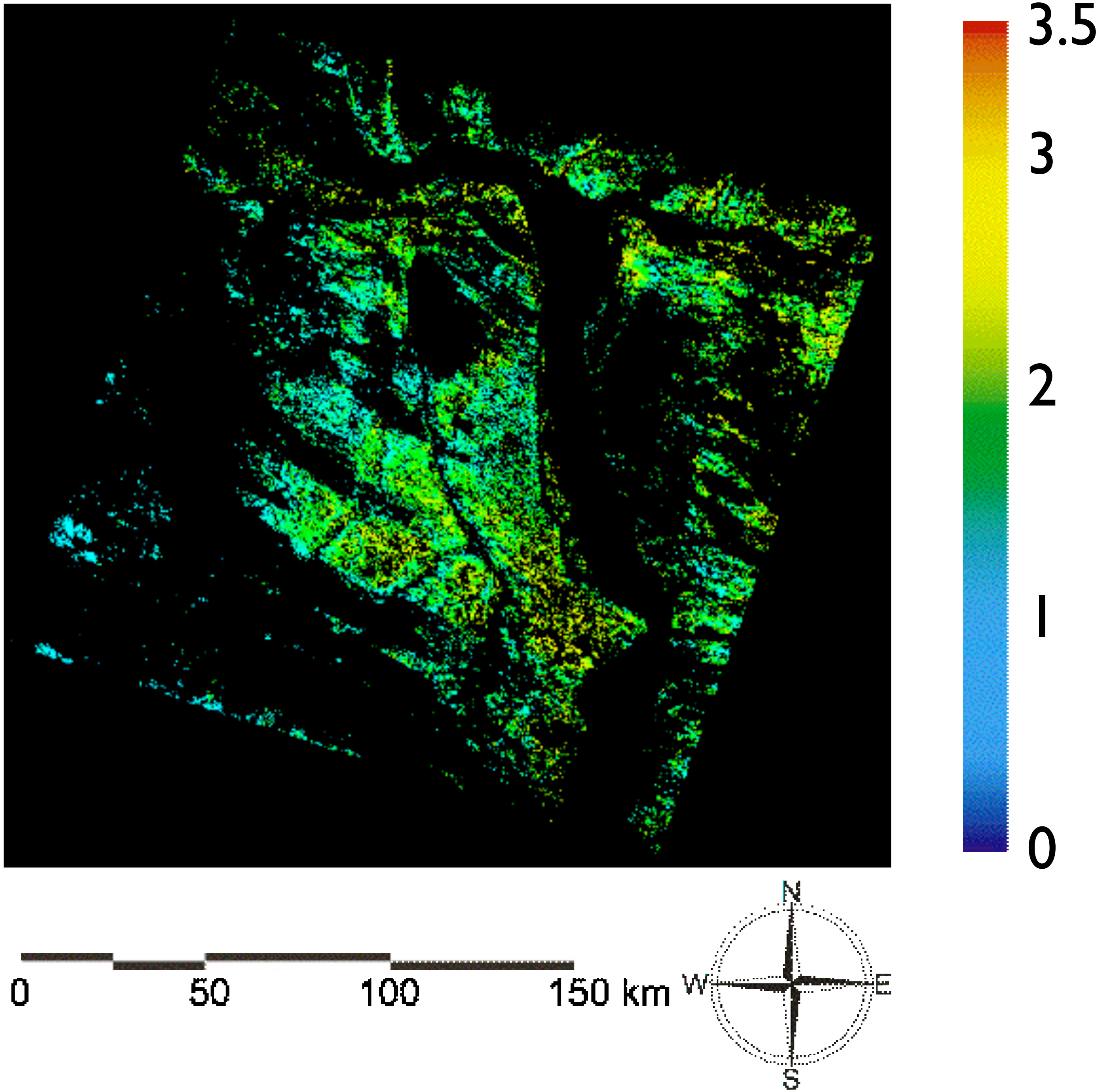
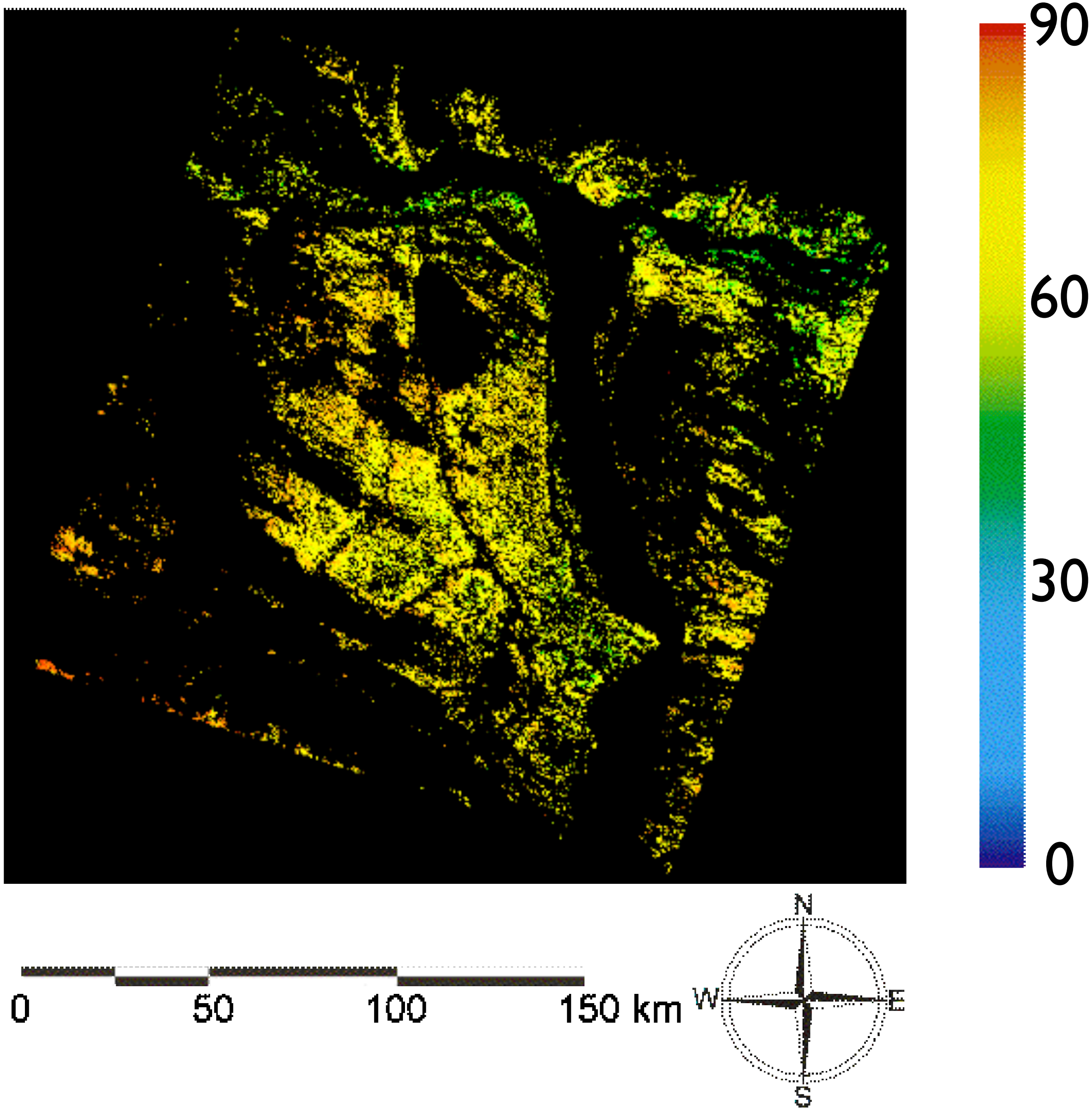
LAI



