

Ecosystem services under changing climate



Oleg Anisimov

oleg@oa7661.spb.edu

State Hydrological Institute, St.Petersburg, Russia

Overview

1. Ecosystems, including vegetation, provide important services to the population and environment
2. Distribution and productivity of vegetation are likely to change under changing climatic conditions
3. How vegetation zones can change in the 21st century?
4. How vegetation productivity can change?

Vegetation change



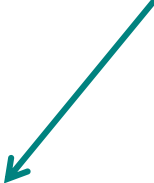
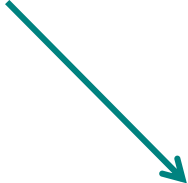
Biome shift

Productivity changes



Biome boundaries model

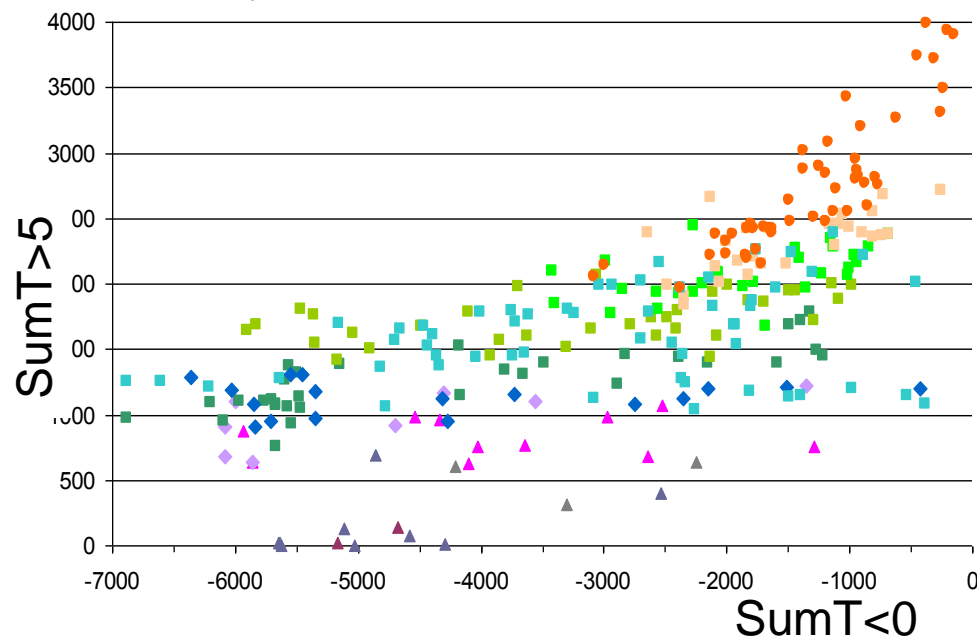
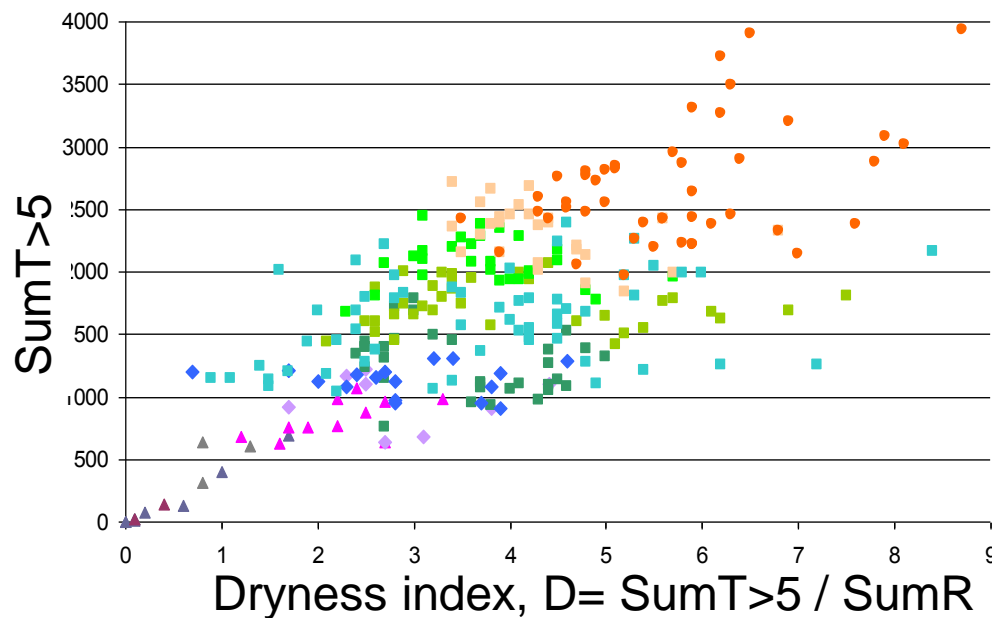
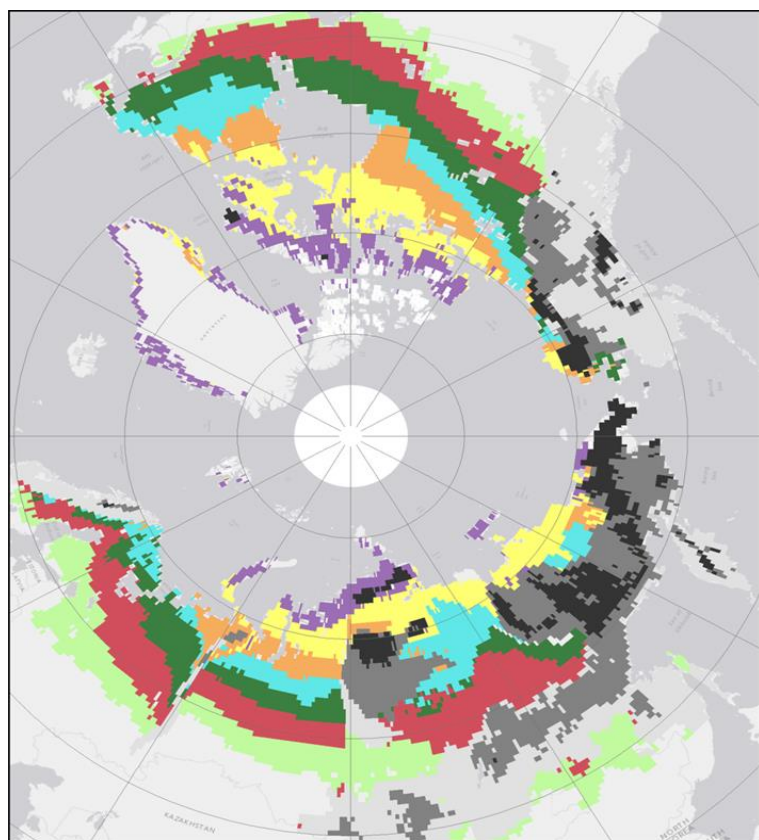
Productivity model



