

体系的な土地被覆変化の抽出と分断化指標による解析
— 知床開拓跡地における事例 —

Analyzing about sixty years of land-cover change and
associated landscape fragmentation
in Shiretoko Peninsula, Northern Japan

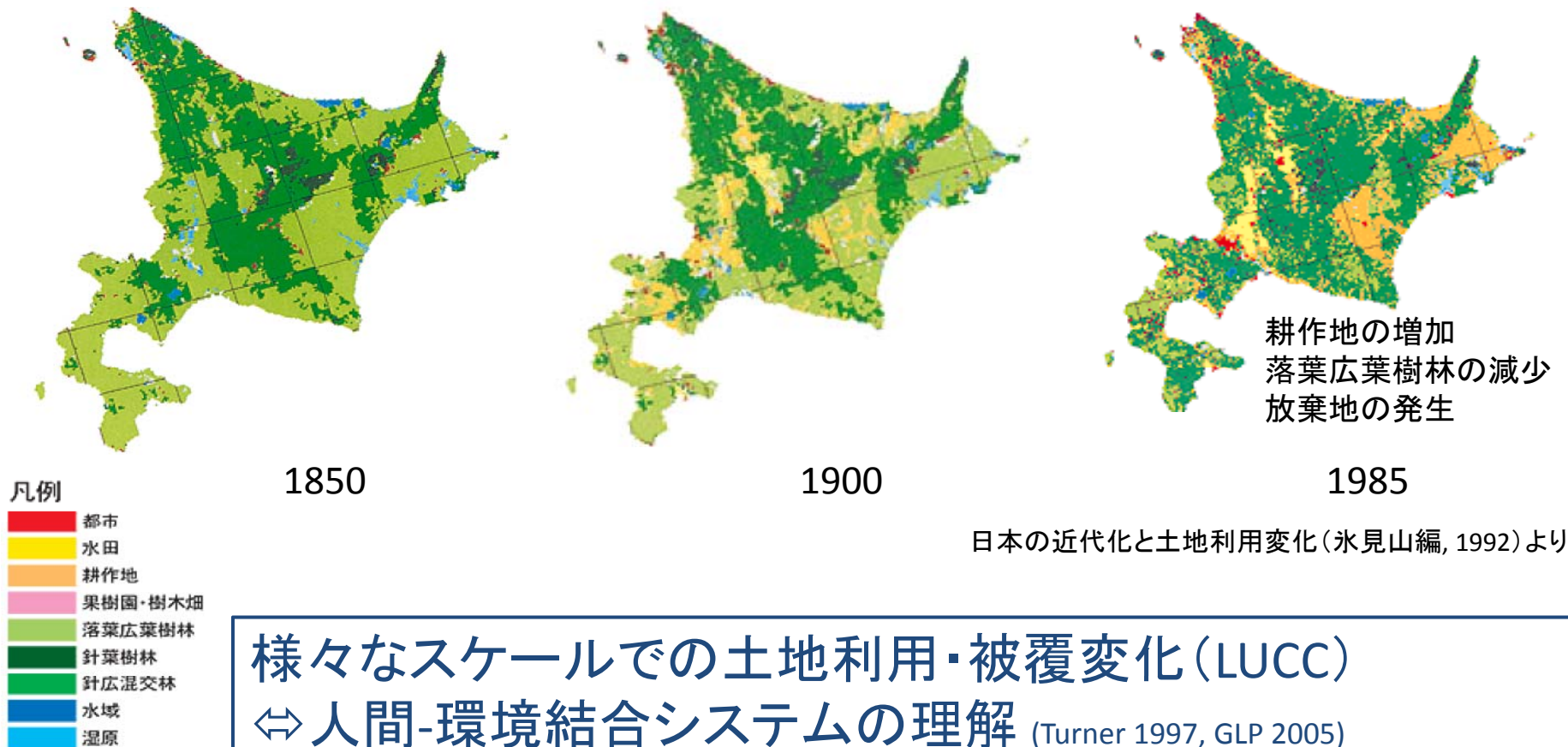
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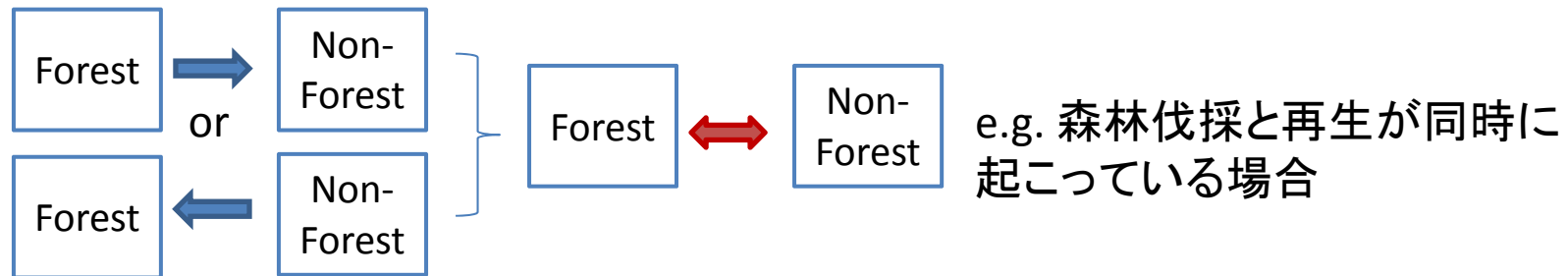
はじめに —土地利用の構造的変化—