FVC
[%]



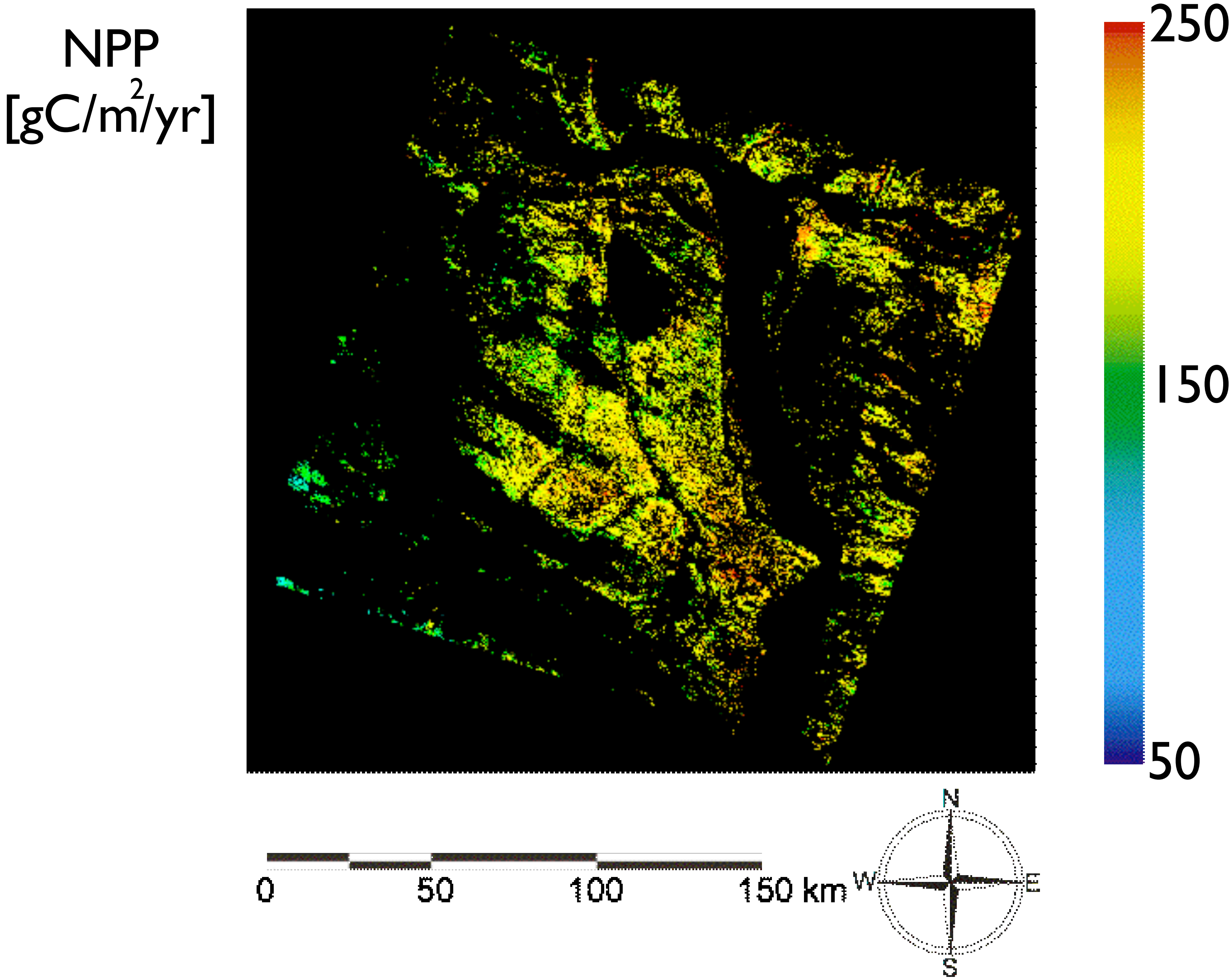

NPP
[gC/m^2/yr]
250
150
50
0
50
100
150 km
N
W
E
S

Table 4. Evaluation of the estimation using field observations.

	Estimated[a]			Observed	References
(a) Neleger site					
LAI	2.2	±	0.3	2.4	*Shibuya et al.* [2004], *Kanazawa and Osawa* [1994]
FVC, %	61	±	9	52[b]	this study
NPP, $gC \cdot m^{-2} \cdot y^{-1}$	222	±	24	130–180[c]	*Machimura et al.* [2005], *Sawamoto et al.* [2001], *Sawamoto et al.* [2003]
(b) 185 km × 185 km area					
LAI	1.7	±	0.4	—	—
FVC, %	69	±	8	—	—
NPP, $gC \cdot m^{-2} \cdot y^{-1}$	194	±	22	—	—

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   (burn ratio of forest floor sphagnum mosses)

In Russian boreal forest
Surface fire:
50-80%
of the total burnt area
(Conard et al., 2002)