Ecosystem services change

Statistical vegetation zones model

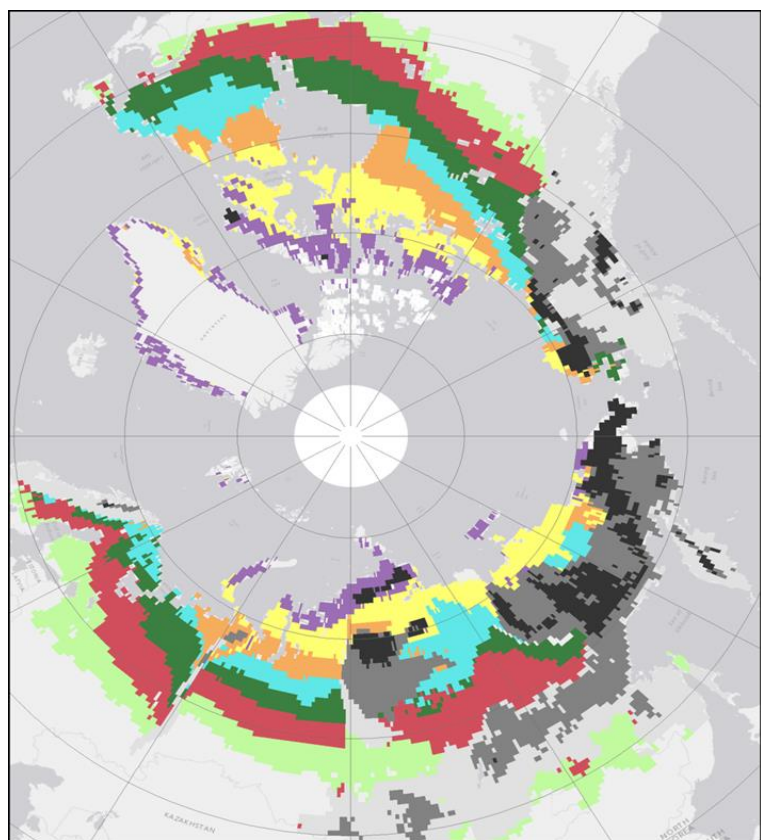
(Anisimov et al. 2017)



- Northern tundra
- Typical tundra
- Southern tundra
- Forest-tundra
- Northern taiga
- Middle taiga
- Southern taiga
- Alpine