- 1900年- 全国的な土地利用の構造的変化
平野部の都市・農地増加・森林減少 ⇔ 荒廃山地の森林化 (鈴木 2004)
- 本州の都市化 ⇔ 北海道地域の農地化・森林減少 (氷見山 1992)



研究の目的

- クロス集計表に基づいた土地被覆変化の解析手法が提案 (Pontius et al. 2004)、応用され体系的な土地変化プロセスが明らかになってきた (Braimoh 2006; Alo and Pontius 2008; Manandhar et al. 2008; Versace et al. 2008)
- 純変化 (Net change) と置換 (Swap) の定量化



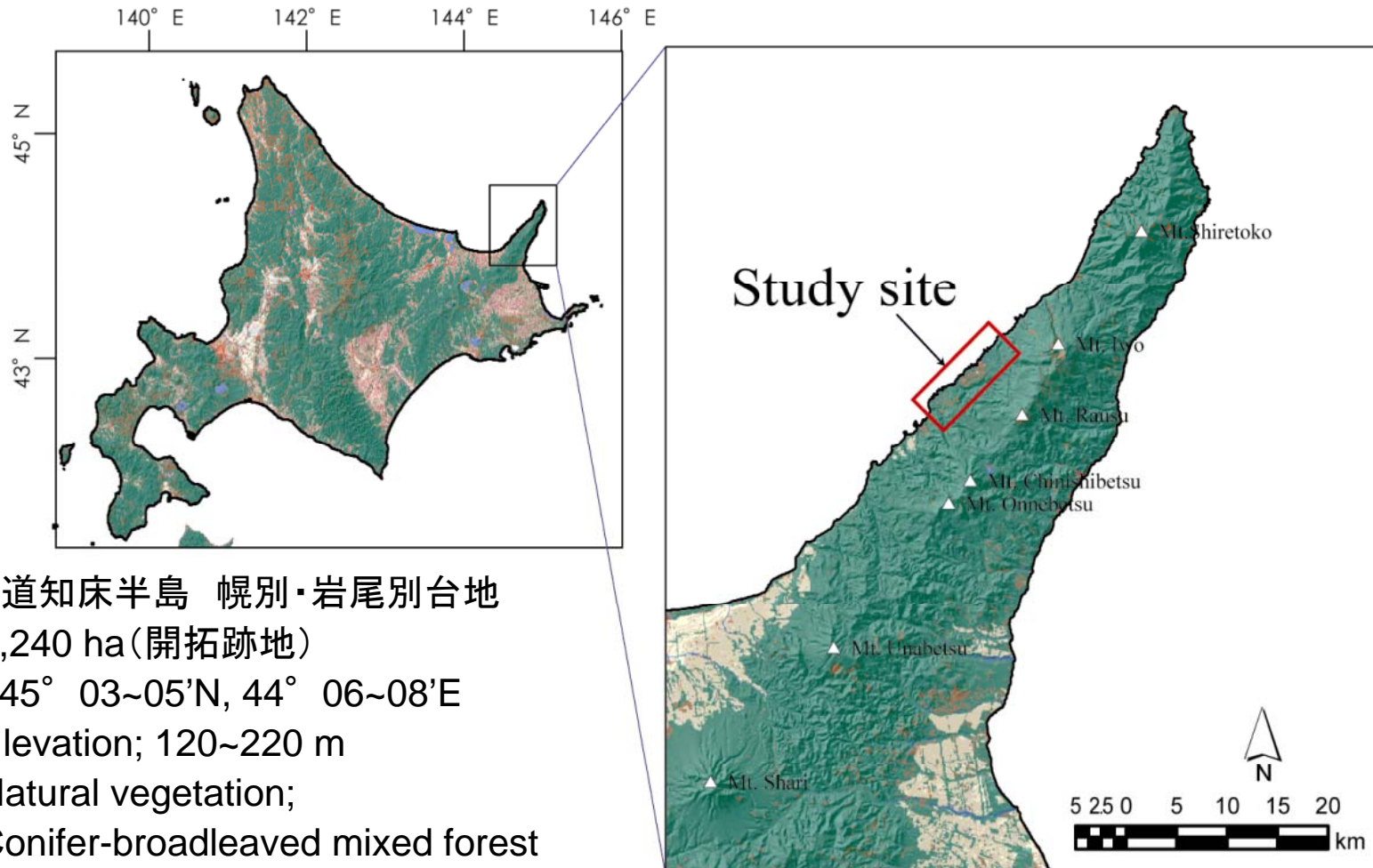
《本研究の目的》

- 日本国内のテストサイトへの応用、社会的環境変化に伴う土地変化プロセスと景観特性の把握

《手法》

- (1)体系的な土地被覆変化の抽出 (Cross-Tabulation matrix)
- (2)景観指標を用いた解析 (Landscape pattern matrix)

研究对象地



北海道知床半島 幌別・岩尾別台地

- 1,240 ha(開拓跡地)
- $145^{\circ} 03\sim 05'N$, $44^{\circ} 06\sim 08'E$
- Elevation; 120~220 m
- Natural vegetation;
Conifer-broadleaved mixed forest
(針広混交林)

Vegetation

➤ Conifer-broadleaved mixed forests

Pan Mixed Forest Zone;

Hokkaido, Primorie, Far Eastern Russia, Southern part of Sakhalin, Northeastern China, Northern Korean peninsula

Dominant species;

Abies sachalinensis

Quercus mongolica, *Acer mono*



過去57年間の土地利用・被覆変化

(Shoyama 2008)

▶ 社会環境の変化に伴う土地利用ステージの定義 (文献調査)

Year	Land use / Events (Household)	
1945		
1949	3rd settlement Reclamation work begins	(25)
1950		(37)
1952-1956	The introduction of dairy farming	(58)
1964		(34)
1966	Facilitation of the settler's	(24)
1975	Complete evacuation of settlers Farmland is abandoned	(0)
1977	Trust movement	
1978	Plantation movement	
1997	Reforestation project	

Post- WW II rapid
cultivation stage
(開拓期)

全国的な戦後一斉開拓事業

Abandonment stage
(放棄期)

開拓から自然保護政策へ
国立公園指定

Plantation stage
(植林期)

地元(斜里町)による
トラスト運動, 植林,
森林再生事業

過去57年間の土地利用・被覆変化

(Shoyama 2008)

