Changes of Land Use and Land Cover and Biogeochemistry in Northern Eurasia

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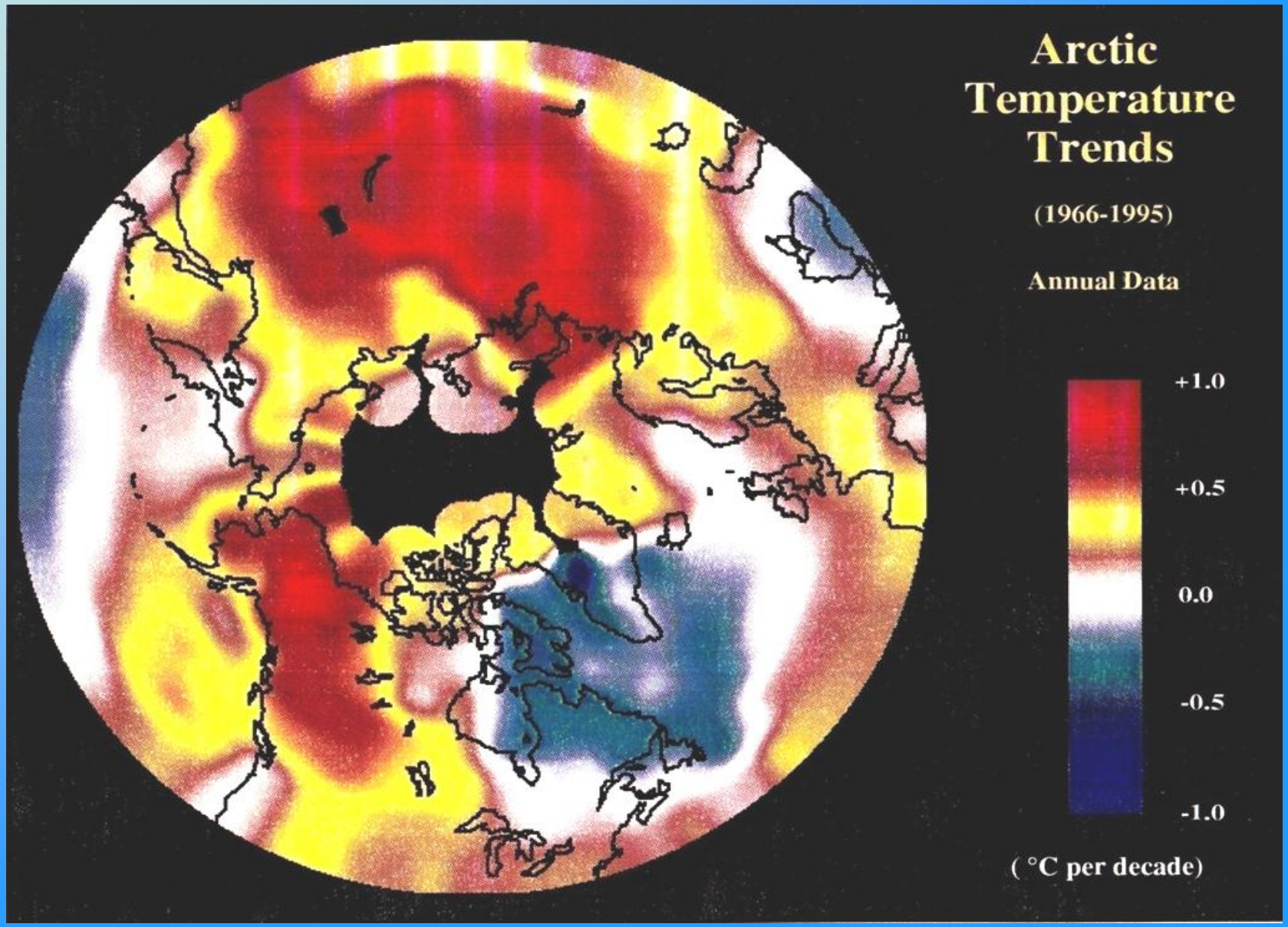
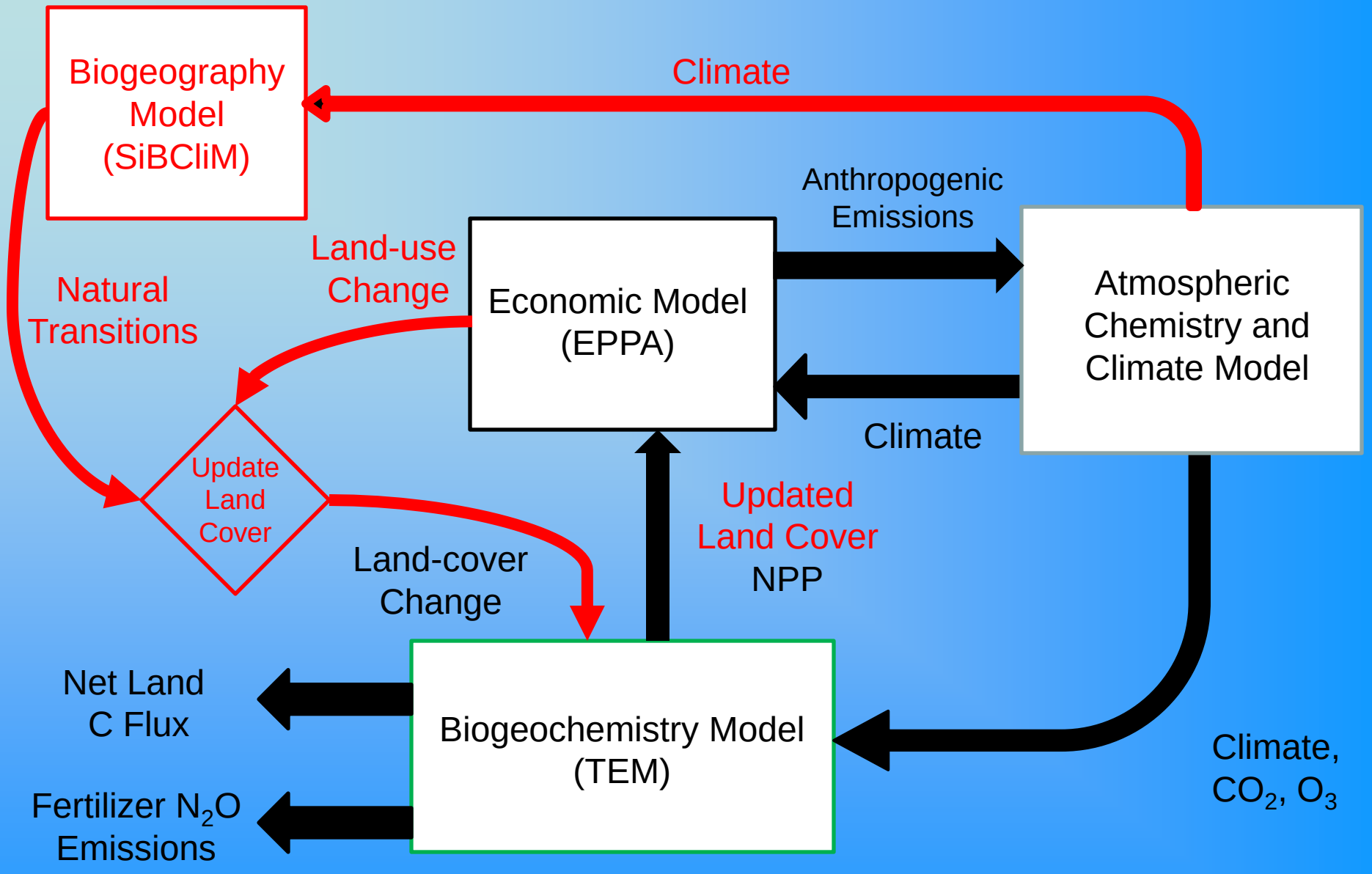


Serreze et al., 2000, Climatic Change

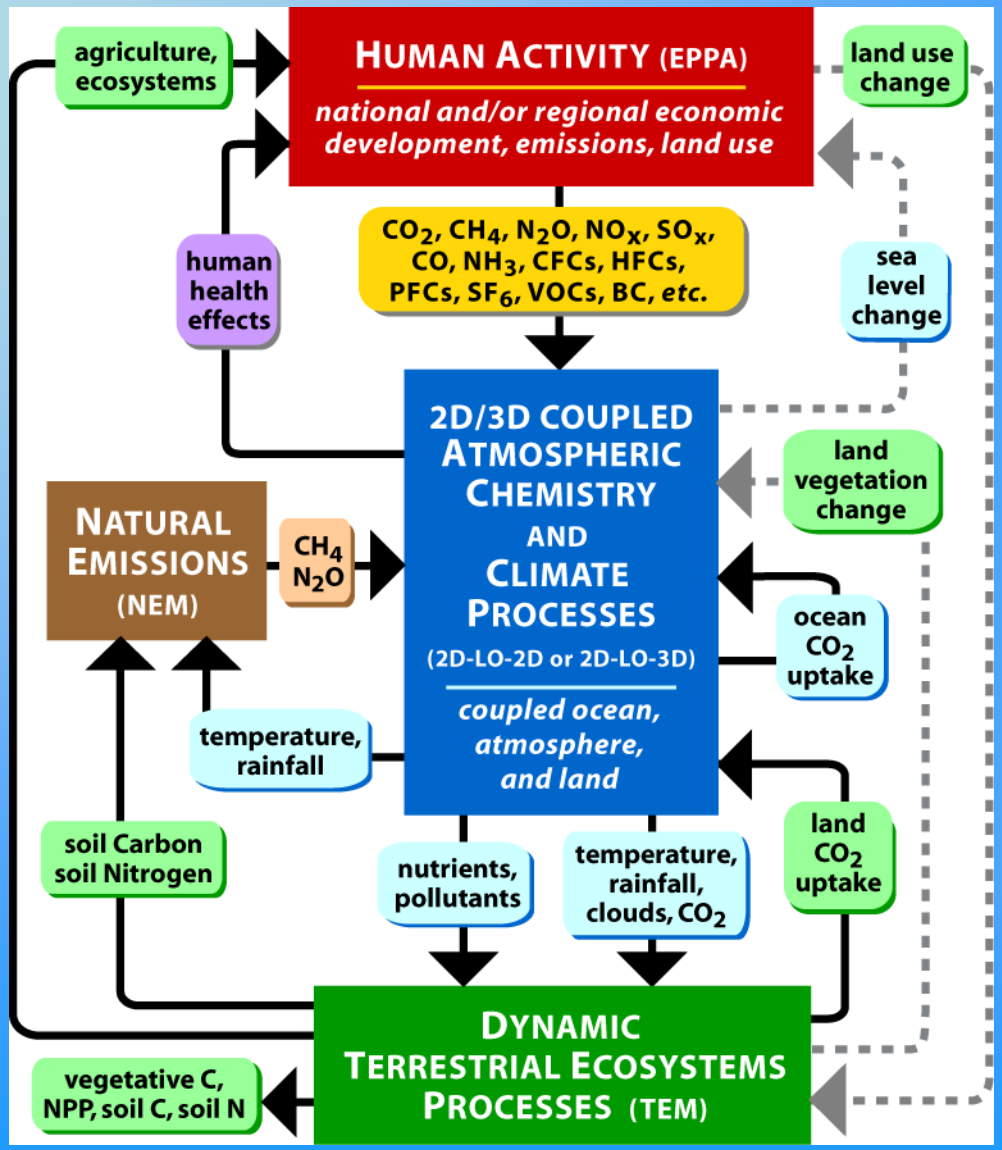
Research Questions

- How the land use and land cover in the region will be affected by natural and anthropogenic changes in this century?

- How the biogeochemical cycles of carbon and water will be affected by changes of land use and land cover and climate?