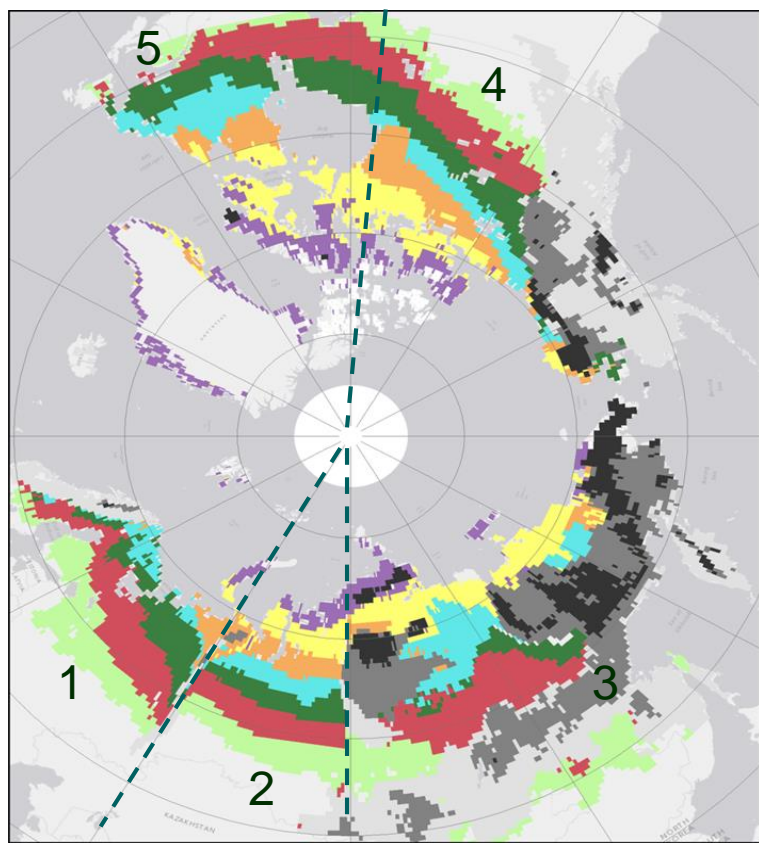
Climatic limits of the vegetation zones

(Anisimov et al. 2017)



- Northern tundra
- Typical tundra
- Southern tundra
- Forest-tundra
- Northern taiga
- Middle taiga
- Southern taiga
- Alpine

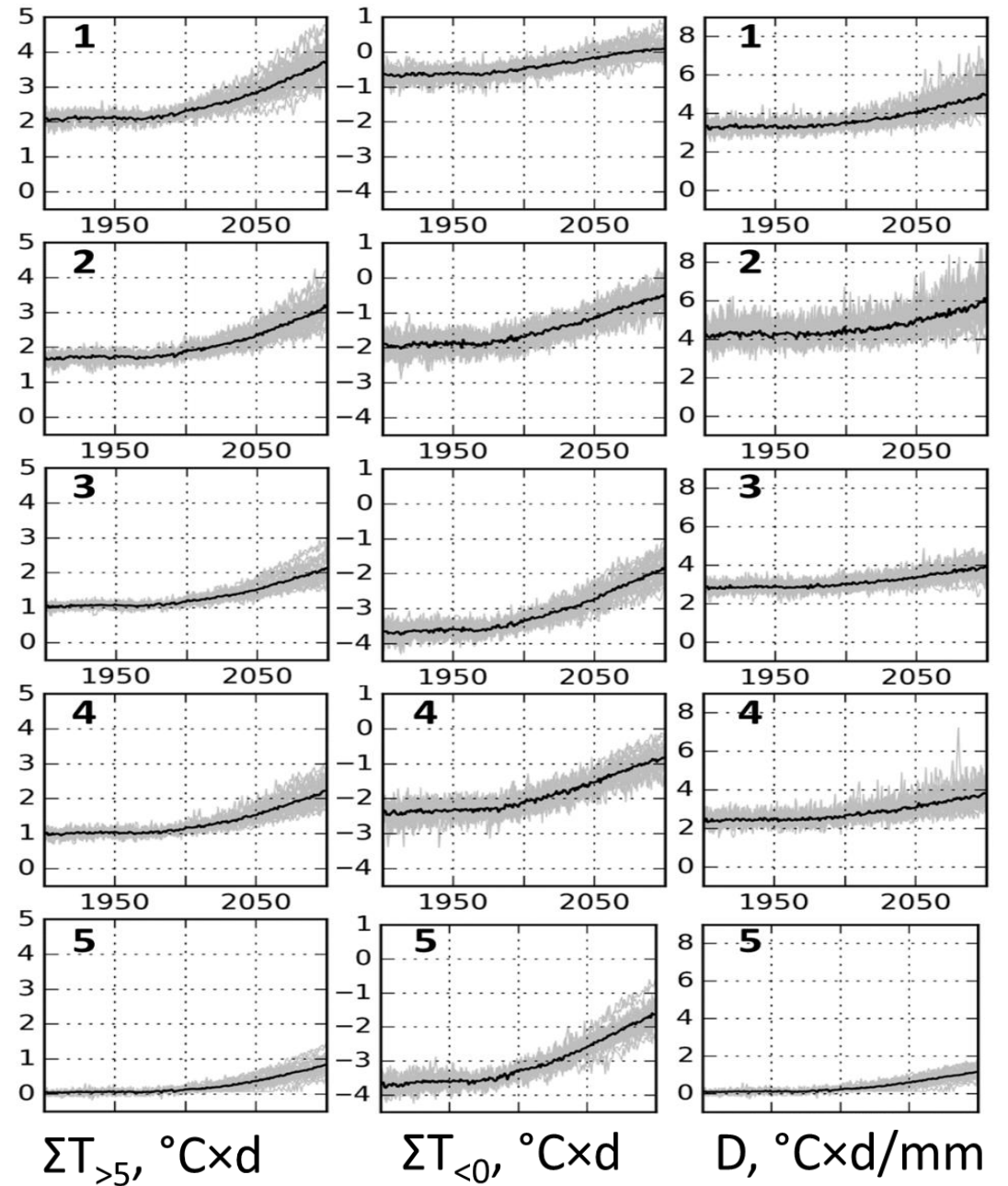
#	$\Sigma T_{>5}, ^\circ\text{C}\times\text{days}$		$\Sigma T_{<0}, ^\circ\text{C}\times\text{days}$		D, $^\circ\text{C}\times\text{d}/\text{mm}$	
	Lower	Upper	Lower	Upper	Lower	Upper
1	0	50÷110	-9000	-4000	0.0	1.1÷1.7
2	0÷90	400÷1000	-8000	-1100	0.0	2.1÷6.1
3	50÷250	800÷1250	-7500	-1090	0.0÷0.2	2.5÷7.5
4	200÷800	1100÷1600	-7000	-1050	0.5÷1.7	3.1÷7.6
5	500÷1000	1200÷1500	-6800	-1020	0.8÷2.3	1.8÷7.2
6	650÷1100	1700÷1950	-6000	-1000	0.8÷2.1	3.5÷7.9
7	1200÷1550	2000÷2300	-5400	-700	0.9÷2.7	4.0÷8.5
8	1500÷1800	2200÷2700	-3800	-400	1.1÷3.4	4.3÷8.7
9	700	2500÷3000	-6000	0.0	0.6	10.0
10	200	1500	-8000	-1500	0.0	5.0÷7.0
11	0	1200	-9000	-2500	0.0	3.9÷5.0