▶ 空中写真判読による土地被覆図作成

➤ Methods

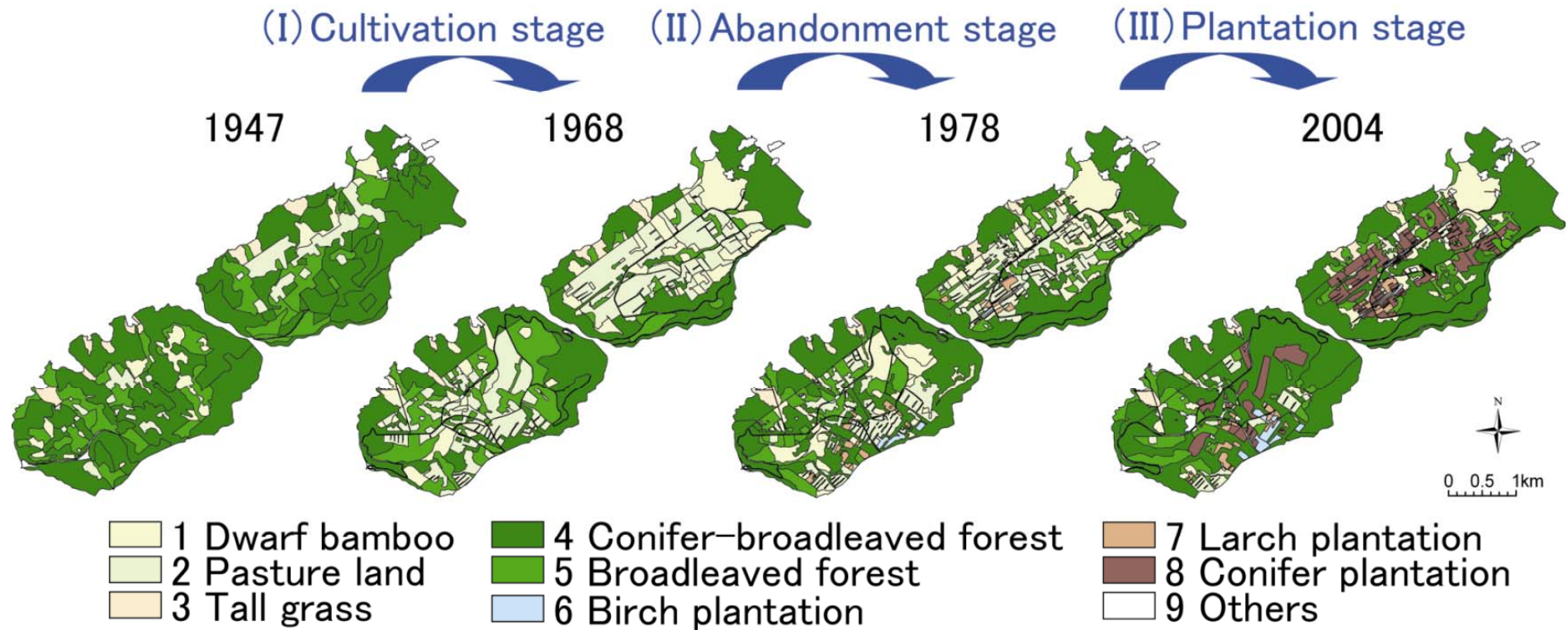
- Deciphering aerial photographs using stereoscopic methodology + field data
- Geometrically correct with a 50m DEM
- Maps prepared in GIS

➤ Photos for three stages

- 1947, 1:50,000, U.S. Armed Forces
- 1968, 1:20,000, Forestry Agency
- 1978, 1:15,000, Geographical Survey Institute
- 2004, 1:15,000, Photo Techno Co., Ltd. and Info Seeds Co., Ltd.

過去57年間の土地利用・被覆変化

(Shoyama 2008)



1. 体系的な土地被覆変化の抽出

(1) Cross-Tabulation matrix (クロス集計表) の作成

Time1	Vegetation Type in Time2									Total	Loss
	1	2	3	4	5	6	7	8	9		
1	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{1+}	$P_{1+}-P_{11}$
2	P_{21}	.	.	.	.	.	.	.	.	.	.
3	P_{31}	.	.	.	.	.	.	.	.	.	.
4	P_{41}	.	.	.	.	.	.	.	.	.	.
5	P_{51}	.	.	.	.	.	.	.	.	.	.
6	P_{61}	.	.	.	.	.	.	.	.	.	.
7	P_{71}	.	.	.	.	.	.	.	.	.	.
8	P_{81}	.	.	.	.	.	.	.	.	.	.
9	P_{91}	.	.	.	.	.	.	.	P_{99}	P_{9+}	$P_{9+}-P_{99}$
Total	P_{+1}	.	.	.	.	.	.	.	P_{+9}	1	
Gain	$P_{+1}-P_{11}$	.	.	.	.	.	.	.	$P_{+9}-P_{99}$		

$$Net\ change_j = |P_{+j} - P_{j+}|$$

$$Swap_j = 2 \times \text{MIN}(P_{+j} - P_{jj}, P_{j+} - P_{jj})$$

(I) 開拓期における被覆変化

(I) Post-World War II rapid-cultivation stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	11.64	2.79	14.43	5.58	8.85
2. Pasture land	21.18	1.44	22.62	2.88	19.74
3. Tall grassland	0.09	0.25	0.34	0.18	0.16
4. Conifer-broadleaved forest	2.82	29.89	32.71	5.64	27.07
5. Broadleaved forest	8.53	11.73	20.26	<u>17.06</u>	3.20
6. Birch plantation	-	-	-	-	-
7. Larch plantation	-	-	-	-	-
8. Conifer plantation	-	-	-	-	-
9. Others	2.00	0.16	2.16	0.32	1.84
Total	46.26	46.26	92.52	<u>31.66</u>	60.86