Total burn/wither

Total burn/wither

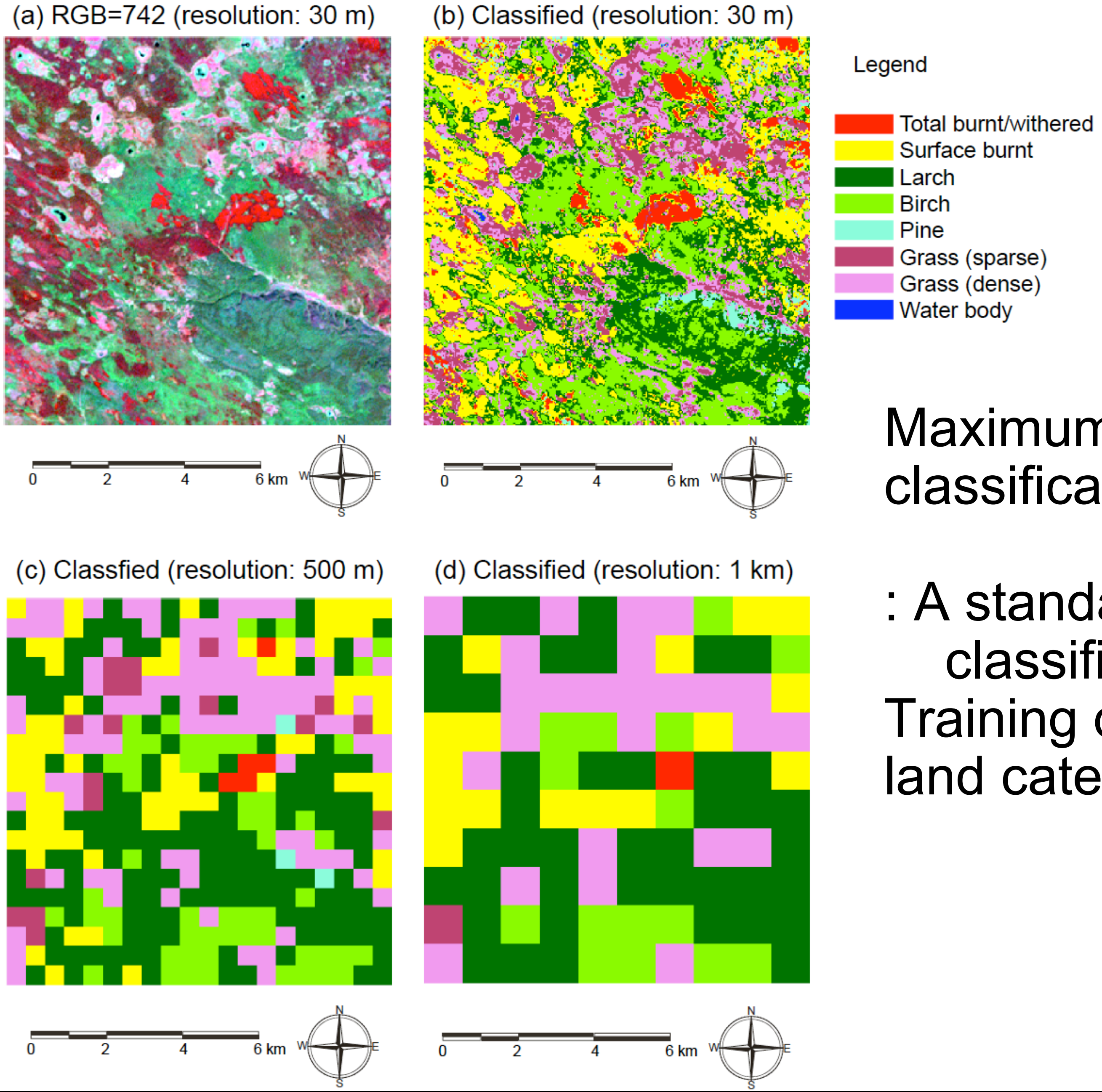
Surface burn

A larch forest near Yakutsk

Table 1. Landsat ETM+ and MODIS wavelength

Landsat ETM+		MODIS	
Band	Wavelength (nm)	Band	Wavelength (nm)
1	450 ～520	3	459 ～479
2	530 ～610	4	545 ～565
3	630 ～690	1	620 ～670
4	750 ～900	2	841 ～876
5	1550 ～1750	6	1628 ～1652
7	2090 ～2350	7	2105 ～2155