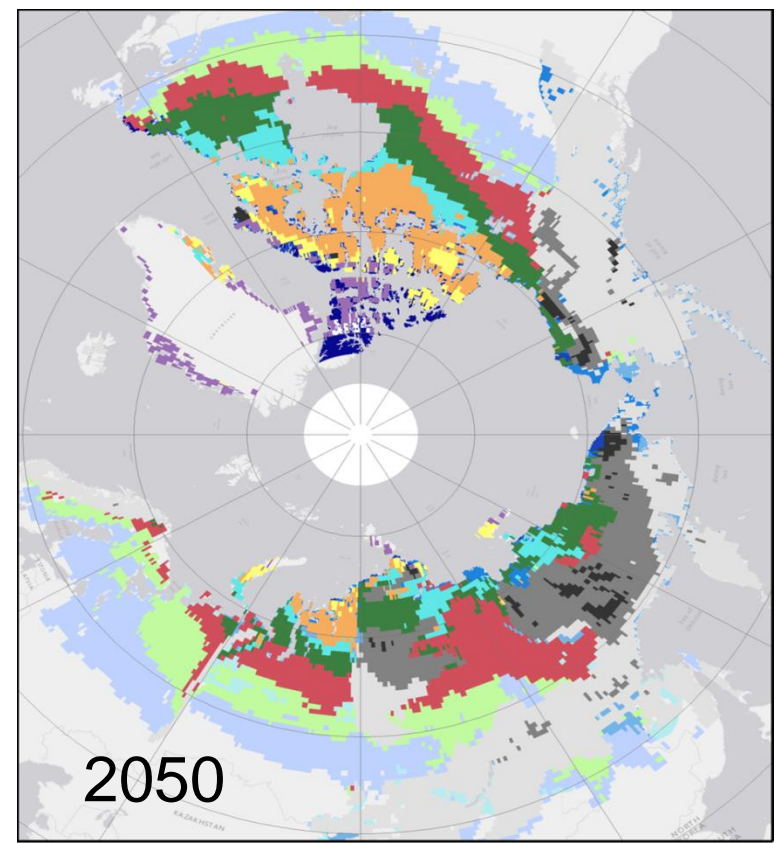
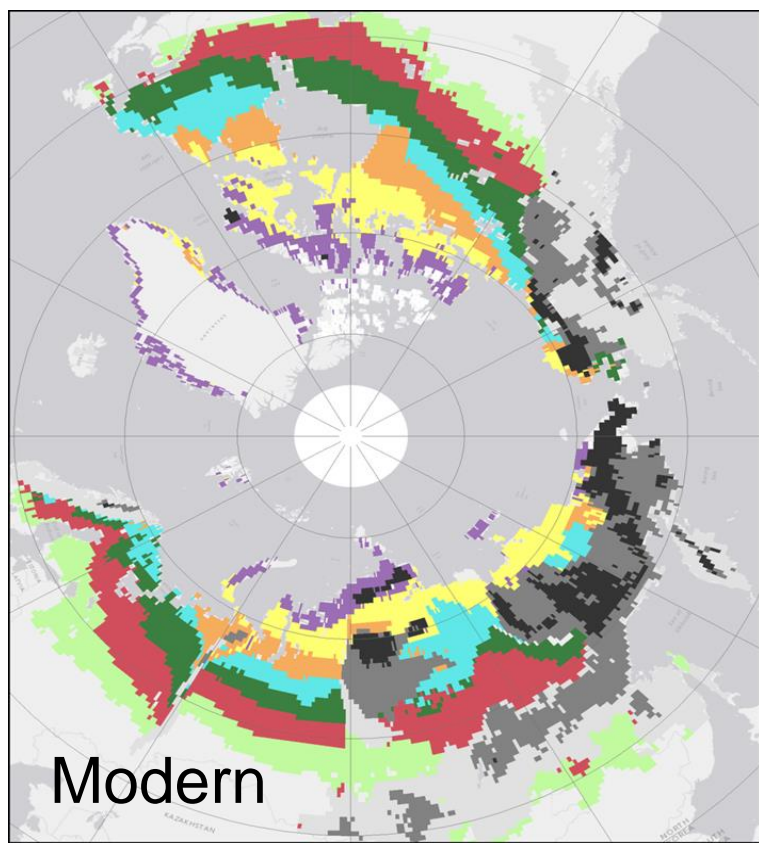