(I) 開拓期における被覆変化

(I) Post-World War II rapid-cultivation stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	11.64	2.79	14.43	5.58	8.85
2. Pasture land	21.18	1.44	22.62	2.88	19.74
3. Tall grassland	0.09	0.25	0.34	0.18	0.16
4. Conifer-broadleaved forest	2.82	29.89	32.71	5.64	27.07
5. Broadleaved forest	8.53	11.73	20.26	<u>17.06</u>	3.20
6. Birch plantation	-	-	-	-	-
7. Larch plantation	-	-	-	-	-
8. Conifer plantation	-	-	-	-	-
9. Others	2.00	0.16	2.16	0.32	1.84
Total	46.26	46.26	92.52	<u>31.66</u>	60.86

開拓 → 森林減少, 牧草地, ササ地増加

(Ⅱ)放棄期における被覆変化

(II) Abandonment stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	11.26	4.09	15.35	8.18	7.17
2. Pasture land	3.65	9.65	13.30	7.3	6.00
3. Tall grassland	0.11	0.19	0.30	0.22	0.08
4. Conifer-broadleaved forest	7.24	2.26	9.50	4.52	4.98
5. Broadleaved forest	5.81	11.83	17.64	<u>11.62</u>	6.02
6. Birch plantation	-	-	-	-	-
7. Larch plantation	-	-	-	-	-
8. Conifer plantation	-	-	-	-	-
9. Others	0.03	0.08	0.11	0.06	0.05
Total	28.10	28.10	56.20	<u>31.90</u>	24.30

(Ⅱ)放棄期における被覆変化

(II) Abandonment stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	11.26	4.09	15.35	8.18	7.17
2. Pasture land	3.65	9.65	13.30	7.3	6.00
3. Tall grassland	0.11	0.19	0.30	0.22	0.08
4. Conifer-broadleaved forest	7.24	2.26	9.50	4.52	4.98
5. Broadleaved forest	5.81	11.83	17.64	<u>11.62</u>	6.02
6. Birch plantation	-	-	-	-	-
7. Larch plantation	-	-	-	-	-
8. Conifer plantation	-	-	-	-	-
9. Others	0.03	0.08	0.11	0.06	0.05
Total	28.10	28.10	56.20	<u>31.90</u>	24.30

放棄 → 森林増加, 牧草地減少, ササ地増加

(Ⅲ) 植林期における被覆変化

(III) Plantation stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	3.43	9.97	13.40	6.86	6.54
2. Pasture land	0.83	12.3	13.13	1.66	11.47
3. Tall grassland	0.14	0.09	0.23	0.18	0.05
4. Conifer-broadleaved forest	8.2	2.62	10.82	5.24	5.58
5. Broadleaved forest	7.26	8.29	15.55	<u>14.52</u>	1.03
6. Birch plantation	1.44	0.04	-	-	-
7. Larch plantation	2.49	0.31	-	-	-
8. Conifer plantation	11.61	0	-	-	-
9. Others	0.65	0.13	0.78	0.26	0.52
Total	36.05	33.75	53.91	<u>28.72</u>	25.19

(Ⅲ) 植林期における被覆変化

(III) Plantation stage

	Gain	Loss	Total change	Swap	Net change
1. Dwarf bamboo brush	3.43	9.97	13.40	6.86	6.54
2. Pasture land	0.83	12.3	13.13	1.66	11.47
3. Tall grassland	0.14	0.09	0.23	0.18	0.05
4. Conifer-broadleaved forest	8.2	2.62	10.82	5.24	5.58
5. Broadleaved forest	7.26	8.29	15.55	<u>14.52</u>	1.03
6. Birch plantation	1.44	0.04	-	-	-
7. Larch plantation	2.49	0.31	-	-	-
8. Conifer plantation	11.61	0	-	-	-
9. Others	0.65	0.13	0.78	0.26	0.52
Total	36.05	33.75	53.91	<u>28.72</u>	25.19

植林 → 森林・人工林増加，牧草地・ササ地減少

(2) Expected Gain / Loss - 期待値と観測値の比較 -

Time1	Vegetation Type in Time2									Total	Loss
	1	2	3	4	5	6	7	8	9		
1	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{1+}	$P_{1+}-P_{11}$
2	P_{21}
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6	P_{61}
7	P_{71}
8	P_{81}
9	P_{91}	P_{99}	P_{9+}	$P_{9+}-P_{99}$
Total	P_{+1}	P_{+9}	1	
Gain	$P_{+1}-P_{11}$	$P_{+9}-P_{99}$		


$$G_{ij} = (P_{+j} - P_{jj}) \left(\frac{P_{i+}}{\sum_{i=1, i \neq j}^J P_{i+}} \right)$$

$$L_{ij} = (P_{i+} - P_{ii}) \left(\frac{P_{+j}}{\sum_{j=1, j \neq i}^J P_{+j}} \right)$$