Resolution:	30m	500m
Interval:	16 days	1 day
Coverage:	about 200km	continental

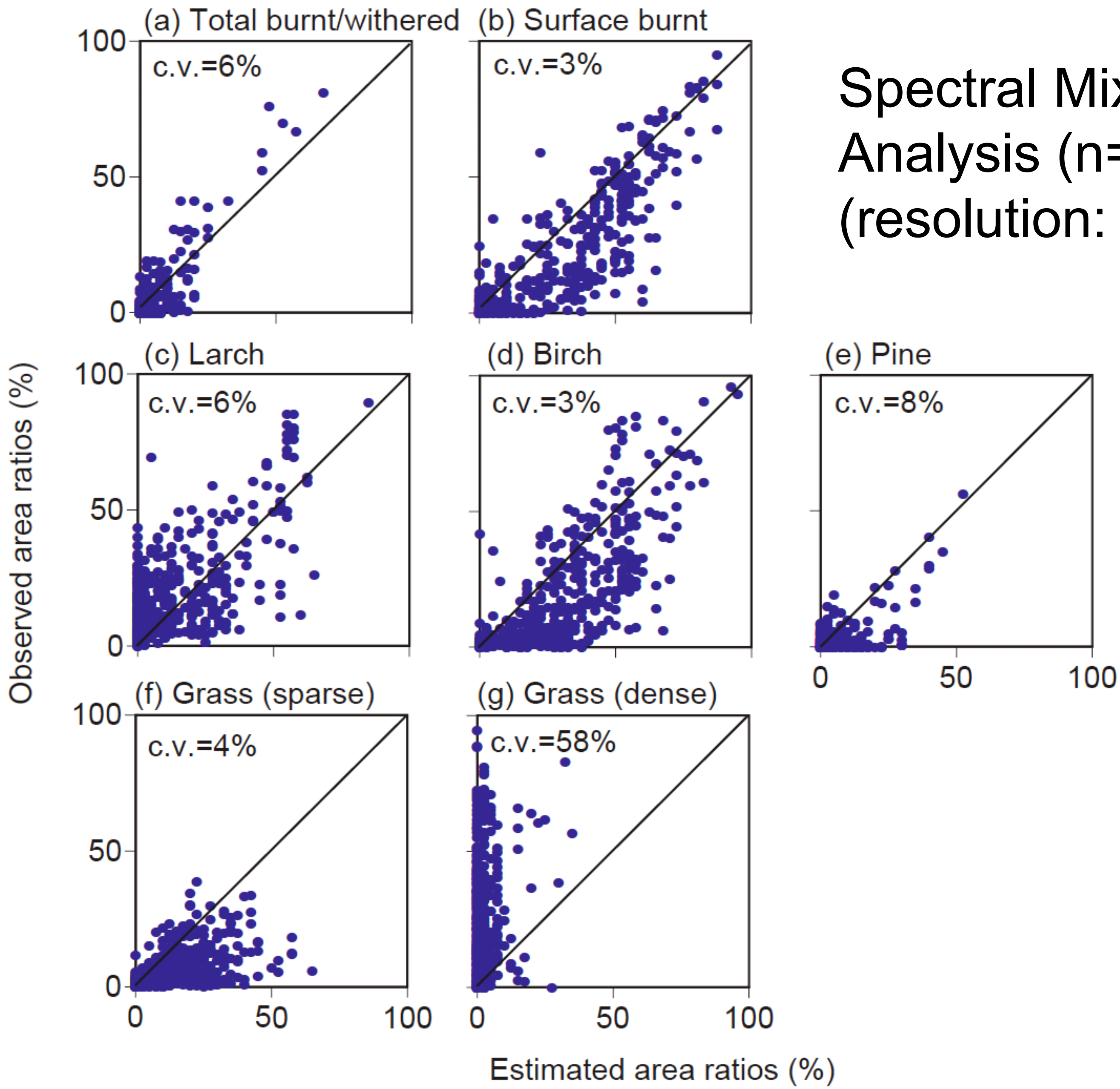


Maximum likelihood classification

: A standard satellite image classification method

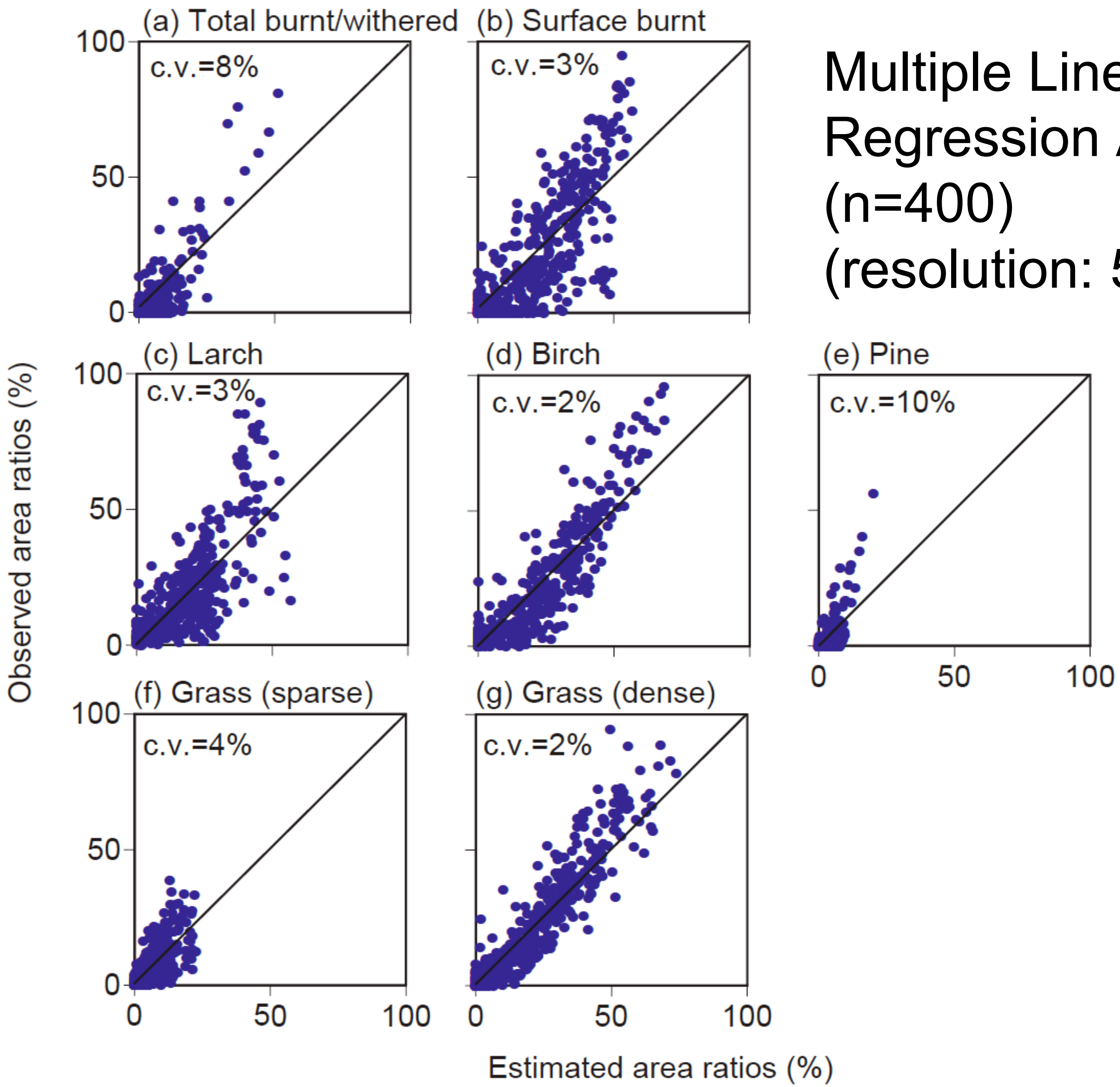
Training data for each land category is necessary.

Kushida, K., Isaev, A.P., Takao, G., Maximov, T.C., & Fukuda, M. (2007) Remote sensing of total and surface burn ratios in 30 m – 1 km resolutions after a wildfire in East Siberia. Eurasian Journal of Forest Research, 10(1), 105-114.



Spectral Mixture Analysis (n=400) (resolution: 500 m)

Kushida, K., Isaev, A.P., Takao, G., Maximov, T.C., & Fukuda, M. (2007) Remote sensing of total and surface burn ratios in 30 m – 1 km resolutions after a wildfire in East Siberia. Eurasian Journal of Forest Research, 10(1), 105-114.



Multiple Linear Regression Analysis (n=400) (resolution: 500 m)

Kushida, K., Isaev, A.P., Takao, G., Maximov, T.C., & Fukuda, M. (2007) Remote sensing of total and surface burn ratios in 30 m – 1 km resolutions after a wildfire in East Siberia. Eurasian Journal of Forest Research, 10(1), 105-114.