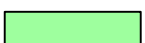

- Northern tundra
- Typical tundra
- Southern tundra
- Forest-tundra
- Northern taiga
- Middle taiga
- Southern taiga
- Alpine

Projected climate parameters change

(Anisimov and Kokorev 2016)



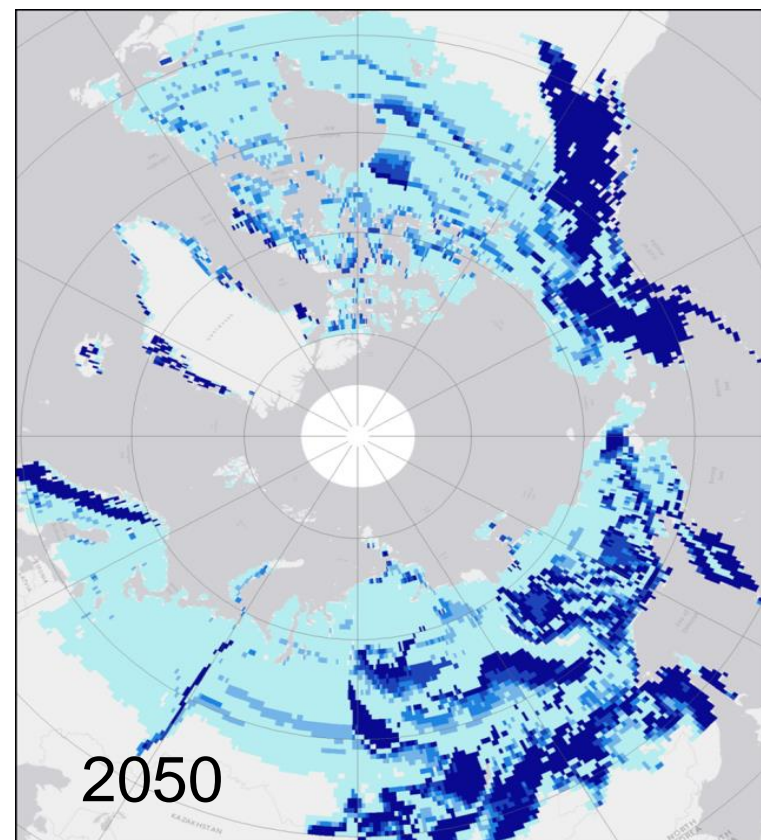
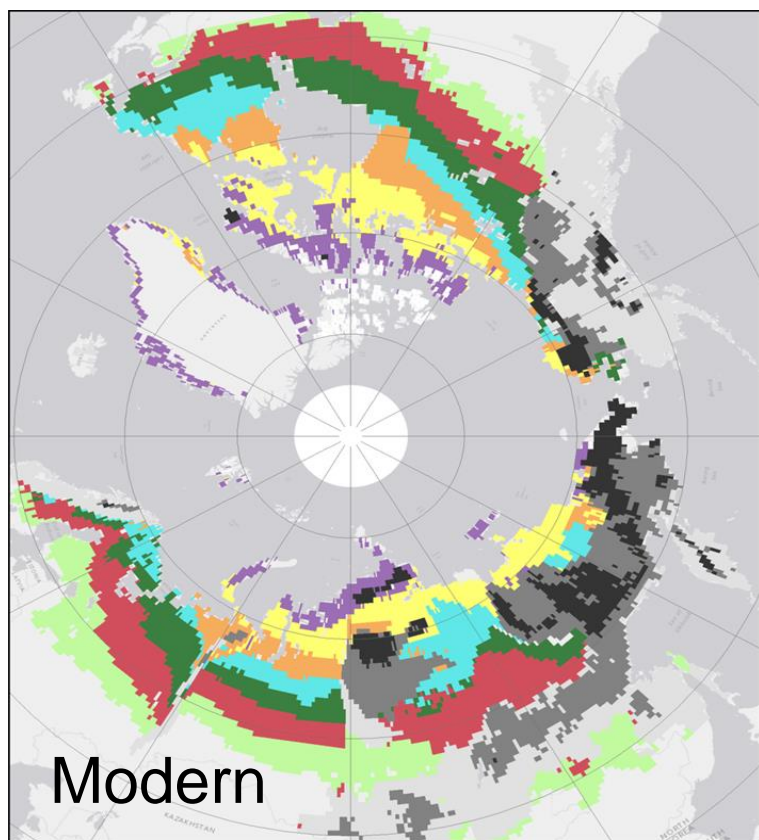










-  Northern tundra
-  Typical tundra
-  Southern tundra
-  Forest-tundra
-  Northern taiga
-  Middle taiga
-  Southern taiga
-  Alpine