Systematic Gain

期待値 < 観測値

- Deference between observed transition and expected value

(I)	1947		1968		
	Broadleaved forest		Dwarf bamboo brush		1.04
	Dwarf bamboo brush		Pasture land		0.56
	Broadleaved forest		Pasture land		0.96
	Broadleaved forest		Conifer-broadleaved fores		1.36
	Dwarf bamboo brush		Broadleaved forest		0.46
	Conifer-broadleaved forest		Broadleaved forest		0.31
(II)	1968		1978		
	Pasture land		Dwarf bamboo brush	Gain	4.01
	Dwarf bamboo brush		Pasture land		0.44
	Broadleaved forest		Pasture land		1.28
	Broadleaved forest		Conifer-broadleaved fores		5.34
	Dwarf bamboo brush		Broadleaved forest		2.03
	Pasture land		Broadleaved forest		0.23
(III)	1978		2004		
	Pasture land		Dwarf bamboo brush		2.23
	Broadleaved forest		Conifer-broadleaved fores		6.06
	Dwarf bamboo brush		Broadleaved forest		3.01
	Dwarf bamboo brush		Conifer plantation		2.68
	Pasture land		Conifer plantation		5.19

Systematic Loss

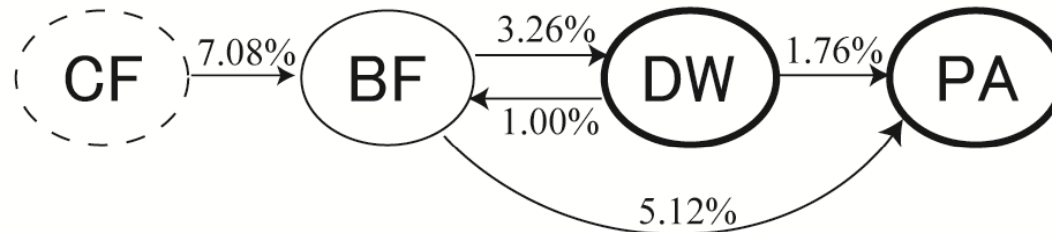
期待値 < 観測値

- Deference between observed transition and expected value

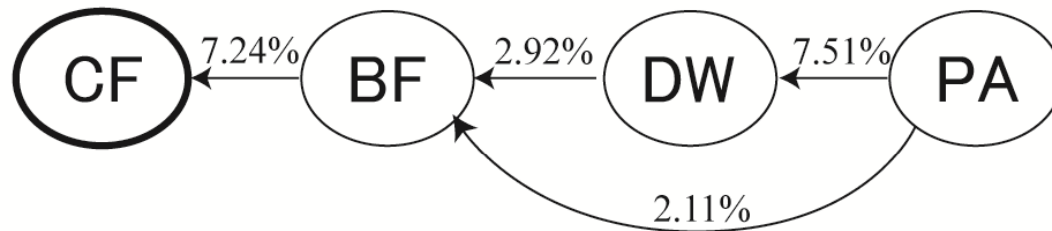
(I)	1947		1968		
	Conifer-broadleaved forest		Dwarf bamboo brush		0.50
	Broadleaved forest		Dwarf bamboo brush		1.32
	Dwarf bamboo brush		Pasture land		0.87
	Conifer-broadleaved forest		Pasture land		1.06
	Broadleaved forest		Pasture land		1.33
	Dwarf bamboo brush		Broadleaved forest		0.52
(II)	1968		1978		
	Pasture land	Loss	Dwarf bamboo brush		5.06
	Conifer-broadleaved forest		Dwarf bamboo brush		0.24
	Broadleaved forest		Conifer-broadleaved fores		1.48
	Dwarf bamboo brush		Broadleaved forest		2.40
	Pasture land		Broadleaved forest		0.88
(III)	1978		2004		
	Pasture land		Dwarf bamboo brush		1.73
	Broadleaved forest		Conifer-broadleaved fores		3.10
	Dwarf bamboo brush		Broadleaved forest		2.98
	Conifer-broadleaved forest		Broadleaved forest		1.18
	Dwarf bamboo brush		Conifer plantation		3.21
	Pasture land		Conifer plantation		5.59