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  (as indicators of NPP distribution)

4. Fire severity
   (burn ratio of forest floor sphagnum mosses)

Area ratios of burnt mosses are related with:

1. Vegetation regeneration

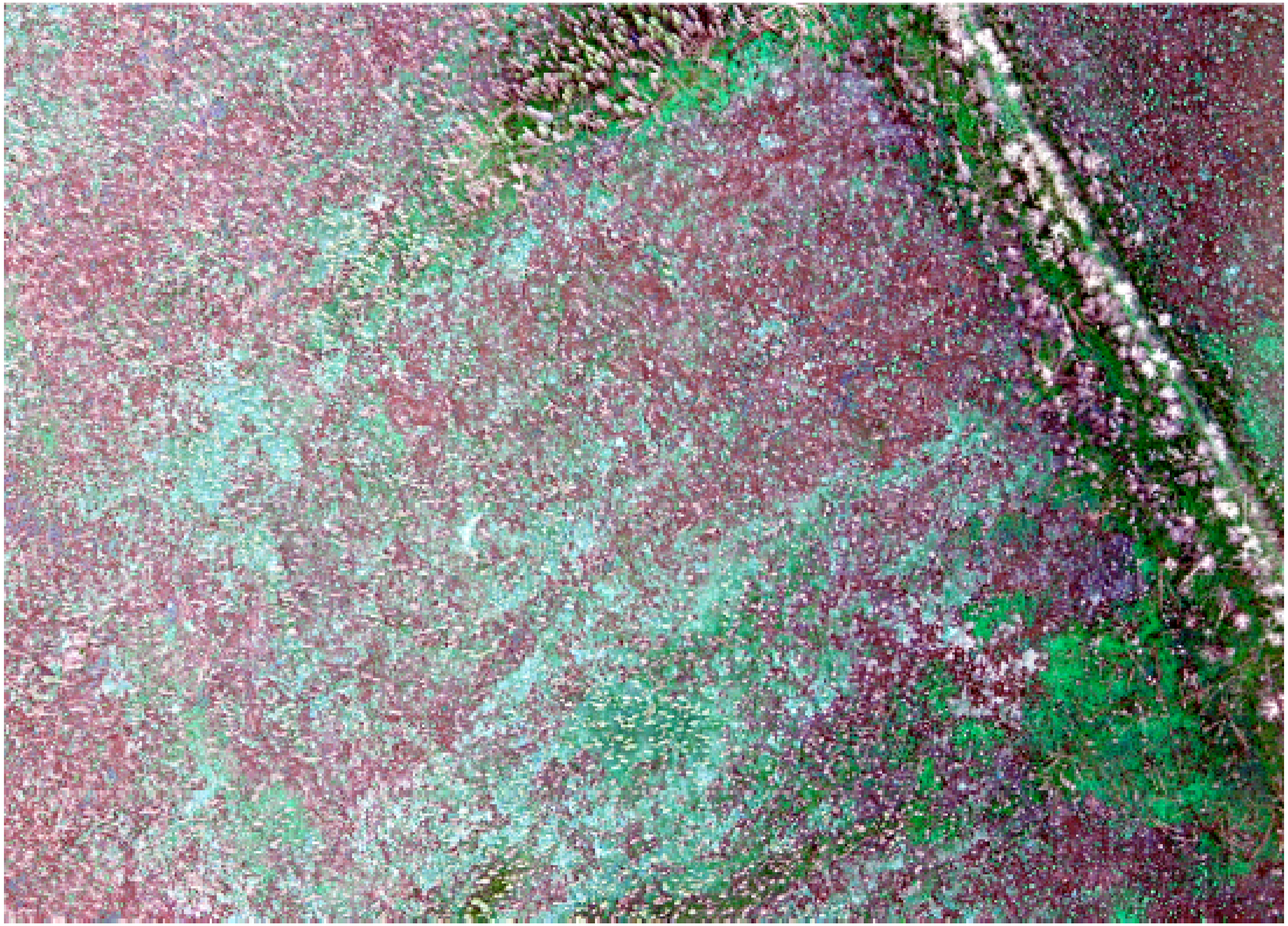