Biogeography Model (SiBCliM)
Climate
Anthropogenic Emissions
Land-use Change
Natural Transitions
Economic Model (EPPA)
Atmospheric Chemistry and Climate Model
Climate
Update Land Cover
Updated Land Cover
NPP
Land-cover Change
Net Land C Flux
Biogeochemistry Model (TEM)
Climate, CO_2, O_3
Fertilizer N_2O Emissions

MIT Integrated Global System Model



Major Features of EPPA and TEM

EPPA

- Multiple regions - Globe divided into 16 economic regions
- Multiple fuels - Fossil, Nuclear, Wind, Solar, Biomass, Biofuels
- Multiple sectors – Industry, Transportation, Households, Agriculture, Forestry
- International trade

TEM

- Cycling of carbon, nitrogen, and water
- Spatial information on soils, vegetation, climate, elevation, atmospheric chemistry (carbon dioxide, tropospheric ozone)
- Coupled with permafrost and fire dynamics

Major Features of SiBCliM

- A static envelope-type large-scale bioclimatic model based on the vegetation classification of Shumilova (1962)
- SiBCliM uses three bioclimatic indices: (1) growing degree-days above 5^0C; (2) negative degree-days below 0^0C; and (3) an annual moisture index (ratio of growing degree days above 5^oC to annual precipitation)
- SiBCliM has been updated to include permafrost (the active layer depth)

Land Cover and Land Use Modeling

$$S_{l,n} = \alpha_l + \sum_i \beta_{l,i} NPP_{l,n} + \sum_i \chi_{l,i} NPP_{l,n}^2 + \delta_l T_n + \phi_l T_n^2 + \varphi_l P_n + \gamma_l P_n^2 + \eta_l D_n + \varepsilon_l$$

where subscripts l and i represent the land use categories (i.e., cropland, pasture, managed forest, unmanaged forest and unmanaged grassland), n represents the grid cell, $S_{l,n}$ is the share of land use class l in grid cell n, $NPP_{l,n}$ is the averaged net primary productivity of the prior 5 years as estimated by TEM, T_n is the surface air temperature of grid cell n, P_n is the precipitation in grid cell n, D_n is distance between the center of grid cell n and the closest urban area. The parameters associated with each explanatory variable are represented by $\beta_{l,i}$, χ_{li}, δ_l, ϕ_l, φ_l, γ_l and η_l. α_l is the linear intercept and ε_l is the error term. Equation S2 is estimated for each land-use class in each EPPA region, based on historical and simulated data for the period 1970 to 2000.

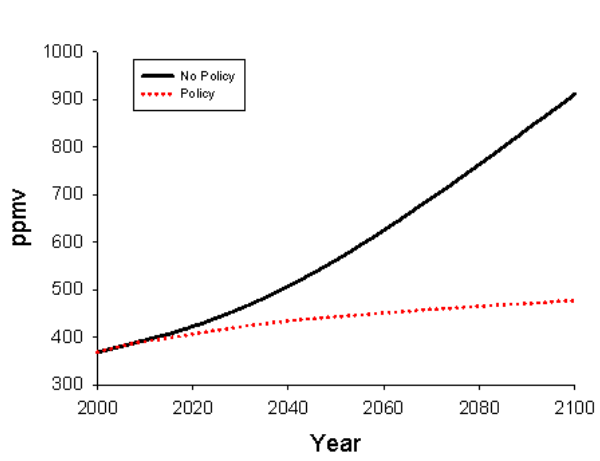
(Melillo et al., 2010)

Climate Policy

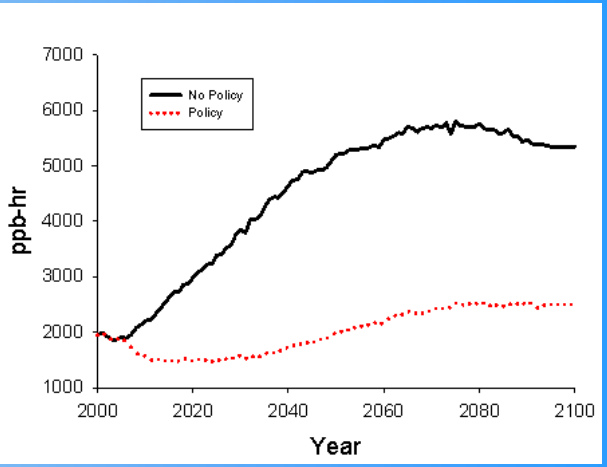
- An aggressive climate policy – CO_2-eq. of 650 ppmv
- Free trade in biofuels
- Global participation in carbon constraint from 2015
- Cumulative emissions 2.3 Tt CO_2-eq over 2001-2100, about 29% of no-policy scenario
- Target 2.4 w/m^2 increase in radiative forcing by 2100 relative to 2000

Atmospheric Climate and Chemistry during the 21st century

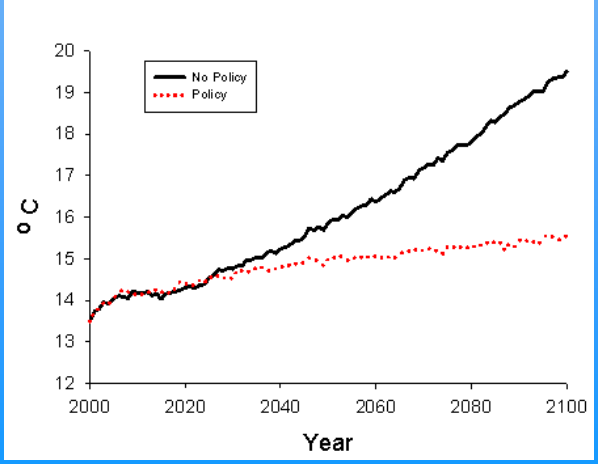
a) Atmospheric CO_2 concentrations



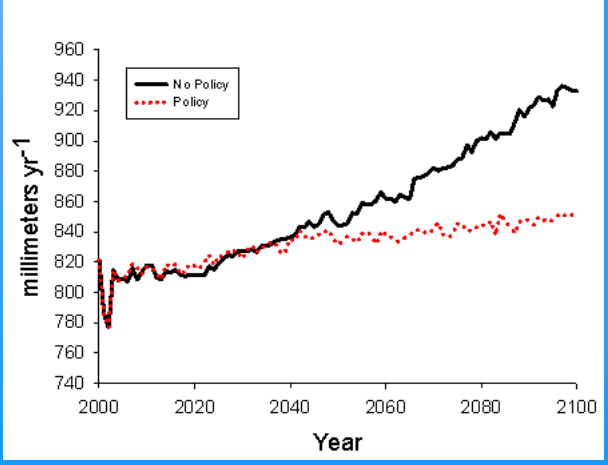
b) AOT40 ozone index



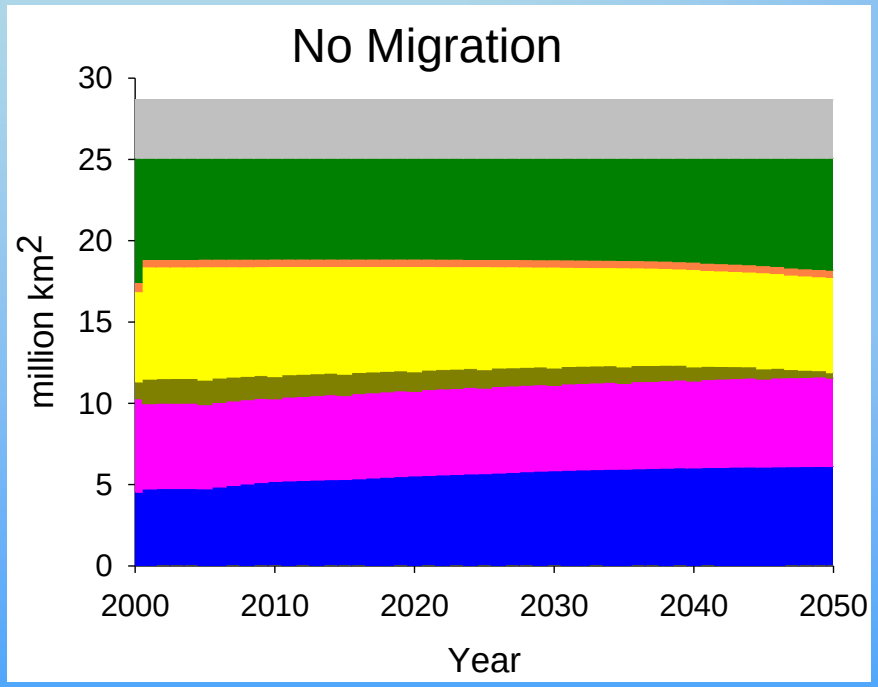
c) Global mean air temperature

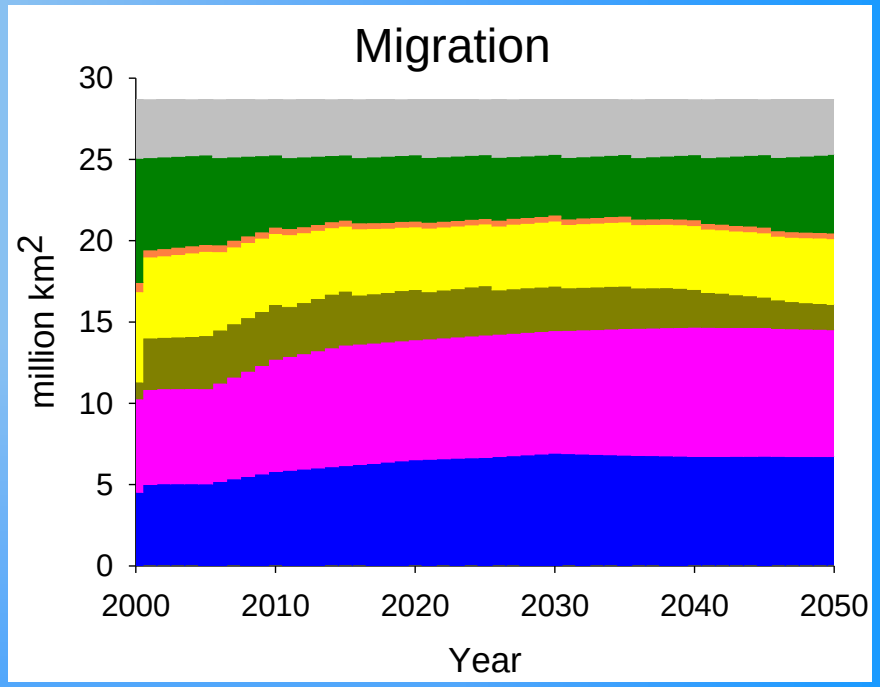


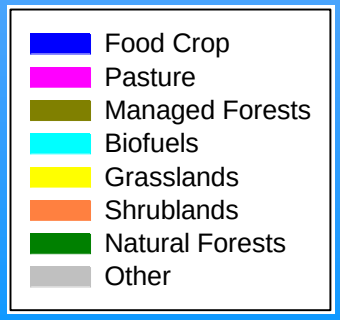
d) Global mean precipitation



Land-use Change in the Northern Eurasia over the first-half of the 21st Century (No Policy)

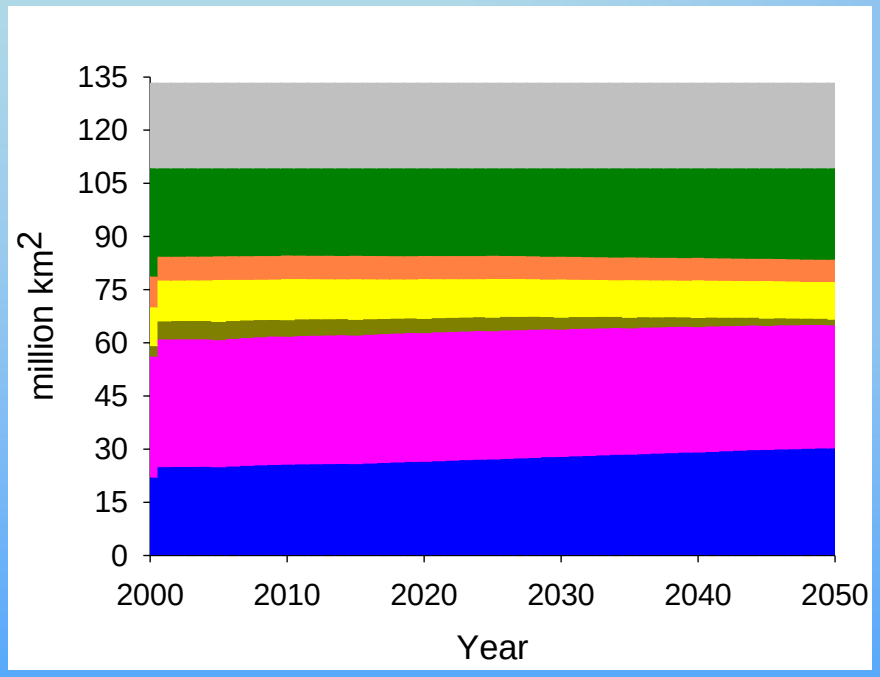




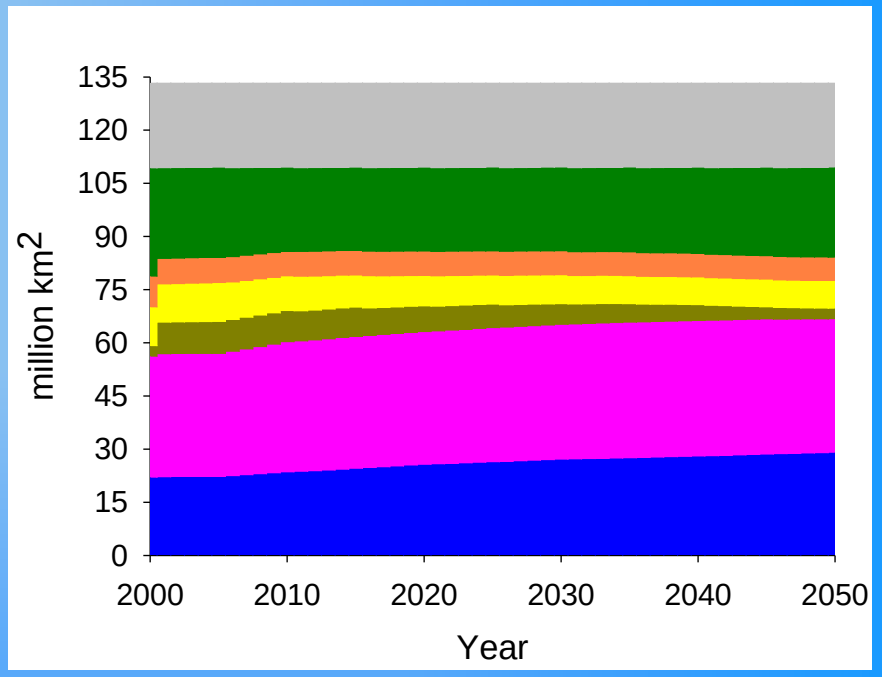


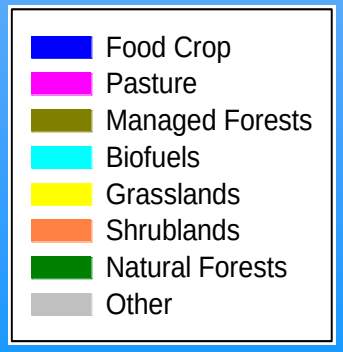
Global Land-use Change over the first-half the 21st Century (No Policy)