体系的な土地被覆変化 (Systematic transitions)

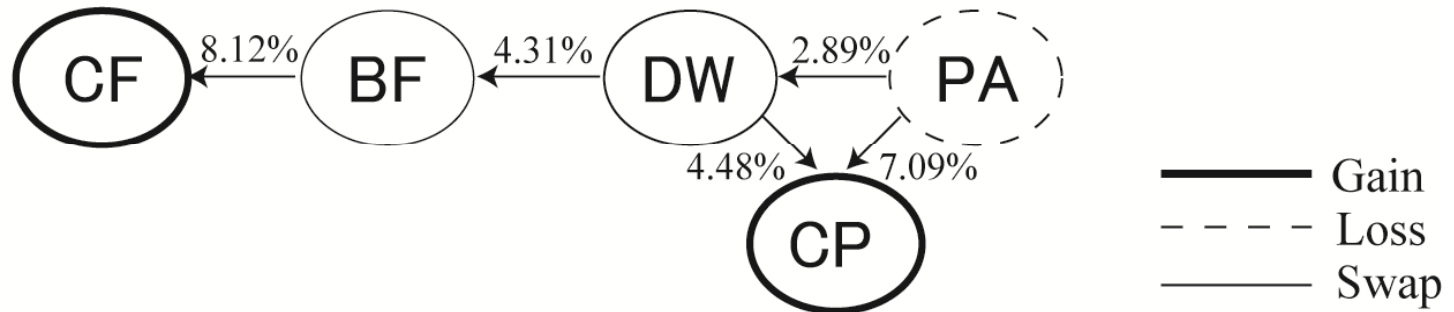
(I) Post-World War II rapid-cultivation stage



(II) Abandonment stage



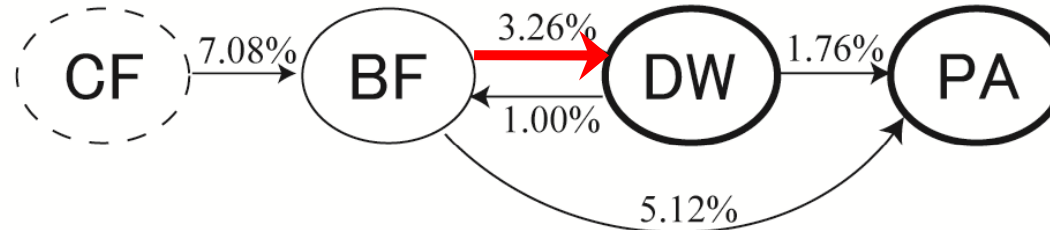
(III) Plantation stage



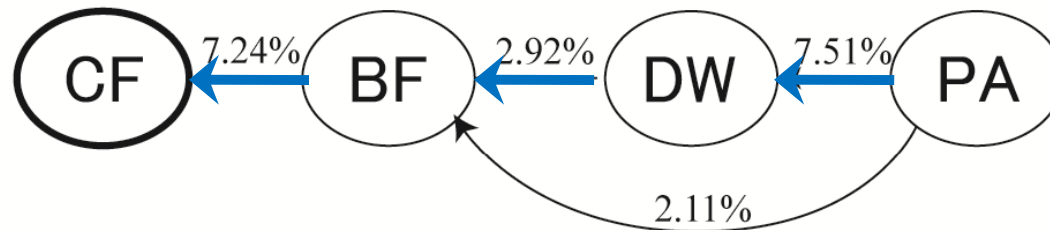
PA; Pastureland, DW; Dwarf bamboo brush, BF; Broadleaved forest
 CF; Conifer-broadleaved forest, CP; Conifer plantation

主要な土地被覆変化 (Dominant signals)

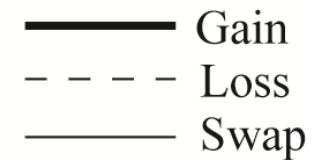
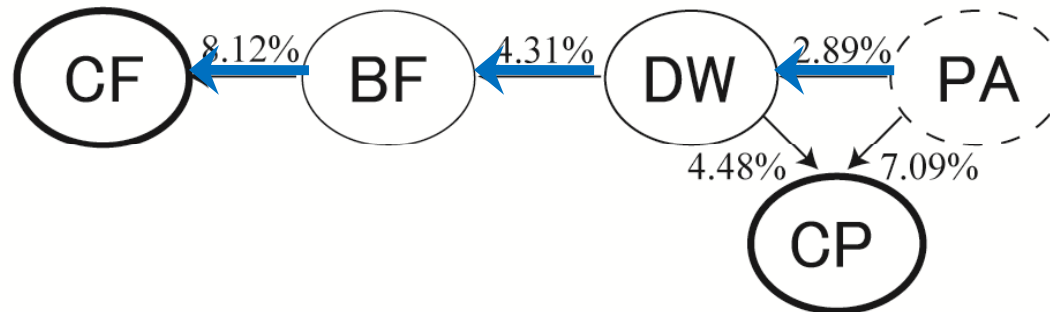
(I) Post-World War II rapid-cultivation stage