Mosses: black spruce

Burnt mosses: other plant species

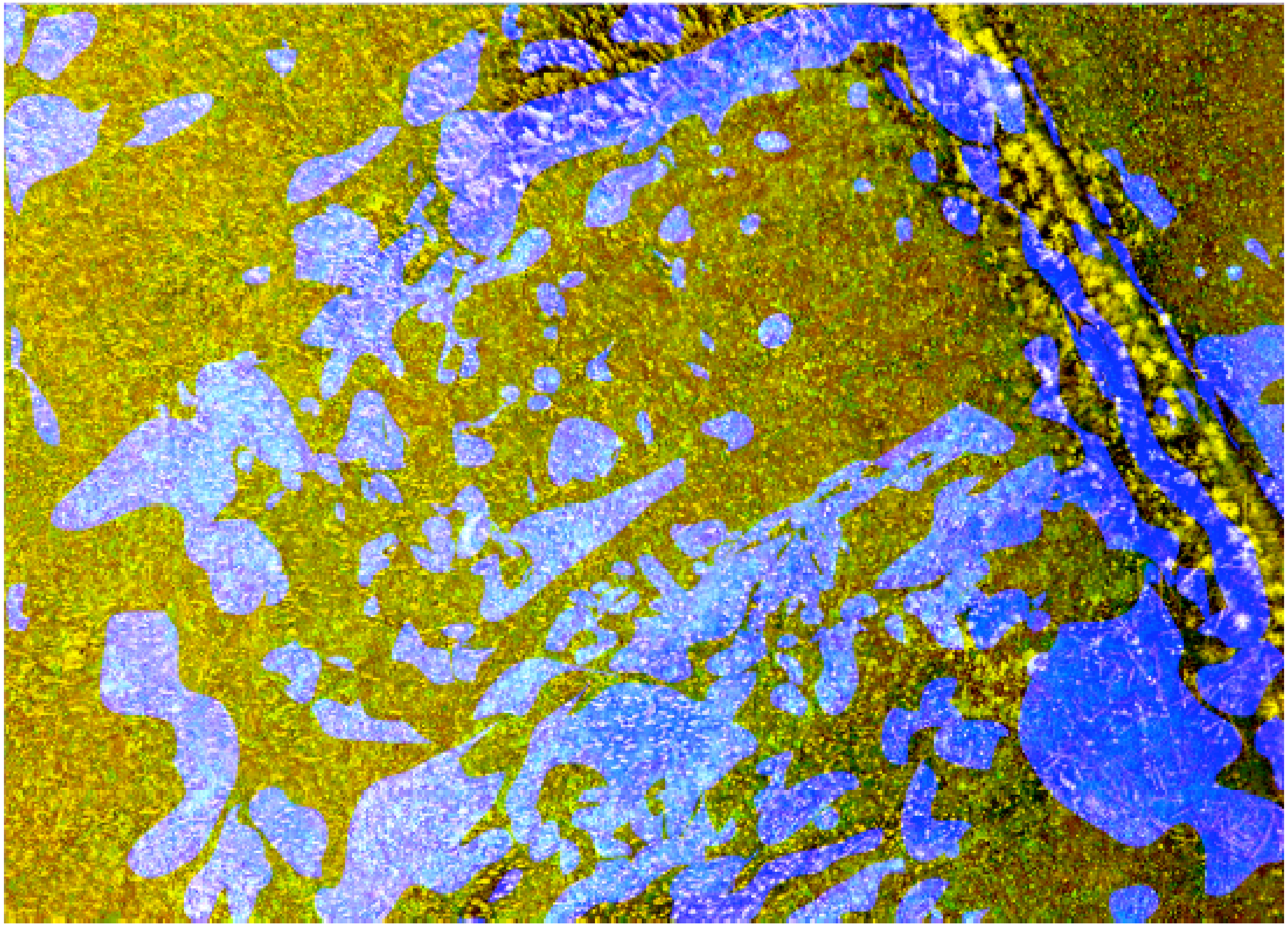
2. Carbon emission during the fire

Amount of organic layer burns

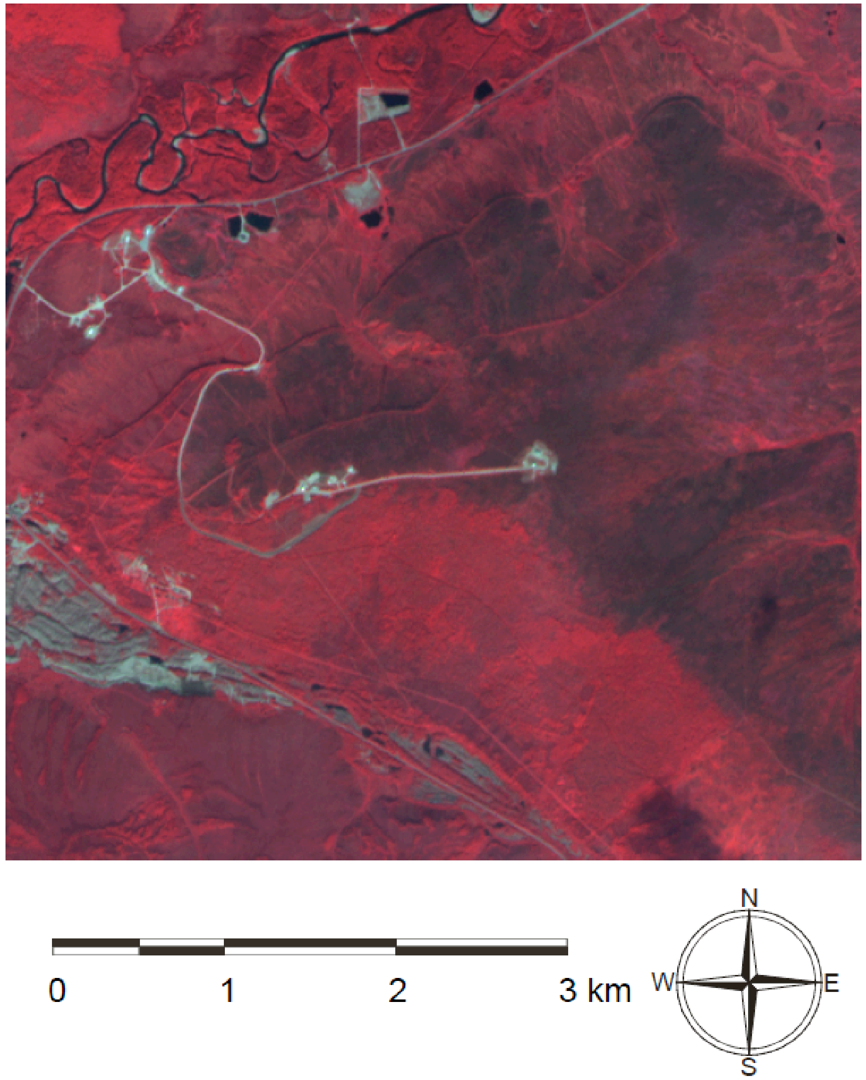
An aerial photo taken from “Asuka” of Asahi-simbun