-  Temperate forest

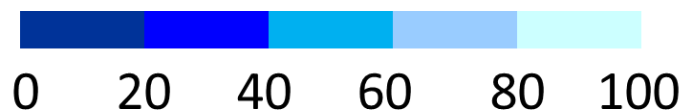
Projected by 2050
vegetation zones shift

(Anisimov et al. 2017)



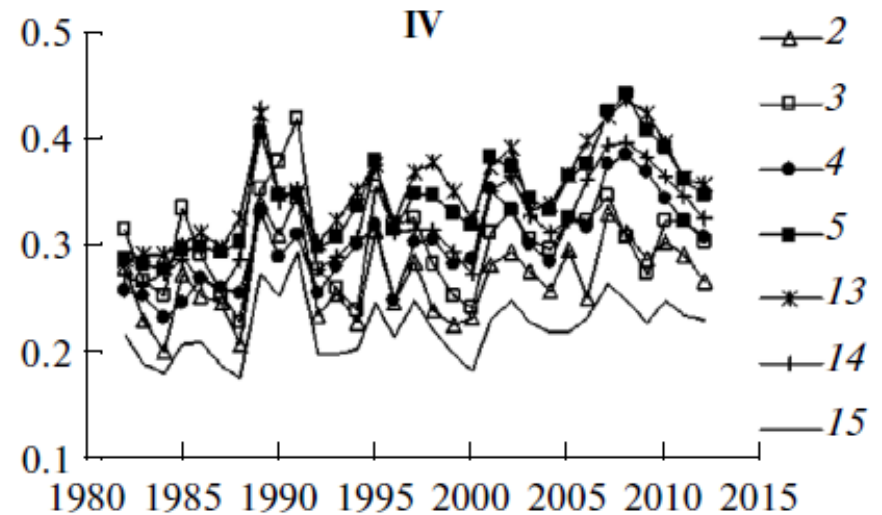
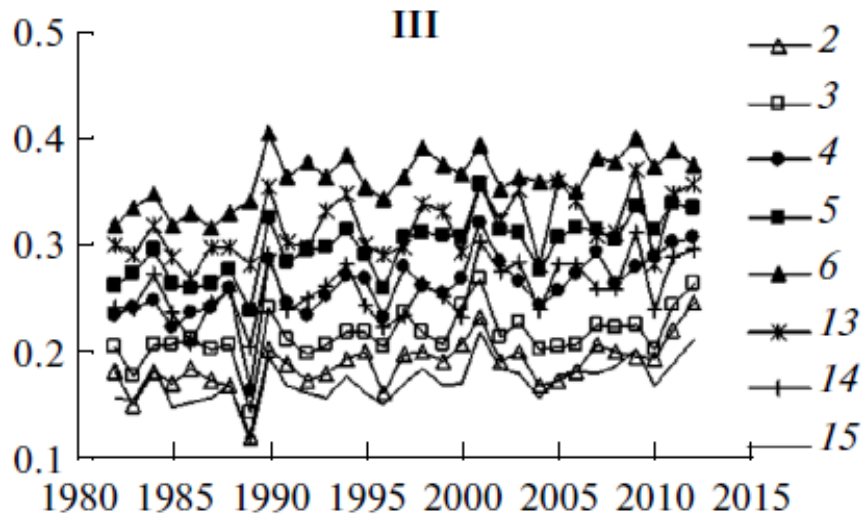
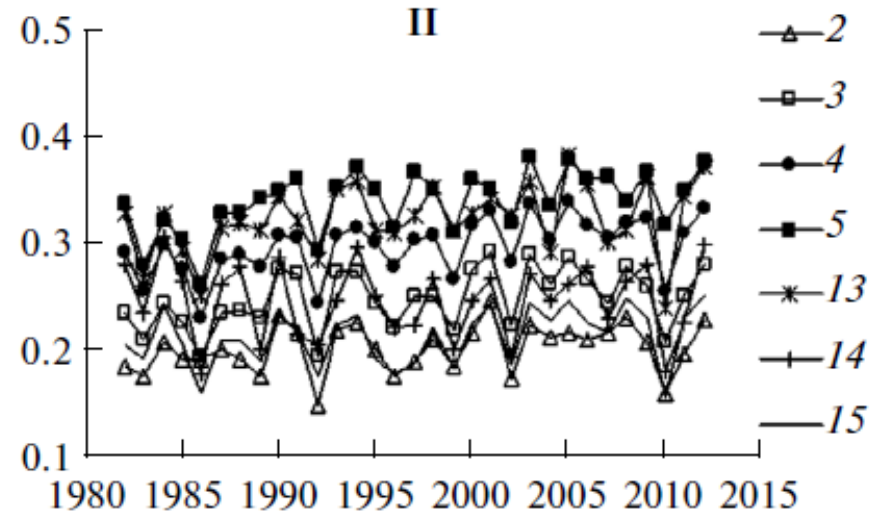
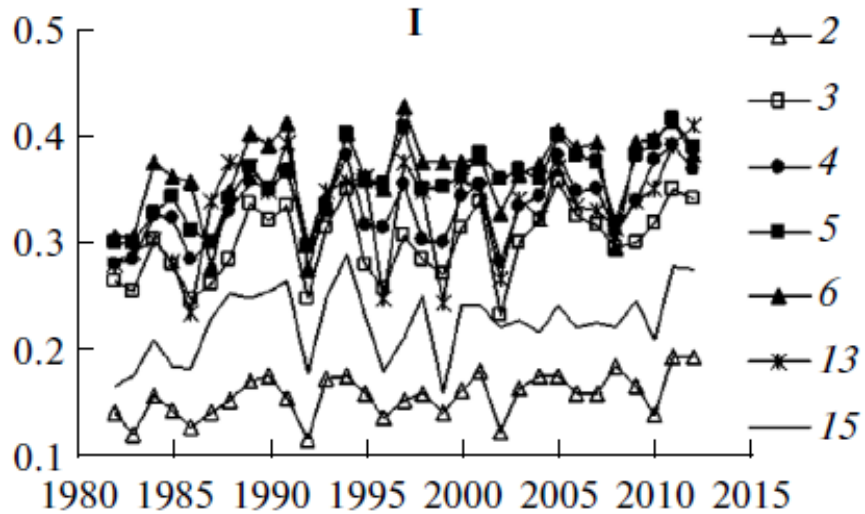
-  Northern tundra
-  Typical tundra
-  Southern tundra
-  Forest-tundra
-  Northern taiga
-  Middle taiga
-  Southern taiga
-  Alpine