No Migration in Northern Eurasia



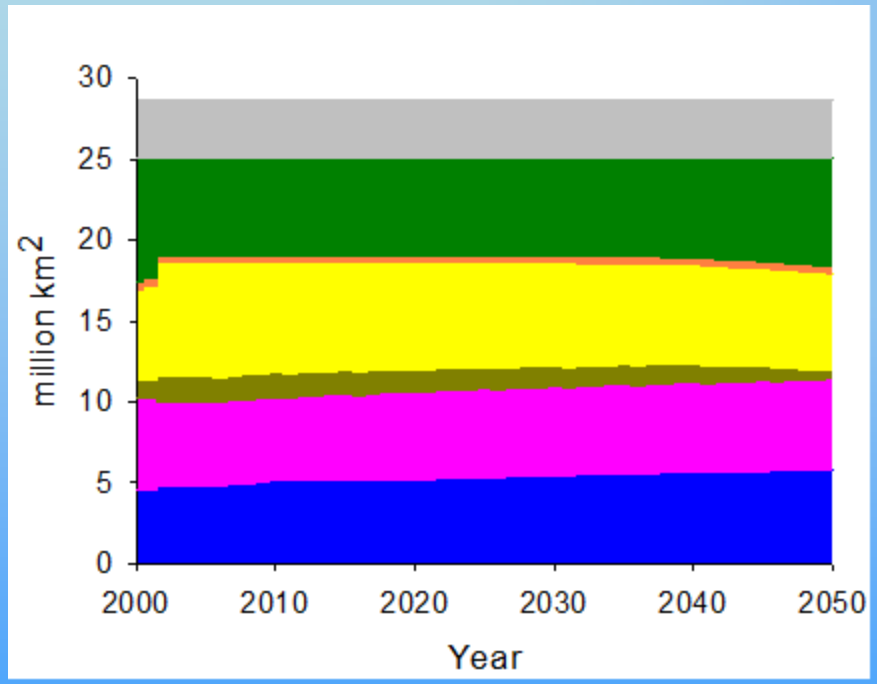
Migration in Northern Eurasia



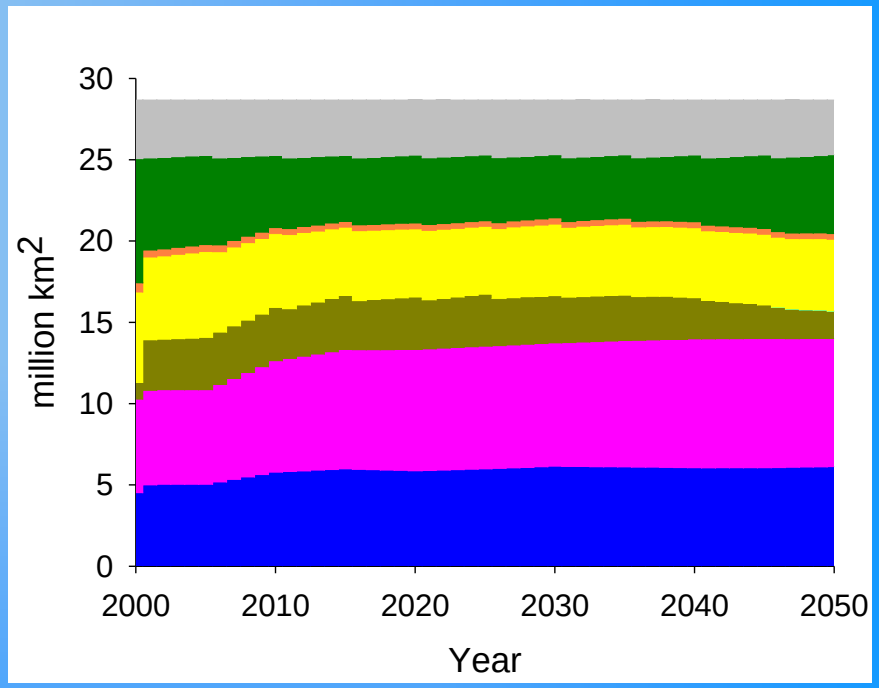


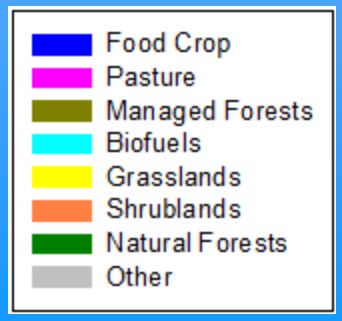
Land-use Change in Northern Eurasia over the first-half of the 21st Century (Policy)

No Migration



Migration





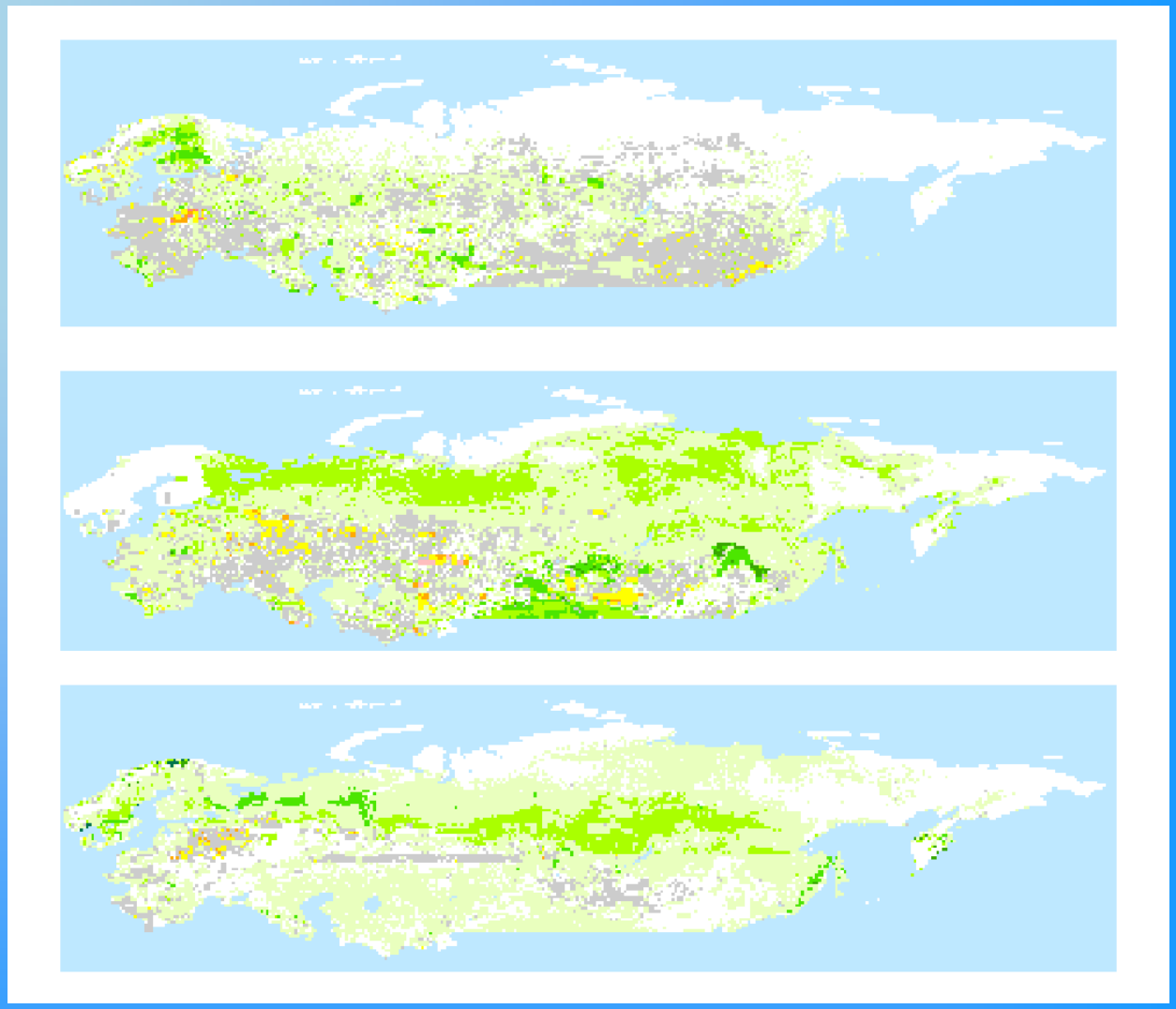
Difference in Land Use due to Migration in Northern Eurasia in 2050