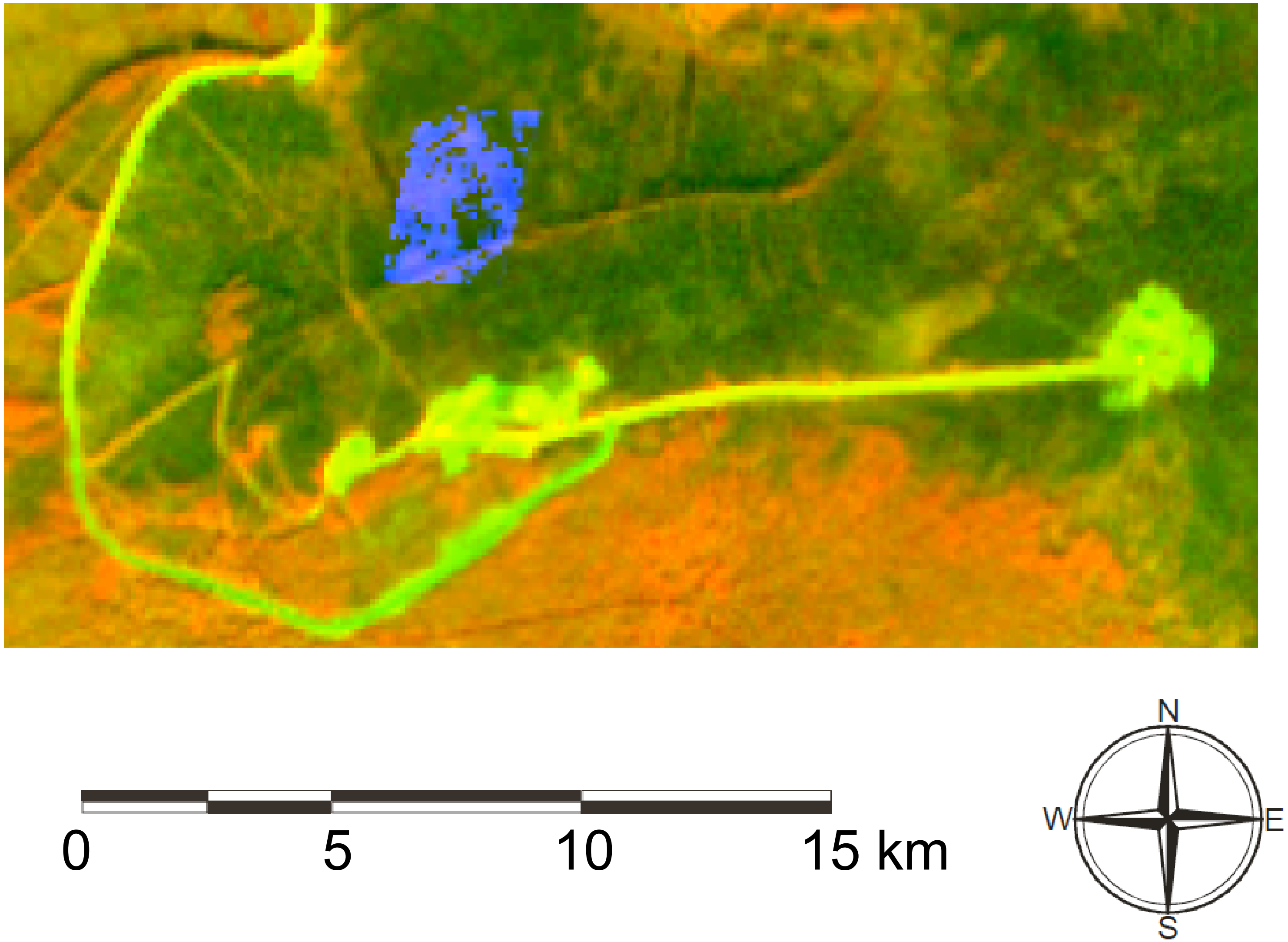
Extraction of forest floor burn (yellow area)



Poker Flat site in interior Alaska
ALOS image
(2006.7.24, RGB=432)



ALOS/AVNIR-2 and the aerial photo（blue area）



Black spruce in interior Alaska
Two years after fire

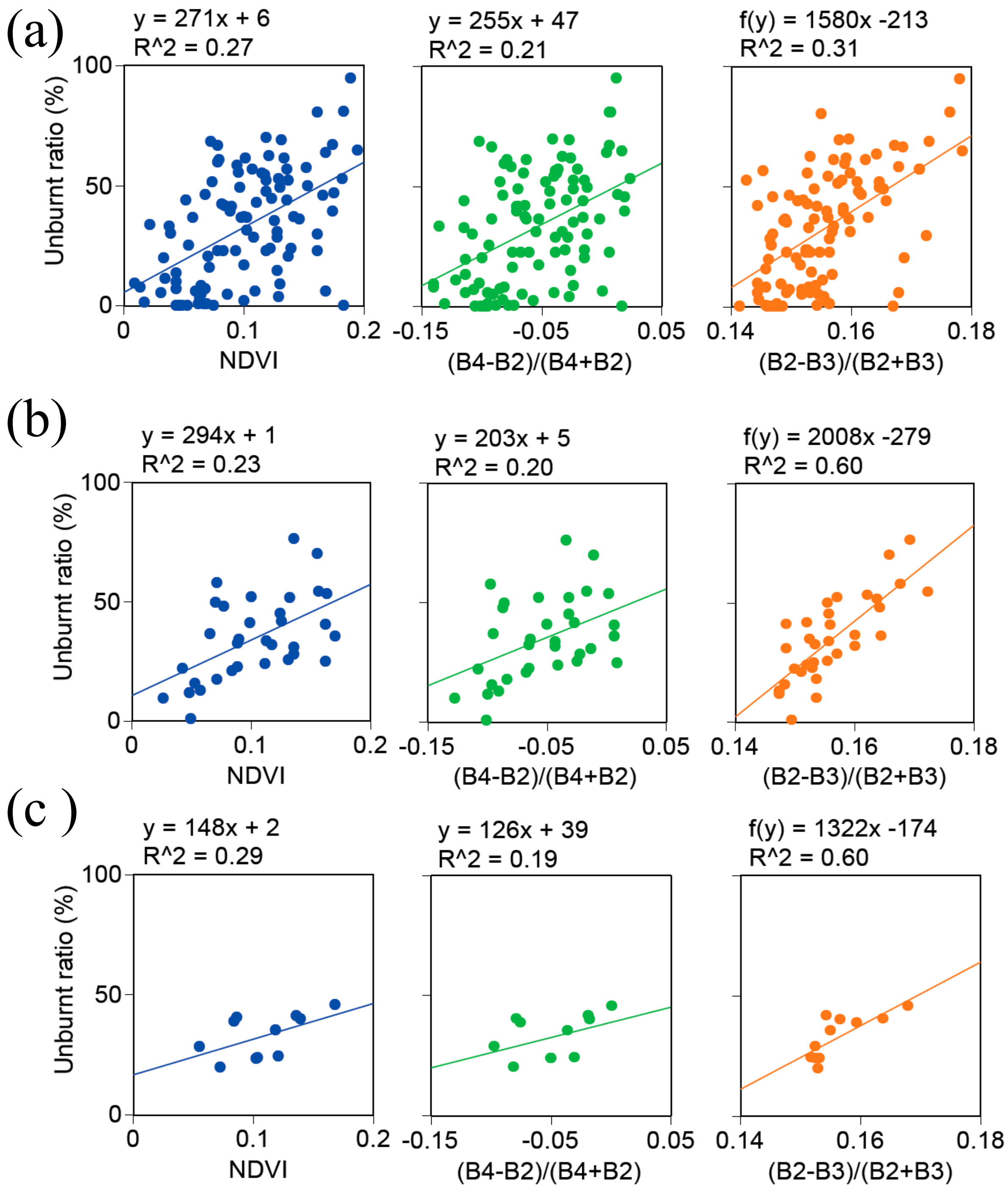
ALOS/AVNIR-2 v.s.
unburnt ratios of forest floor (%)

Unit scales were
(a): 30 m × 30m,
(b): 50 m × 50m, and
(c): 90 m × 90 m.