(II) Abandonment stage



(III) Plantation stage



PA; Pastureland, DW; Dwarf bamboo brush, BF; Broadleaved forest
 CF; Conifer-broadleaved forest, CP; Conifer plantation

2. 景観指標を用いた解析

Metrics	Abbr.	Description	Unit	分断化
Patch density (パッチ密度)	PD	$PD = \frac{n_i}{A}(10,000)(100)$	number/ 100ha	+
Mean patch size (平均パッチサイズ)	MPS	$MPS = \frac{\sum_{j=1}^n a_{ij}}{n_i} \left(\frac{1}{10,000} \right)$	ha	-
Landscape shape index (パッチ形状)	LSI	$LSI = \frac{0.25 \sum_{k=1}^m e''_{ik}}{\sqrt{A}}$	-	+
Mean proximity index (近接指数)	MPI	$MPI = \frac{\sum_{j=1}^n \sum_{s=1}^n \frac{a_{ijs}}{h_{ijs}^2}}{n_i}$	-	-
Interspersion juxtaposition index (分散指数)	IJI	$IJI = \frac{-\sum_{k=1}^{m'} \left[\left(\frac{e_{ik}}{\sum_{k=1}^{m'} e_{ik}} \right) \ln \left(\frac{e_{ik}}{\sum_{k=1}^{m'} e_{ik}} \right) \right]}{\ln(m'-1)} (100)$	%	+

FRAGSTATS(MacGarigal and Marks, 1995)

各ステージにおける指標の比較

	Year				Annual rate of change (%)		
	1947	1968	1978	2004	I	II	III
PD (100ha ⁻¹)	0.08	0.30	0.39	0.35	13.10 ↓	3.00 ↓	-0.39
MPS (ha)	<u>12.03</u>	3.35	2.57	2.88	-3.44 ↓	-2.33 ↓	0.46
LSI	9.06	13.36	15.60	14.41	2.26	1.68	-0.29
MPI (m ha ⁻¹)	208.93	132.35	191.25	69.58	-1.75	4.45	-2.45
IJI(%)	72.44	85.47	76.98	82.41	0.86	-0.99	0.27

I = Rapid Cultivation Stage, II = Abandonment Stage, III = Plantation Stage

各ステージにおける指標の比較

	Year				Annual rate of change (%)		
	1947	1968	1978	2004	I	II	III
PD (100ha ⁻¹)	0.08 +	0.30 +	0.39 -	0.35	13.10	3.00	-0.39
MPS (ha)	12.03 -	3.35 -	2.57 +	2.88	-3.44	-2.33	0.46
LSI	9.06 +	13.36 +	15.60 -	14.41	2.26	1.68	-0.29
MPI (m ha ⁻¹)	208.93 -	132.35 +	191.25 -	69.58	-1.75	4.45	-2.45
IJI(%)	72.44 +	85.47 -	76.98 +	82.41	0.86	-0.99	0.27

分断化

開拓 放棄 植林

連結性の低下
分散化への影響

I = Rapid Cultivation Stage, II = Abandonment Stage, III = Plantation Stage

まとめ

■ 体系的変化の抽出:

- (1) 社会的環境変化(土地利用政策の転換)に伴う土地被覆変化プロセスを明示
- (2) 森林再生を目的とした植林は、植生遷移の停滞による人為植生の減少に寄与

■ 景観指標による解析:

- (1) 開拓期と放棄期におけるパッチサイズの低下と分断化
- (2) 開拓や植林行為はパッチの連結性の低下や分散化に影響

- ✓ 変化プロセスと景観パターンの相互把握は、土地利用計画において重要
- ✓ 体系的変化の抽出は国内のローカルスケールにおいても適用可能
- ✓ 課題:置換(Swap)の検出に影響する分析解像度の検証