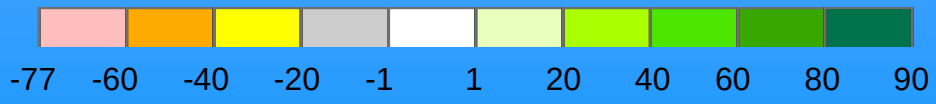
Food Crops

Pasture

Managed Forests

Policy
Northern Eurasia

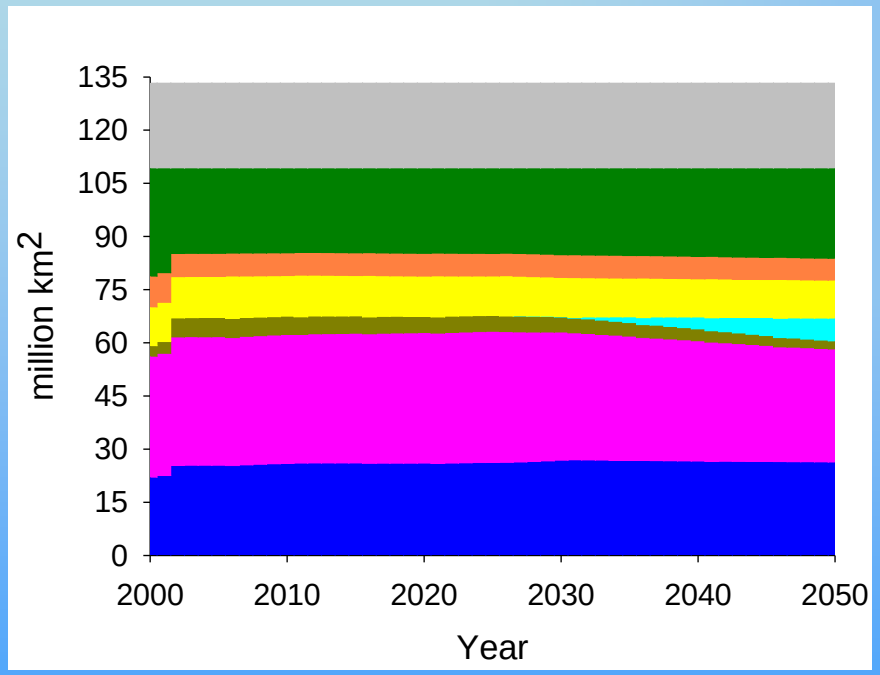




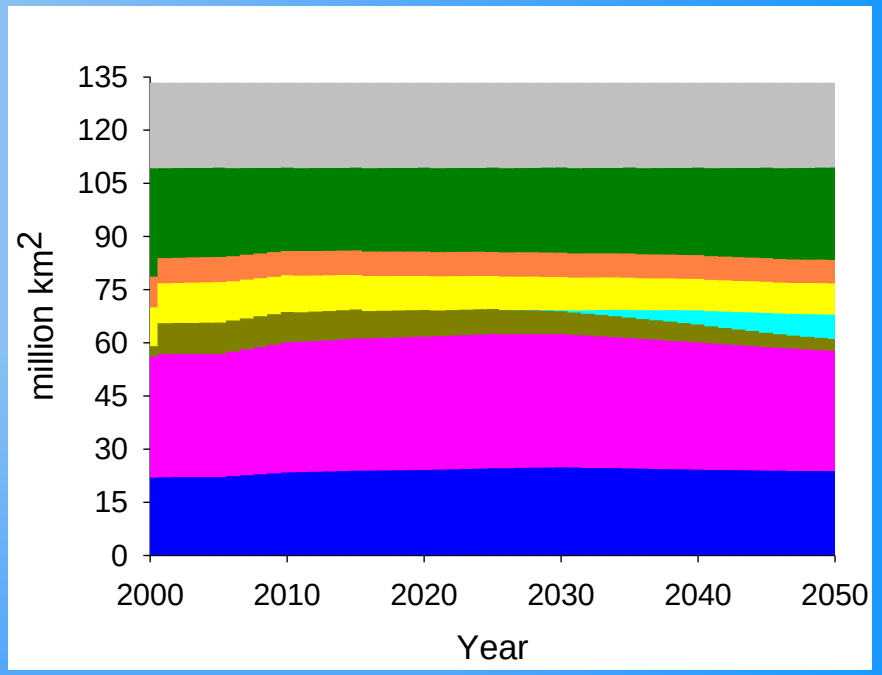
Percent

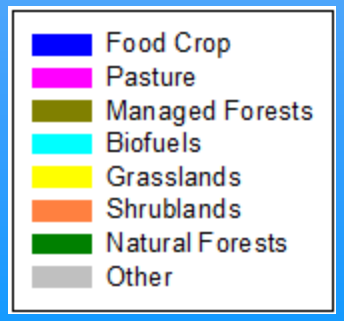
Global Land-use Change over the first-half of the 21st Century (Policy)

No Migration in Northern Eurasia



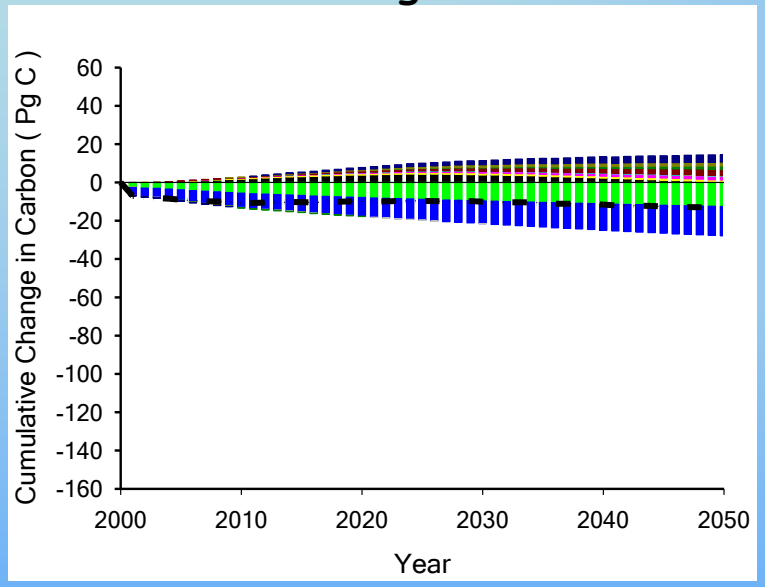
Migration in Northern Eurasia



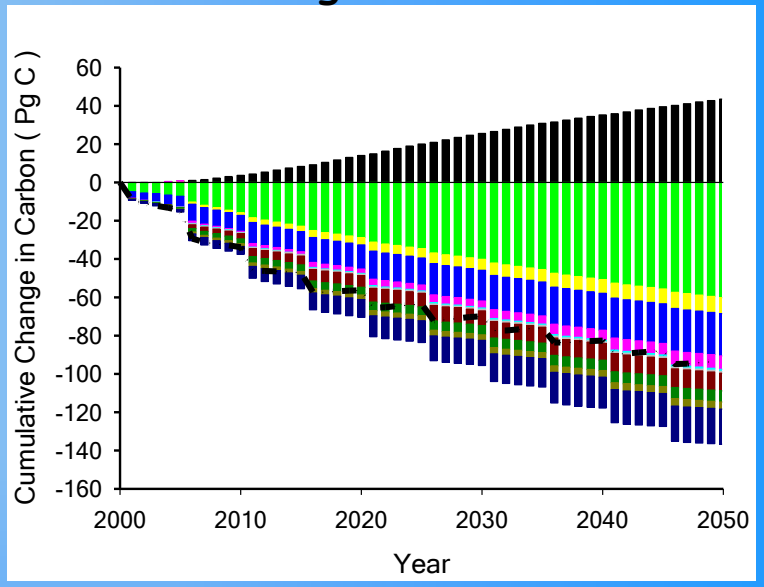


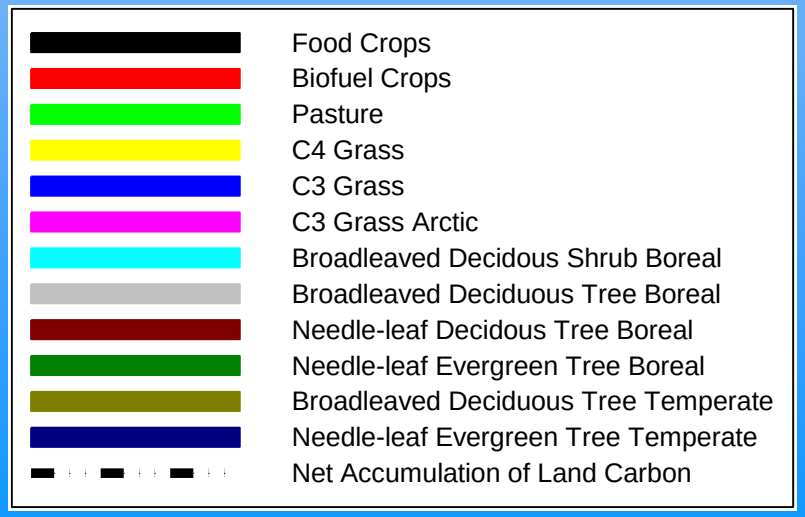
Net Land Carbon Flux (Pg C) in the Northern Eurasia (No Policy)

No Migration



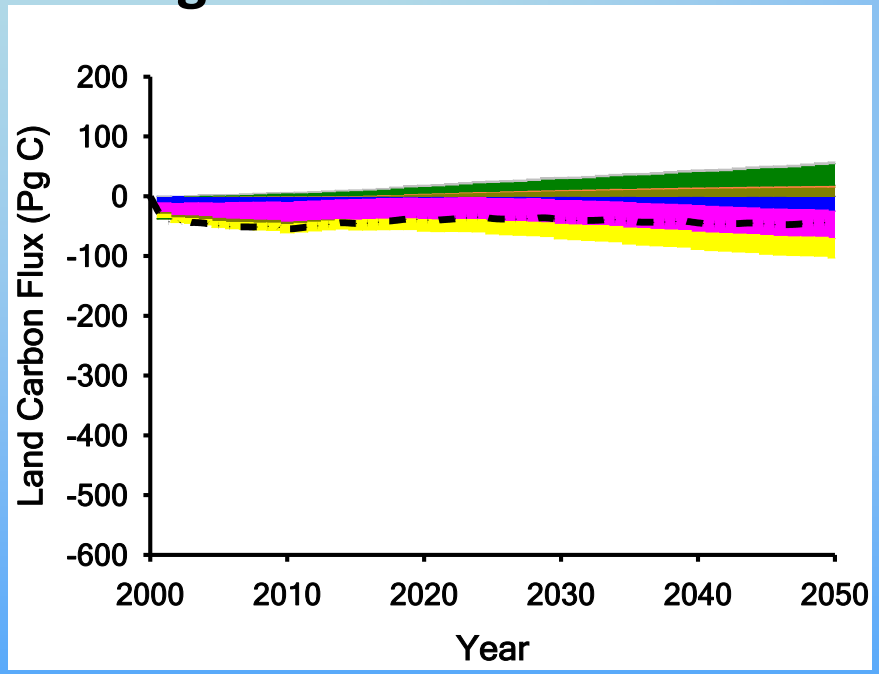
Migration



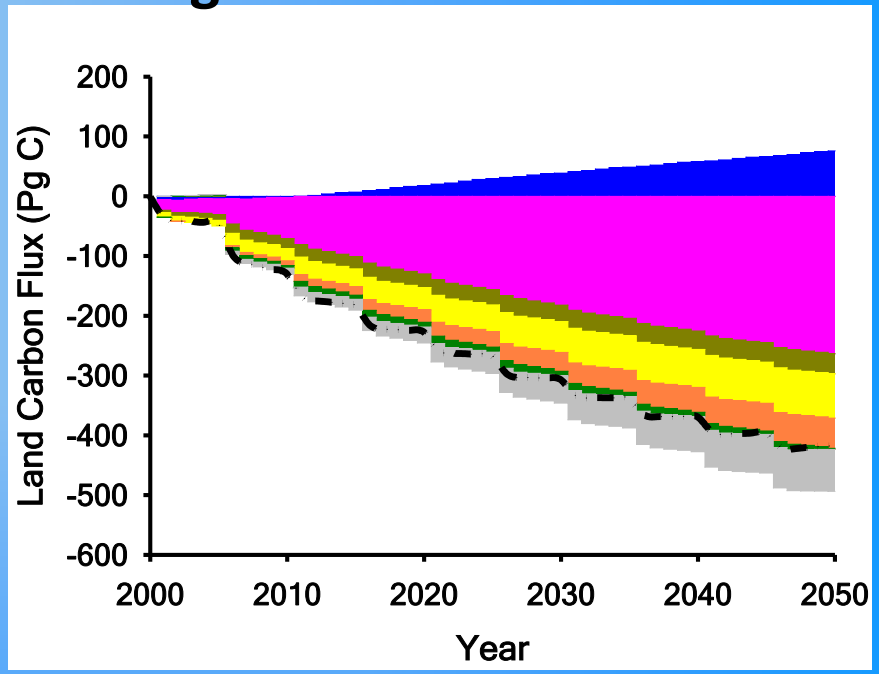


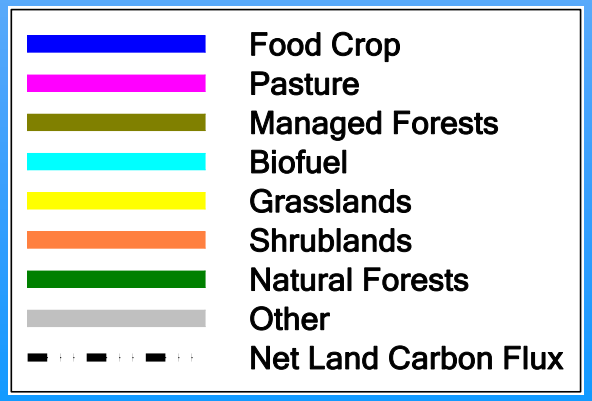
Global Land Carbon Flux (Pg C)
(No Policy)