Probability of biome
change by 2050, %



(Anisimov et al. 2017)

NDVI-based biome productivity model (*Anisimov et al. 2017*)



NDVI variations in 4 sectors in the NH

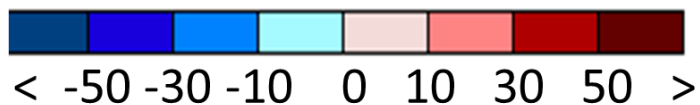
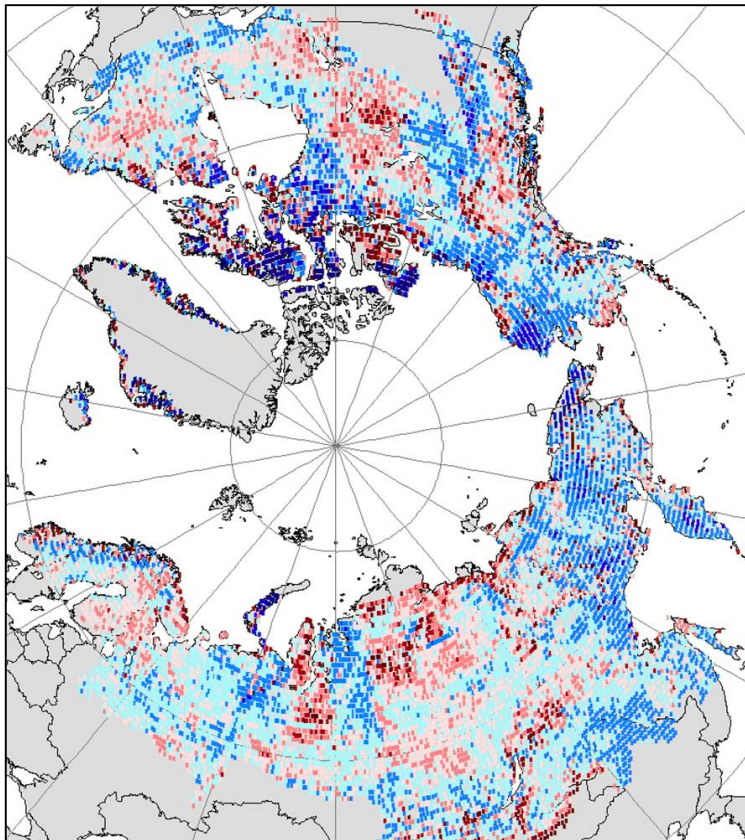
NDVI-based biome productivity model (*Anisimov et al. 2017*)

Zone	European Russia				West Siberia				East Siberia				Far East			
	average	trend (% per 10 years)	correlation coefficients		average	trend (% per 10 years)	correlation coefficients		average	trend (% per 10 years)	correlation coefficients		average	trend (% per 10 years)	correlation coefficients	
			ΣT_{5+}	ΣR			ΣT_{5+}	ΣR			ΣT_{5+}	ΣR			ΣT_{5+}	ΣR
2	0.157	7	0.78	-0.16	0.225	3.5	0.66	-0.55	0.129	7.9	0.73	-0.29	0.272	4.8	0.70	-0.04
3	0.300	5.7	0.70	-0.09	0.201	5.2	0.78	-0.54	0.190	5.5	0.68	-0.37	0.305	2	0.54	-0.15
4	0.333	5.4	0.64	-0.09	0.248	5.1	0.77	-0.36	0.217	8	0.81	-0.07	0.302	10.9	0.65	0.05
5	0.356	7	0.50	-0.23	0.296	4.7	0.69	-0.33	0.263	7	0.74	0.04	0.345	9.9	0.62	0.17
6	0.365	4.7	0.39	-0.10	—	—	—	—	0.301	4.7	0.42	-0.08	—	—	—	—
13	0.365	5.1	0.80	-0.19	0.338	3.4	0.64	-0.42	0.319	4.7	0.66	-0.37	0.354	9	0.59	0.37
14	—	—	—	—	0.322	-0.4	0.57	-0.60	0.260	5.8	0.74	-0.30	0.326	8.6	0.64	0.20
15	0.331	5.8	0.64	-0.06	0.246	4.2	0.86	-0.44	0.174	6.9	0.82	-0.31	0.225	4.9	0.72	-0.12