B2, B3, and B4 denote
green, red, and near infrared
bands of AVNIR-2, respectively.

NDVI = (B4-B3)/(B4+B3).

(B2-B3)/(B2+B3) was effective
in the scales of more than
50 m × 50m.



Kushida et al. unpublished

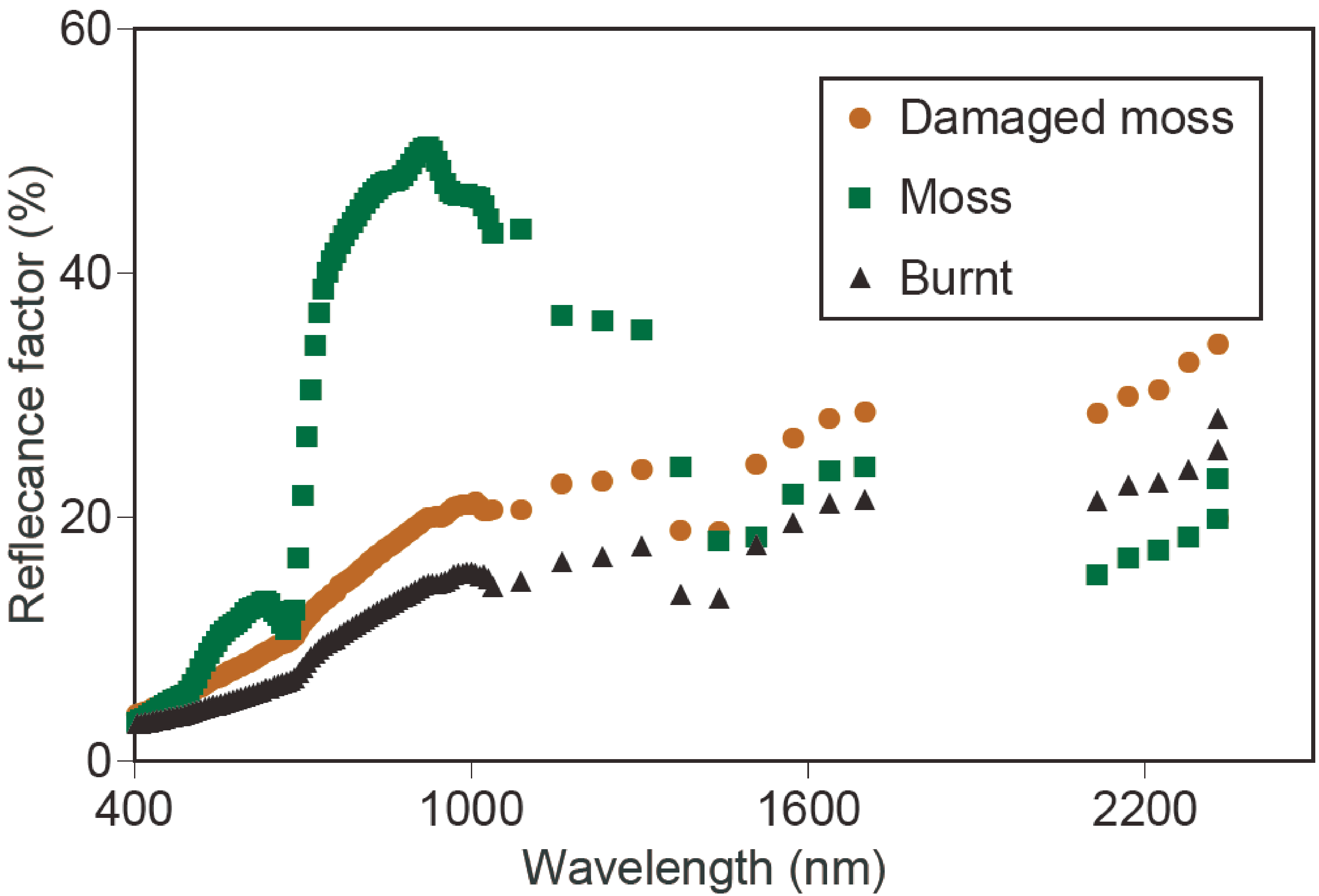


Figure. Spectral reflectance of three forest floor types one year after the burn.

Kushida et al. unpublished

Table. Field-observed spectral characteristics one year after fire of black spruce forest in Landsat ETM+ bands (Average±S.D., Unit: %, Numbers of samples are; Moss: 42, Dead moss 33, Burnt: 38) ALOS AVNIR-2 bands 1,2,3, and 4 corresponds to Landsat ETM+ bands 1,2,3, and 4, respectively.

Band	Wavelength	Moss	Dead moss	Burnt
Band1	0.45 ～0.52μm	5.2 ± 2.1	5.8 ± 1.8	4.0 ± 1.5
Band2	0.53 ～0.61μm	9.8 ± 4.4	8.1 ± 3.6	5.5 ± 2.2
Band3	0.63 ～0.69μm	14.7 ± 10.0	18.8 ± 7.1	9.0 ± 4.0
Band4	0.75 ～0.90μm	42.3 ± 14.6	16.8 ± 8.2	12.3 ± 6.7
Band5	1.55 ～1.75μm	23.0 ± 9.9	28.8 ± 11.1	21.2 ± 10.8
Band7	2.09 ～2.35μm	19.2 ± 9.6	31.7 ± 10.0	25.5 ± 7.1
Band7/Band4	-	0.453 ± 0.05	2.13 ± 0.6	2.42 ± 0.83

Kushida et al. unpublished

Conclusion

We estimated geographical distribution of

1. LAI & forest floor vegetation cover
(as indicators of NPP distribution)
2. Fire severity (total burn/wither or surface burn)
for a larch forest in East Siberia
3. LAI & forest floor mosses/lichens cover
(as indicators of NPP distribution)
4. Fire severity
(burn ratio of forest floor sphagnum mosses)
for a black spruce forest in interior Alaska
using optical sensors.

ALOS/PALSAR ?

Free from cloud contamination
Correction (Incident angle etc.) and interpretation

Optical sensor - SAR fusion

Field campaign in Alaskan tundra
(Arctic National Wildlife Refuge)
July-August 2007

Fukuda (PI: Hokkaido U.), Watanabe (Tohoku U.), Kadosaki (JAXA), Kim (UAF), Ishikawa, Sawada, and Kushida (Hokkaido U.)