No Migration in Northern Eurasia

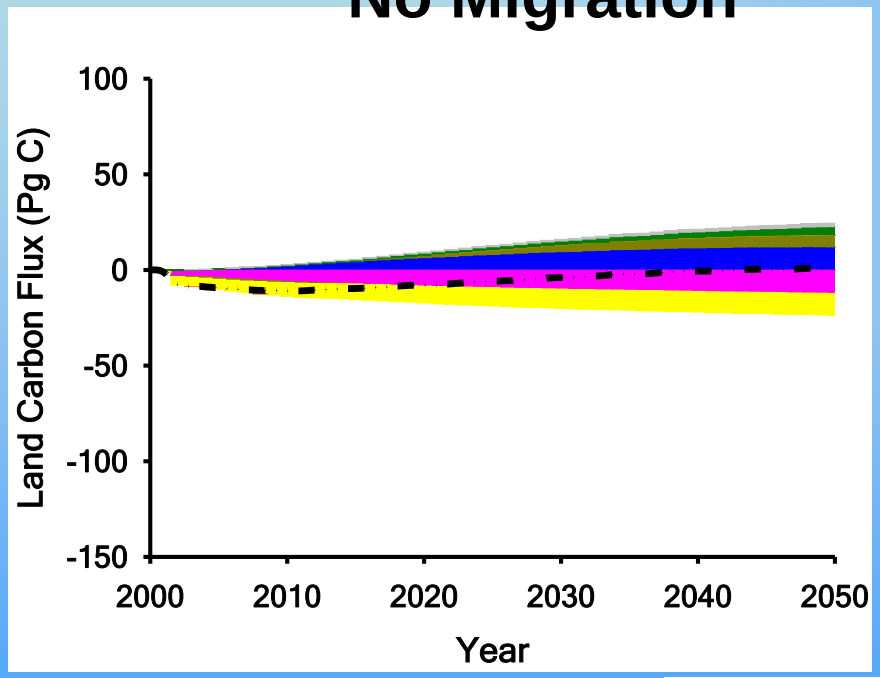


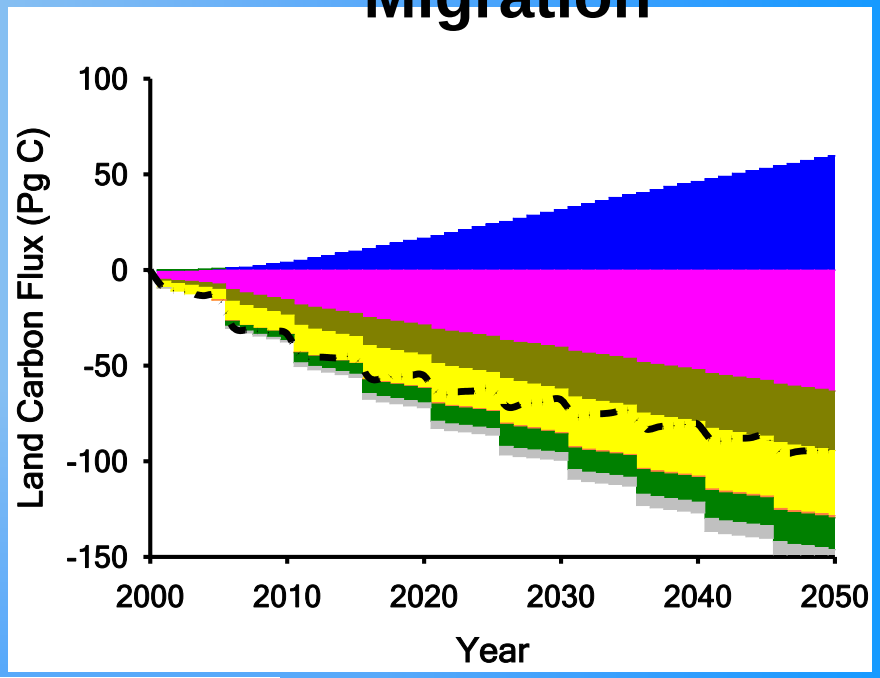
Migration in Northern Eurasia

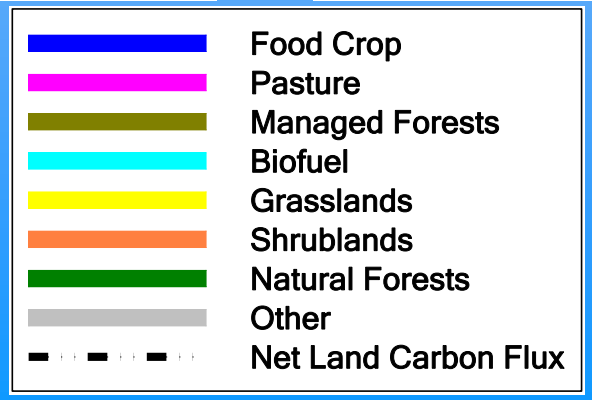




Net Land Carbon Flux (Pg C) in the Northern Eurasia (Policy)

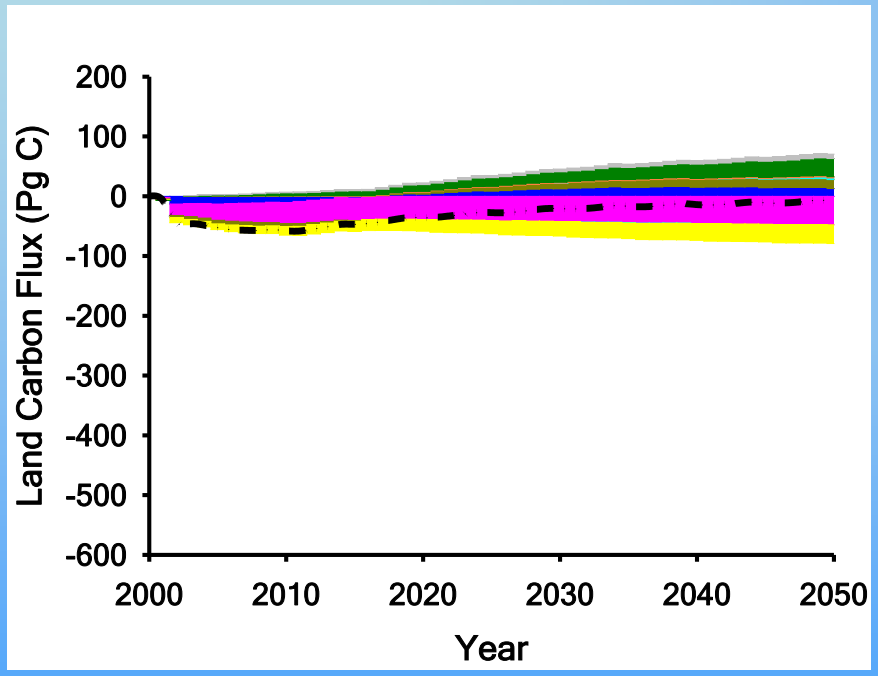




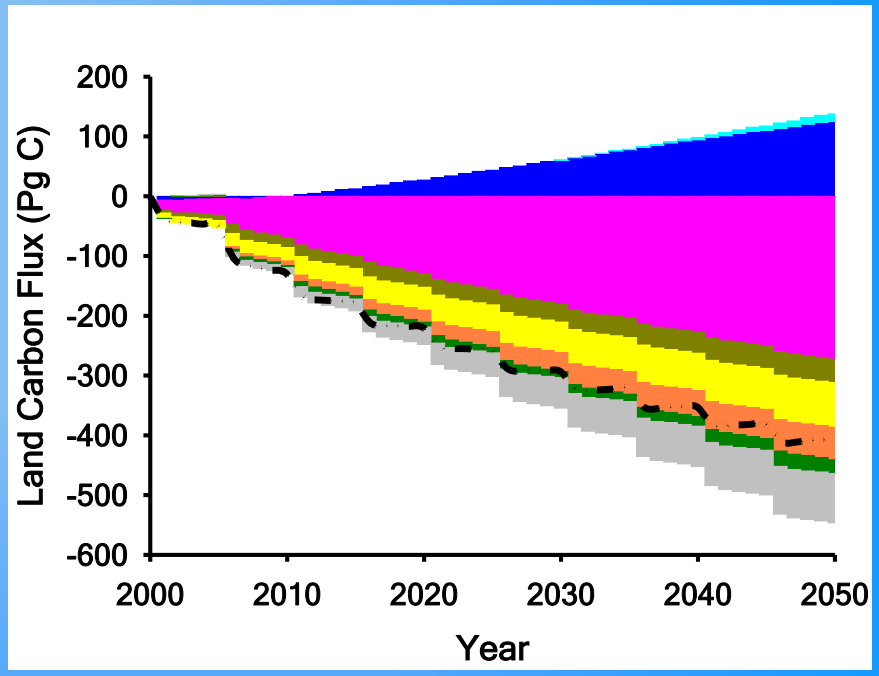


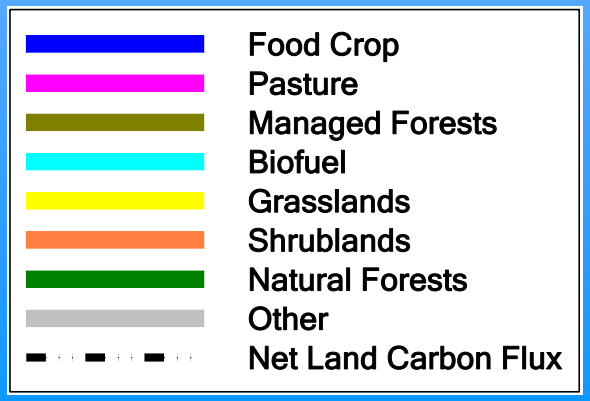
Global Land Carbon Flux (Pg C) (Policy)

No Migration



Migration in Northern Eurasia





Changes in land cover (million km^2) of Northern Eurasia during the first half of the 21st century

Land Cover	Current (2000)	No Policy (2050)		Policy (2050)	
		No Migration	Migration	No Migration	Migration
Food Crops	4.53	6.11	6.73	5.82	6.13
Biofuel Crops	0.00	0.00	0.00	0.00	0.01
Pasture	5.75	5.44	7.81	5.61	7.88
Managed Forests	1.04	0.33	1.55	0.51	1.68
Natural Forests	7.64	6.88	4.84	6.72	4.86
Shrublands	0.57	0.44	0.35	0.42	0.35
Grasslands	5.55	5.88	4.04	6.00	4.41
Other	3.60	3.60	3.36	3.60	3.36
Total	28.68	28.68	28.68	28.68	28.68

Changes in global land cover (million km^2) during the first half of the 21st century

Land Cover	Current (2000)	No Policy (2050)		Policy (2050)	
		No Migration	Migration	No Migration	Migration
Food Crops	22.12	30.36	29.14	26.42	23.99
Biofuel Crops	0.00	0.00	0.00	6.45	6.91
Pasture	34.12	34.73	37.70	31.89	33.88
Managed Forests	3.00	1.61	2.95	2.27	3.36
Natural Forests	30.56	25.80	25.44	25.52	26.09
Shrublands	8.67	6.22	6.56	6.15	6.61
Grasslands	10.93	10.68	7.85	10.70	8.80
Other	23.90	23.90	23.66	23.90	23.66
Total	133.30	133.30	133.30	133.30	133.30

Net land carbon flux (Pg C) from terrestrial ecosystems in Northern Eurasia during the first half of the 21st century

Land Cover	No Policy (2001 to 2050)		Policy (2001 to 2050)	
	No Migration	Migration	No Migration	Migration
Food Crops	-0.02	43.53	12.08	59.66
Biofuel Crops	0.00	0.00	0.00	0.01
Pasture	-12.53	-60.17	-12.25	-63.23
Managed Forests	5.89	-26.34	6.05	-31.17
Natural Forests	5.21	-11.68	4.29	-16.63
Shrublands	0.27	-1.03	0.24	-1.04
Grasslands	-14.18	-30.40	-11.47	-34.09
Other	1.99	-7. 05	1.82	-7.57
Total	-13.37	-93.14	0.76	-94.06

Net land carbon flux (Pg C) from global terrestrial ecosystems during the first half of the 21st century. Migration only occurs in Northern Eurasia

Land Cover	No Policy (2001 to 2050)		Policy (2001 to 2050)	
	No Migration	Migration	No Migration	Migration
Food Crops	-24.76	76.11	12.99	125.11
Biofuel Crops	-0.00	-0.00	2.60	12.51
Pasture	-45.91	-263.40	-47.71	-272.34
Managed Forests	15.49	-33.59	15.12	-39.97
Natural Forests	36.07	-2.01	30.30	-22.83
Shrublands	2.86	-50.49	2.16	-54.63
Grasslands	-37.23	-66.17	-31.27	-73.92
Other	7.80	-78.03	7.33	-82.43
Total	-45.68	-417.58	-8.48	-408.50

Progress Summary

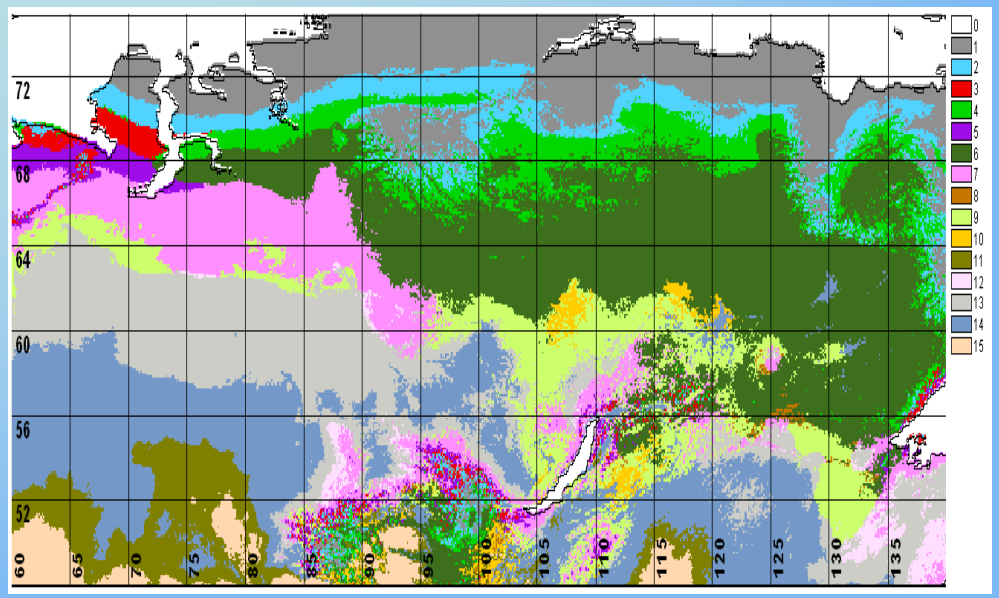
- Northern Eurasia: By year 2050, under policy and migration conditions, the food crops will change from 5 to 6, pasture from 6 to 8, managed forests from 1 to 2, natural forests from 8 to 5, grasslands from 6 to 4 million km^2, respectively. There is a similar land-use change trend under no-policy and migration conditions, but with smaller magnitudes.

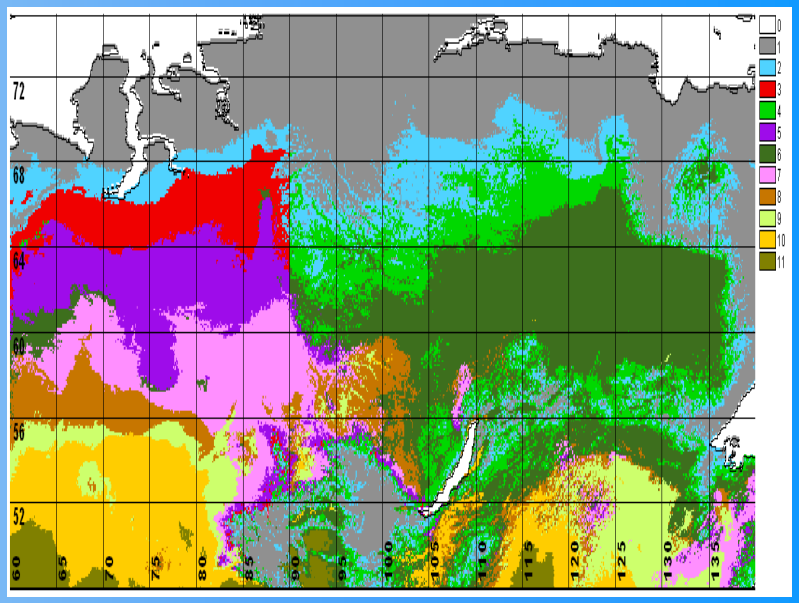
- Globe: By year 2050, under policy and migration conditions, the food crops will change from 22 to 24, managed forests from 3 to 3.4, natural forests from 31 to 26, grasslands from 11 to 9 million km2, respectively. Under no-policy and migration conditions, the food crops will change from 22 to 29, pasture from 34 to 38, natural forests from 31 to 25, and grasslands from 11 to 8 million km^2, respectively.

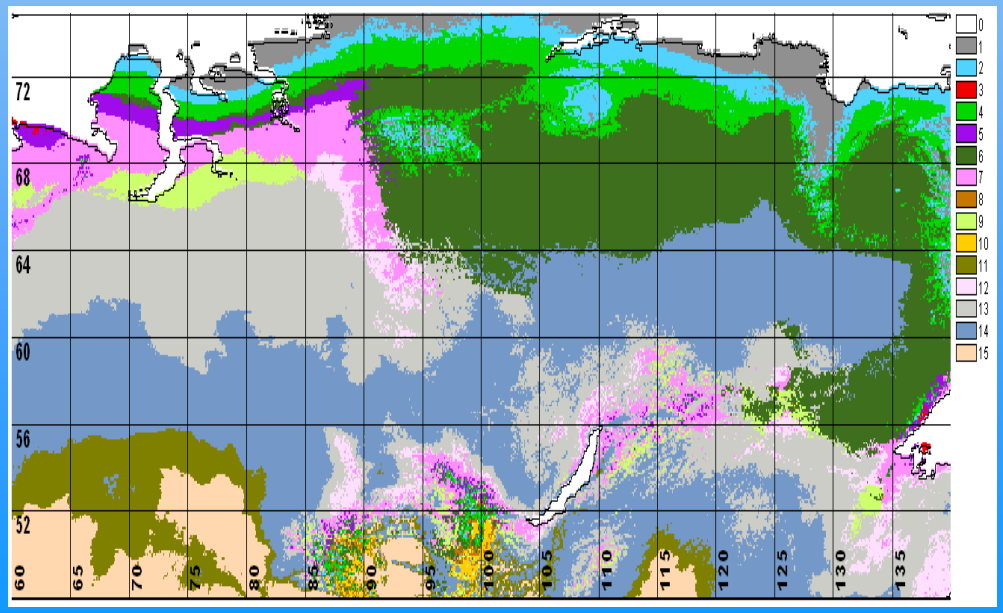
- Northern Eurasia: During the first 50 years of this century, the cumulative net carbon exchange is -13 and -93 Pg C under no-policy and no-migration and migration conditions, respectively. With policy, the region will act as a sink of 0.8 and a source of -94 Pg C under no-migration and migration conditions, respectively.

- Globe: Under the no-policy condition, the cumulative net carbon exchange is -46 and -428 Pg C over the globe under no-migration and migration in northern Eurasia by year 2050. Under the policy condition, the global cumulative source of carbon is smaller with -8 and -409 under no-migration and migration, respectively.

Vegetation Distribution in NE Simulated with SiBCliM







Vegetation distribution in Siberia for the current (top right) and in 2080 mapped by coupling our SiBCliM with bioclimatic indices and the permafrost for HadCM3 B1 (top left) and HadCM3 A2 (bottom) with no albedo feedbacks

Vegetation class key: 0- Water,;Boreal: 1 – Tundra; 2 – Forest-Tundra; Northern Taiga: 3 – dark, 4 – light; Middle taiga: 5 – dark, 6 – light; Southern Taiga: 7 – dark, 8 – light; 9 – Subtaiga, Forest-Steppe; 10– Steppe; 11 – Semidesert

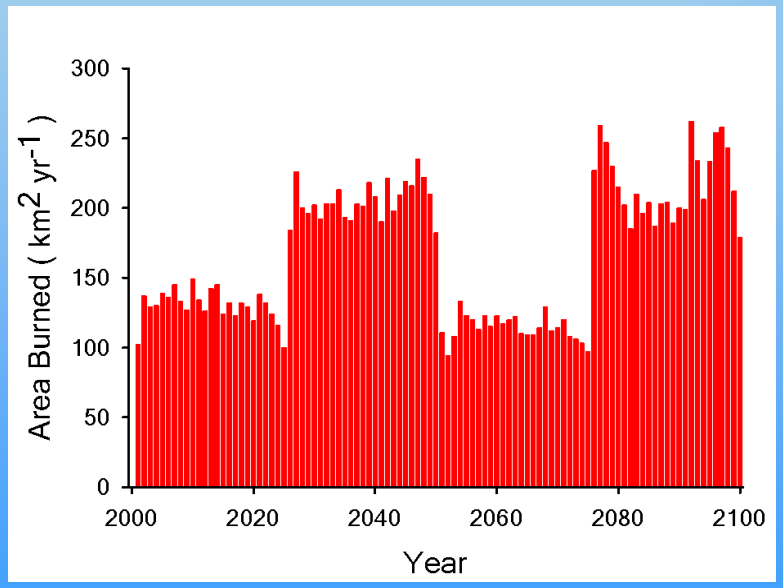
Mechanisms of Vegetation Transitions

New Vegetation Type	Old Vegetation Type								
	Tundra	Needle-leaf Evergreen Forest-Tundra	Needle-leaf Deciduous Forest-Tundra	Needle-leaf Evergreen Taiga	Needle-leaf Deciduous Taiga	Boreal Birch Subtaiga/ Temperate Broadleaf	Temperate Mixed Forest	Forest-Steppe Boreal	Forest-Steppe Temperate
Tundra	No Change	Fire	Fire	Fire	Fire	Fire	Fire	Fire	Fire
Needle-leaf Evergreen Forest-Tundra	Succession	No Change	Fire	Fire	Fire	Fire	Fire	Partial Fire	Fire
Needle-leaf Deciduous Forest-Tundra	Succession	Fire	No Change	Fire	Fire	Fire	Fire	Fire	Fire
Needle-leaf Evergreen Taiga	Succession	Succession	Fire	No Change	Fire	Fire	Fire	Succession	Fire
Needle-leaf Deciduous Taiga	Succession	Fire	Succession	Fire	No Change	Fire	Fire	Fire	Fire
Boreal Birch Subtaiga/ Temperate Broadleaf	Succession	Succession	Succession	Fire	Fire	No Change	Succession	Fire	Succession
Temperate Mixed Forest	Succession	Succession	Succession	Fire	Fire	Succession	No Change	Fire	Succession
Forest-Steppe Boreal	Fire	Partial Fire	Fire	Fire	Fire	Fire	Fire	No Change	Fire
Forest-Steppe Temperate	Fire	Fire	Fire	Fire	Fire	Partial Fire	Partial Fire	Fire	No Change
Steppe Boreal, Temperate	Fire	Fire	Fire	Fire	Fire	Fire	Fire	Fire	Fire
Semi-Desert/Desert	Fire	Fire	Fire	Fire	Fire	Fire	Fire	Fire	Fire

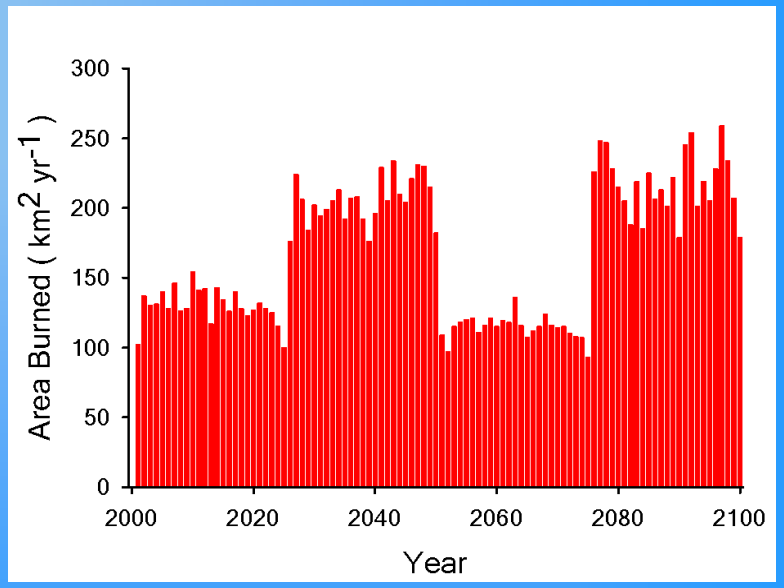
Succession - no loss of carbon due to disturbance; Fire - loss of carbon associated with fire disturbance event; Partial Fire - fire disturbance results in loss of carbon from only grasses, forbs, shrubs and perhaps some

Interannual Variability in Area Burned

No Policy

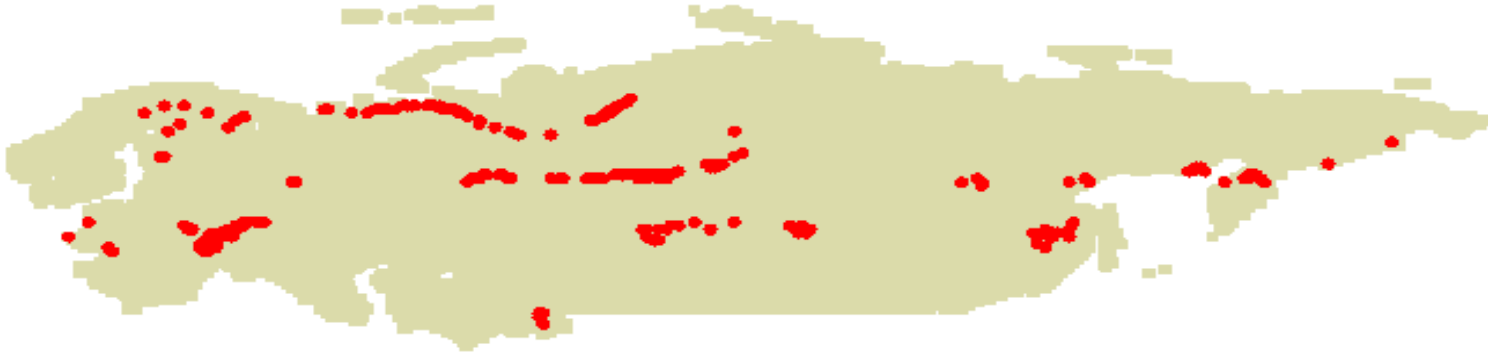


Policy

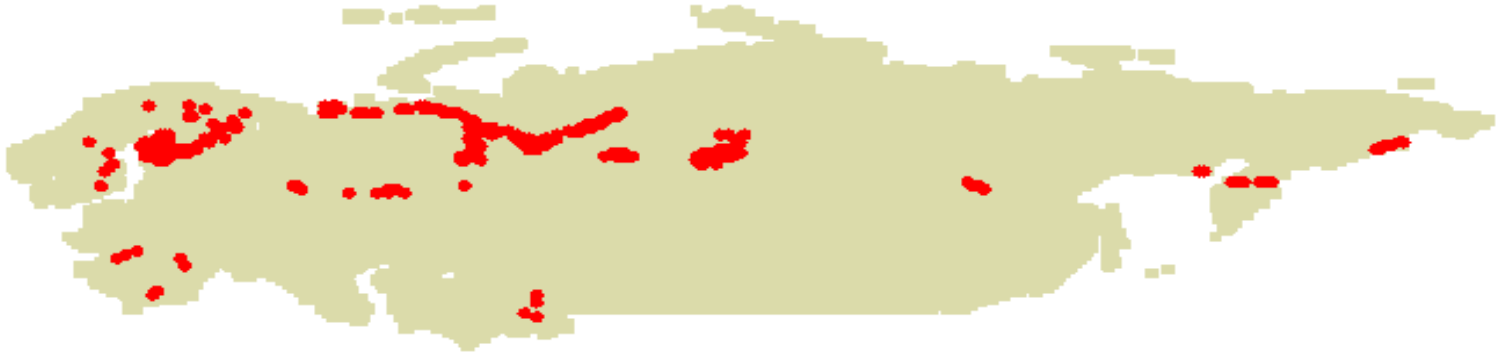


Distribution of Fire Events in the No Policy Scenario

Year 2091



Year 2092



EPPA Model

* The MIT Emissions Prediction and Policy Analysis (EPPA) model is a recursive dynamic multi-regional computable general equilibrium (CGE) model of the world economy

* The model is based on the Global Trade Analysis Project (GTAP) data base with the data aggregated into 16 regions and 25 sectors

* In the version of the model used here (EPPA4), five of these sectors require land inputs that have been stratified into five land classes— cropland, pastureland, managed forest land, unmanaged grasslands, and unmanaged forest.

•The EPPA model also incorporates United States EPA inventory data and projections on greenhouse gas (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) and air pollutant emissions (SO_2, NOx, black carbon, organic carbon, NH_3, CO, VOC) to estimate anthropogenic emissions of these compounds.

* The EPPA model projects the global economy, land use, and associated anthropogenic emissions into the future using a 5-year time step.

Table 1. Countries and Regions in the EPPA Model.

Regions in Earlier Versions	Regions in EPPA4	Europe Detail for Special Studies
Annex B		
United States (USA)	United States (USA)	
European Union (EEC)	European Union[a] (EUR)	
Eastern Europe (EET)	Eastern Europe[b] (EET)	
Japan (JPN)	Japan (JPN)	Great Britain
Former Soviet Union (FSU)	Former Soviet Union[c] (FSU)	Finland
Other OECD (OOE)	Australia & New Zealand (ANZ)	France
	Canada (CAN)	Germany
Non-Annex B		Hungary
China (CHN)	China (CHN)	Italy
India (IND)	India (IND)	Netherlands
Dynamic Asian Economies (DAE)	Higher Income East Asia[d] (ASI)	Poland
Energy Exporting LDCs (EEX)	Middle East (MES)	Spain
Brazil (BRA)	Indonesia (IDZ)	Sweden
Rest of the World (ROW)	Mexico (MEX)	EFTA (Switzerland, Norway, Iceland)
	Central & South America (LAM)	Other
	Africa (AFR)	
	Rest of World[e] (ROW)	

[a] The European Union (EU-15) plus countries of the European Free Trade Area (Norway, Switzerland, Iceland)

[b] Hungary, Poland, Bulgaria, Czech Republic, Romania, Slovakia, Slovenia

[c] Russia and Ukraine, Latvia, Lithuania and Estonia (which are included in Annex B) and Azerbaijan, Armenia, Belarus, Georgia, Kyrgyzstan, Kazakhstan, Moldova, Tajikistan, Turkmenistan, and Uzbekistan (which are not)

[d] South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand

[e] All countries not included elsewhere: Turkey, and mostly Asian countries

Table 5. World Total Fossil Resources (in exajoules).

	Total Oil (EJ)	Total Gas (EJ)	Total Coal (EJ)
USA	**1,128.5**	**1,112.0**	**24,962.9**
CAN	**3,357.3**	**178.1**	**656.8**
MEX	**547.4**	**156.9**	**60.3**
EUR	**773.8**	**1,093.6**	**9,696.9**
Denmark	16.2	20.4	5.1
France	3.6	30.8	8,928.6
Germany	7.1	47.8	4.6
Italy	9.5	62.3	67.2
Netherlands	10.1	185.9	89.3
Spain	0.9	26.3	0.1
UK	321.9	205.8	202.9
Rest of EU	0.0	0.4	398.9
EFTA (Norway)	404.5	513.8	0.1
EET	**57.7**	**75.7**	**2,380.7**
Poland	3.6	13.4	1572.4
Hungary	4.2	13.5	77.8
Rest of EET	49.9	48.8	730.4
RUS+UKR	**7,583.3**	**5,410.5**	**91,965.2**
Russia	7,534.9	5,299.1	75,534.8
Ukraine	48.4	111.4	16,430.4
JPN	**0.0**	**0.0**	**55.9**
ASI	**104.0**	**341.5**	**75.4**
IDZ	**196.5**	**440.6**	**240.7**
CHN	**558.0**	**228.1**	**13,595.0**
IND	**144.6**	**110.4**	**2,491.0**
AFR	**2,100.0**	**994.4**	**5,303.0**
South Africa	0.4	2.2	4,762.9
North Africa	888.6	523.8	5.9
Rest of Africa	1,211.0	468.3	534.2
Morocco	0.0	0.1	0.0
MES	**9,784.6**	**5,994.3**	**58.0**
LAM	**7,497.1**	**1,261.6**	**1,082.7**
Brazil	638.0	310.4	593.8
Venezuela	6,311.2	491.8	23.8
Colombia	132.9	61.3	330.9
Rest of LAM	415.0	398.1	134.2
ANZ	**92.5**	**430.1**	**5,974.1**
ROW	**1,300.7**	**1,128.5**	**20,360.3**
Baltic	0.0	0.0	0.0
Leftover FSU	725.7	799.8	18,671.8
RROW	77.6	241.9	1,171.2
Turkey	11.1	1.6	499.1
Greenland	486.2	85.2	18.3
TOTAL	**35,225.9**	**18,956.2**	**178,959.0**

Table 6. Oil Resources.

		Remaining Reserves (MMBO)	Conventional Reserve growth (MMBO)	Undiscovered (MMBO)	Total reserves + undiscovered (MMBO)	Total reserves + undiscovered (EJ)	Tar sands (EJ)	Total including Tar sands (EJ)	Readjust coefficient	Readjust Total (EJ)
USA		**32,000**	**76,000**	**83,000**	**191,000**	**1,128.5**		**1,128.5**	**1.00**	**1,128.5**
CAN		**4,871**	**3,470**	**2,774**	**11,115**	**65.7**	**1700**	**1,765.7**	**1.90**	**3,357.3**
MEX		**22,273**	**15,869**	**20,569**	**58,711**	**346.9**		**346.9**	**1.58**	**547.4**
EUR		**24,865**	**17,715**	**26,385**	**68,965**	**407.5**		**407.5**	**1.90**	**773.8**
	Denmark	790	563	95	1,448	8.6		8.6	1.90	16.2
	France	0	0	323	323	1.9		1.9	1.90	3.6
	Germany	281	200	156	637	3.8		3.8	1.90	7.1
	Italy	280	199	371	850	5.0		5.0	1.90	9.5
	Netherlands	339	242	319	900	5.3		5.3	1.90	10.1
	Spain	0	0	78	78	0.5		0.5	1.90	0.9
	UK	9,648	6,874	12,162	28,684	169.5		169.5	1.90	321.9
	ROEU	0	0	0	0	0.0		0.0	1.90	0.0
	EFTA (Norway	13,527	9,637	12,881	36,045	213.0		213.0	1.90	404.5
EET		**2,153**	**1,534**	**1,453**	**5,140**	**30.4**		**30.4**	**1.90**	**57.7**
	Poland	66	47	206	319	1.9		1.9	1.90	3.6
	Hungary	133	95	146	374	2.2		2.2	1.90	4.2
	Rest of EET	1,954	1,392	1,101	4,447	26.3		26.3	1.90	49.9
RUS + UKR		**131,242**	**93,504**	**78,722**	**303,468**	**1,793.0**	**2200**	**3,993.0**	**1.90**	**7,583.3**
	Russia	129,507	92,268	77,382	299,157	1,767.5	2200	3,967.5	1.90	7,534.9
	Ukraine	1,735	1,236	1,340	4,311	25.5		25.5	1.90	48.4
JPN		**0**	**0**	**0**	**0**	**0.0**		**0.0**	**n/a**	**0.0**
ASI		**4,003**	**2,852**	**3,228**	**10,083**	**59.6**		**59.6**	**1.75**	**104.0**
IDZ		**7,968**	**5,677**	**7,435**	**21,080**	**124.5**		**124.5**	**1.58**	**196.5**
CHN		**24,519**	**17,469**	**12,115**	**54,103**	**319.7**		**319.7**	**1.75**	**558.0**
IND		**6,693**	**4,768**	**2,556**	**14,017**	**82.8**		**82.8**	**1.75**	**144.6**
AFR		**63,929**	**45,547**	**94,148**	**203,624**	**1,203.1**		**1,203.1**	**1.75**	**2,100.0**
	South Africa	0	0	35	35	0.2		0.2	1.75	0.4
	North Africa	37,876	26,985	21,302	86,163	509.1		509.1	1.75	888.6
	Rest of Africa	26,053	18,562	72,807	117,422	693.8		693.8	1.75	1,211.0
	Morocco	0	0	4	4	0.0		0.0	1.75	0.0
MES		**490,525**	**349,478**	**209,426**	**1,049,429**	**6,200.4**		**6,200.4**	**1.58**	**9,784.6**
LAM		**50,275**	**35,819**	**99,262**	**185,356**	**1,095.1**	**3200**	**4,295.1**	**1.75**	**7,497.1**
	Brazil	8,826	6,288	46,746	61,860	365.5		365.5	1.75	638.0
	Venezuela	29,605	21,092	19,664	70,361	415.7	3200	3,615.7	1.75	6,311.2
	Colombia	4,538	3,233	5,120	12,891	76.2		76.2	1.75	132.9
	Rest of LAM	7,306	5,205	27,732	40,243	237.8		237.8	1.75	415.0
ANZ		**1,869**	**1,332**	**5,032**	**8,233**	**48.6**		**48.6**	**1.90**	**92.5**
ROW		**23,705**	**16,889**	**85,527**	**126,121**	**745.2**		**745.2**	**1.75**	**1,300.7**
	Baltic	0	0	0	0	0.0		0.0	1.75	0.0
	Leftover FSU	21,018	14,974	34,376	70,368	415.8		415.8	1.75	725.7
	RROW	2,494	1,777	3,254	7,525	44.5		44.5	1.75	77.6
	Turkey	193	138	749	1,080	6.4		6.4	1.75	11.1
	Greenland	0	0	47,148	47,148	278.6		278.6	1.75	486.2

Table 7. Gas Resources.

		Remaining Reserves (BCFG)	Conventional Reserve growth (BCFG)	Undiscovered (BCFG)	Total reserves + undiscovered (BCFG)	Total reserves + undiscovered (EJ)	Readjust coefficient	Readjust Total (EJ)
USA		**172,000**	**355,000**	**527,000**	**1,054,000**	**1,112.03**	**1.00**	**1,112.03**
CAN		**51,302**	**36,692**	**24,519**	**112,513**	**118.71**	**1.50**	**178.06**
MEX		**33,213**	**23,754**	**49,272**	**106,239**	**112.09**	**1.40**	**156.92**
EUR		**250,470**	**179,139**	**311,316**	**740,925**	**781.72**	**1.40**	**1,093.55**
	Denmark	7,616	5,447	777	13,840	14.60	1.40	20.43
	France	0	0	20,861	20,861	22.01	1.40	30.79
	Germany	11,320	8,096	12,993	32,409	34.19	1.40	47.83
	Italy	8,720	6,237	27,272	42,229	44.55	1.40	62.33
	Netherlands	68,455	48,960	8,554	125,969	132.90	1.40	185.92
	Spain	0	0	17,795	17,795	18.77	1.40	26.26
	UK	57,985	41,472	39,958	139,415	147.09	1.40	205.77
	ROEU	115	82	70	267	0.28	1.40	0.39
	EFTA (Norway)	96,259	68,846	183,036	348,141	367.31	1.40	513.83
EET		**21,125**	**15,109**	**11,574**	**47,808**	**50.44**	**1.50**	**75.66**
	Poland	3,286	2,350	2,822	8,458	8.92	1.50	13.39
	Hungary	3,510	2,510	2,508	8,528	9.00	1.50	13.50
	Rest of EET	14,329	10,248	6,244	30,821	32.52	1.50	48.78
RUS+UKR		**1,438,135**	**1,028,573**	**1,196,271**	**3,662,979**	**3,864.65**	**1.40**	**5,410.51**
	Russia	1,410,212	1,008,602	1,168,735	3,587,549	3,785.07	1.40	5,299.09
	Ukraine	27,923	19,971	27,536	75,430	79.58	1.40	111.42
JPN		**0**	**0**	**0**	**0**	**0.00**	**n/a**	**0.00**
ASI		**92,621**	**66,244**	**56,939**	**215,804**	**227.69**	**1.50**	**341.53**
IDZ		**111,098**	**79,459**	**107,710**	**298,267**	**314.69**	**1.40**	**440.56**
CHN		**34,001**	**24,318**	**85,786**	**144,105**	**152.04**	**1.50**	**228.06**
IND		**23,035**	**16,475**	**30,279**	**69,789**	**73.63**	**1.50**	**110.45**
AFR		**339,921**	**243,116**	**359,481**	**942,518**	**994.41**	**1.00**	**994.41**
	South Africa	15	11	2,085	2,111	2.23	1.00	2.23
	North Africa	232,489	166,279	97,667	496,435	523.77	1.00	523.77
	Rest of Africa	107,417	76,826	259,623	443,866	468.30	1.00	468.30
	Morocco	0	0	106	106	0.11	1.00	0.11
MES		**1,615,780**	**1,155,627**	**1,286,790**	**4,058,197**	**4,281.63**	**1.40**	**5,994.28**
LAM		**223,610**	**159,929**	**470,576**	**854,115**	**901.14**	**1.40**	**1,261.59**
	Brazil	9,173	6,561	194,408	210,142	221.71	1.40	310.40
	Venezuela	135,079	96,610	101,240	332,929	351.26	1.40	491.76
	Colombia	18,323	13,105	10,101	41,529	43.82	1.40	61.34
	Rest of LAM	61,035	43,653	164,827	269,515	284.35	1.40	398.09
ANZ		**92,013**	**65,809**	**113,954**	**271,776**	**286.74**	**1.50**	**430.11**
ROW		**294,195**	**210,412**	**565,021**	**1,069,628**	**1,128.52**	**1.00**	**1,128.52**
	Baltic	0	0	0	0	0.00	1.00	0.00
	Leftover FSU	230,685	164,989	362,434	758,108	799.85	1.00	799.85
	RROW	63,062	45,103	121,129	229,294	241.92	1.00	241.92
	Turkey	448	320	749	1,517	1.60	1.00	1.60
	Greenland	0	0	80,709	80,709	85.15	1.00	85.15
TOTAL		**4,792,519**	**3,659,656**	**5,196,488**	**13,648,663**	**14,400.10**	**n/a**	**18,956.23**

Table 8. Coal Resources.

	Reserve Coal (MT)	Reserve coal (EJ)	Aggregate UNDP region	Share in aggregated region (%)	Coal resources (EJ) of aggregated region	Coal resource (EJ)
USA	**249,994**	**6,462.06**	**1**	**97**	**25,638**	**24,962.89**
CAN	**6,578**	**170.03**	**1**	**3**	**25,638**	**656.84**
MEX	**1,211**	**31.30**	**2**	**5**	**1,143**	**60.28**
EUR	**71,680**	**1,852.85**	**3**	**95**	**10,196**	**9,696.95**
France	38	0.98	3	0	10,196	5.14
Germany	66,000	1,706.03	3	88	10,196	8,928.55
Italy	34	0.88	3	0	10,196	4.60
Netherlands	497	12.85	3	1	10,196	67.23
Spain	660	17.06	3	1	10,196	89.29
Sweden	1	0.03	3	0	10,196	0.14
United Kingdom	1,500	38.77	3	2	10,196	202.92
Rest of EU	2,949	76.23	3	4	10,196	398.94
AFTA	1	0.03	3	0	10,196	0.14
EET	**33,550**	**867.23**	**4**	**68**	**3,516**	**2,380.66**
Poland	22,160	572.81	4	45	3,516	1,572.44
Hungary	1,097	28.36	4	2	3,516	77.84
Rest of EET	10,293	266.06	4	21	3,516	730.38
RUS+UKR	**191,163**	**4,941.35**	**5**	**83**	**110,637**	**91,965.22**
Russian Fed.	157,010	4,058.53	5	68	110,637	75,534.80
Ukraine	34,153	882.82	5	15	110,637	16,430.42
JPN	**773**	**19.98**	**11**	**1**	**6,030**	**55.87**
ASI	**1,683**	**43.50**	**8**	**21**	**352**	**75.44**
IDZ	**5,370**	**138.81**	**8**	**68**	**352**	**240.70**
CHN	**114,500**	**2,959.70**	**10**	**100**	**13,595**	**13,595.00**
IND	**84,396**	**2,181.54**	**9**	**100**	**2,491**	**2,491.00**
AFR	**55,367**	**1,431.17**	**7**	**100**	**5,303**	**5,303.00**
South Africa	49,728	1,285.41	7	90	5,303	4,762.90
North Africa	62	1.60	7	0	5,303	5.94
Rest of Africa	5,577	144.16	7	10	5,303	534.16
Morocco		0.00	7	0	5,303	0.00
MES	**1,710**	**44.20**	**6**	**100**	**58**	**58.00**
LAM	**21,752**	**562.26**	**2**	**95**	**1,143**	**1,082.72**
Brazil	11,929	308.35	2	52	1,143	593.77
Venezuela	479	12.38	2	2	1,143	23.84
Colombia	6,648	171.84	2	29	1,143	330.91
Rest of LAM	2,696	69.69	2	12	1,143	134.20
ANZ	**82,662**	**2,136.72**	**11**	**99**	**6,030**	**5,974.13**
ROW	**62,064**	**1,604.28**	**n/a**			**20,360.28**
Baltic		0.00	5	0	110,637	0.00
Leftover FSU	38,812	1,003.25	5	17	110,637	18,671.78
RROW	19,380	500.95	8 and 4	10,19 (8) and 32,29 (4)	352	1,171.17
Turkey	3,689	95.36	3	5	10,196	499.05
Greenland	183	4.73	1	0	25,638	18.27
TOTAL	**984,453**	**25,447.00**	**N/a**	**n/a**	**n/a**	**178,958.98**

Table 17. Annual Real GDP Growth Rates for 1997-2005.

	1997-2000	2000-2005
USA	4.23	2.53
CAN	4.89	2.98
MEX	5.32	2.13
JPN	0.62	0.71
ANZ	4.13	3.57
EUR	3.14	1.74
EET	3.26	3.44
FSU	3.12	4.79
ASI	2.4	3.64
CHN	7.34	7.91
IND	6.33	5.77
IDZ	–2.7	4.01
AFR	2.81	4.22
MES	3.41	3.26
LAM	1.18	1.96
ROW	3.35	3.91

Table 18. UN Population Forecast (in millions).

	2000	2025	2050	2075	2100
USA	283.4	347.1	397.4	395.6	392.9
CHN	1,282.0	1,479.5	1,471.7	1,379.9	1,334.3
IND	1,008.9	1,351.8	1,572.1	1,633.5	1,643.3
AFR	792.9	1,357.2	1999.4	2,344.7	2,499.8
JPN	127.1	123.8	109.2	117.0	119.5
CAN	30.8	36.7	40.4	40.2	39.9
MEX	98.9	130.2	146.7	155.3	159.0
EUR	389.6	384.8	352.0	307.5	288.5
EET	96.6	89.6	78.2	68.2	63.9
FSU	290.9	274.1	248.4	235.8	229.8
ASI	211.4	272.9	304.9	326.5	333.6
IDZ	212.8	274.1	312.7	334.9	342.2
MES	174.1	298.3	430.3	460.8	470.8
LAM	419.3	563.7	657.8	696.5	713.4
ANZ	22.9	27.8	30.9	32.4	32.9
ROW	615.1	925.1	1,170.1	1,247.9	1,273.1
World	**6,056.7**	**7,936.7**	**9,322.3**	**9,776.7**	**9,936.9**

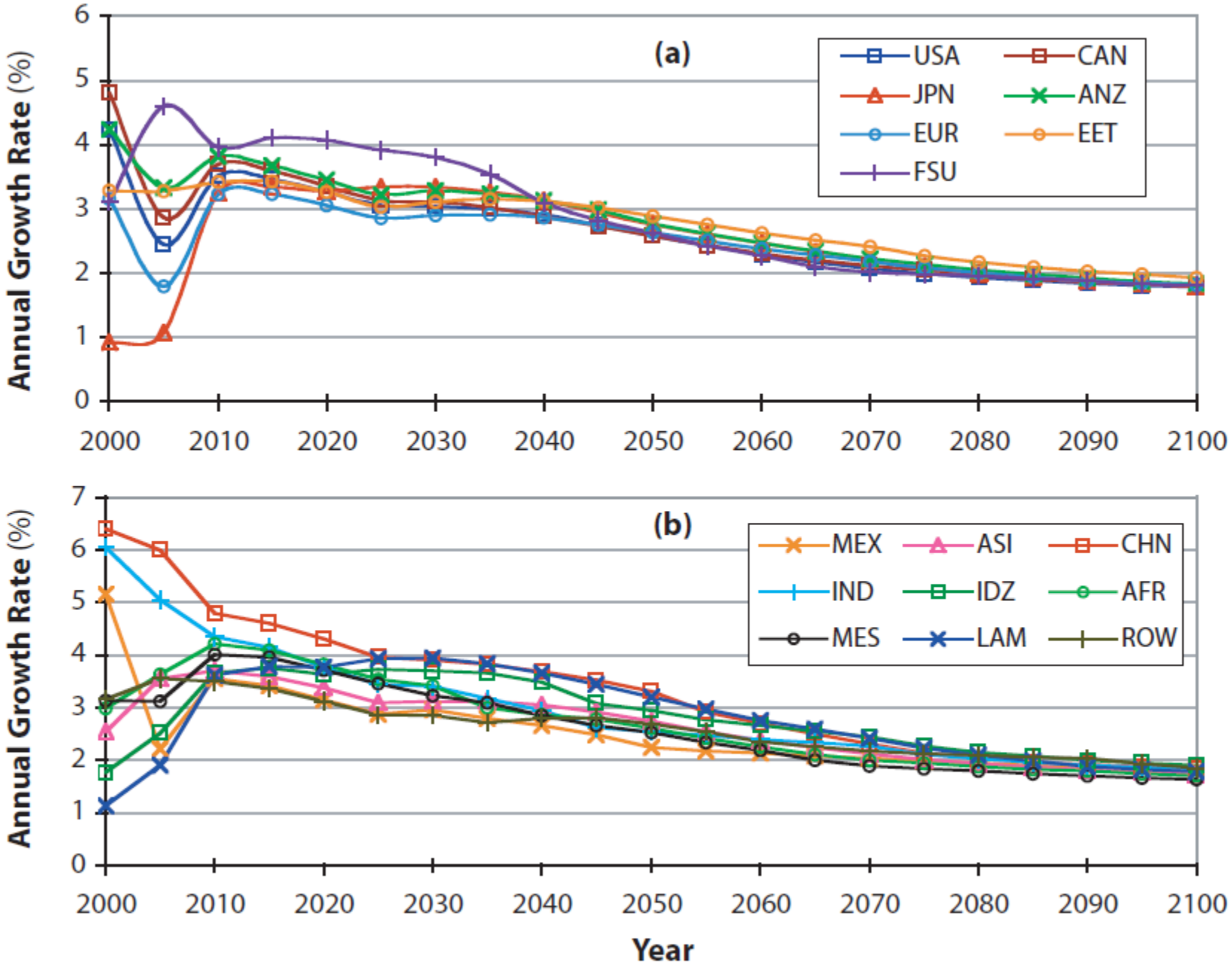


Figure 7. Annual GDP Growth Rates: **(a)** Developed and Transition Countries, **(b)** Developing Countries.