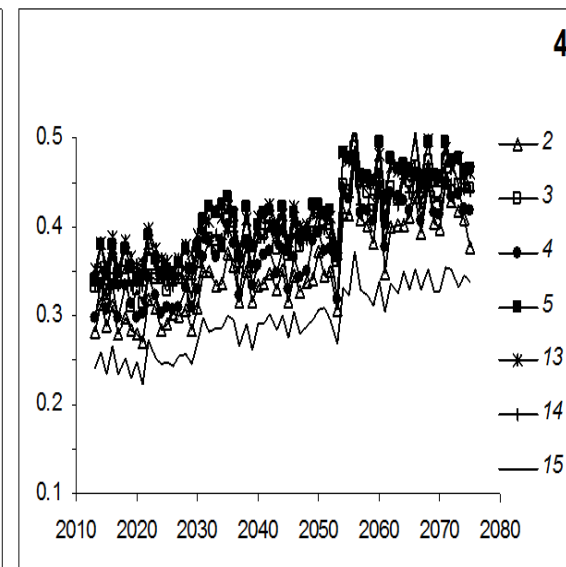
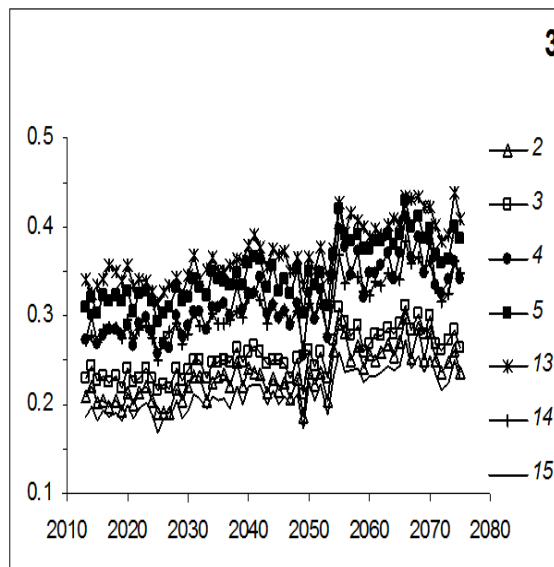
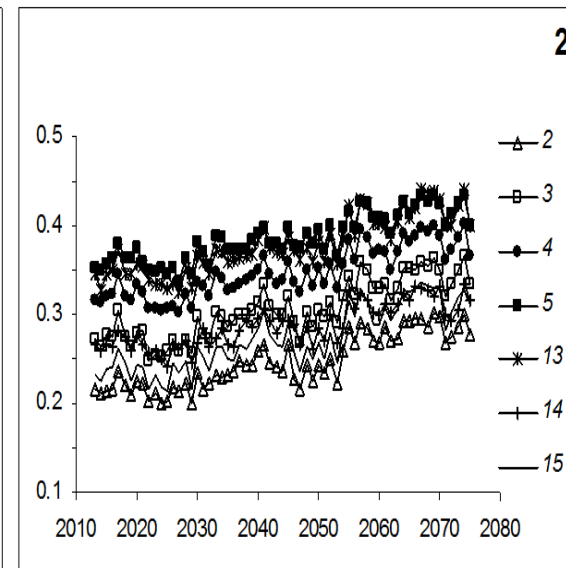
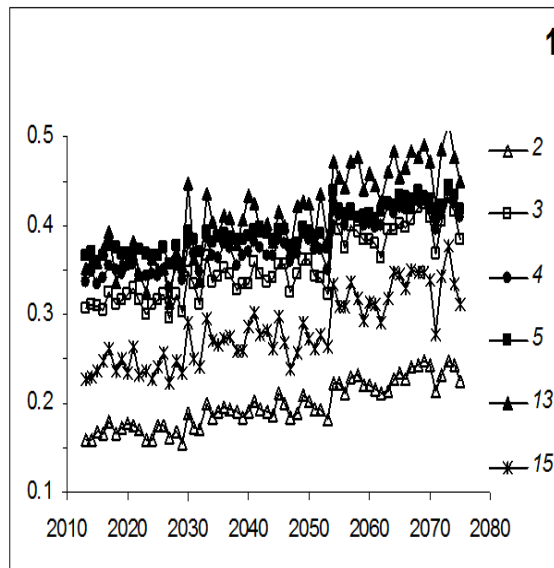
Correlation of NDVI with climate predictors

Projected GPP changes for biomes in 4 sectors (in NDVI units)

(Anisimov et al. 2017)



Difference between observed and calculated NDVI for the 1982-2015 period, (%)



NDVI-based biome productivity model (*Anisimov et al. 2017*)

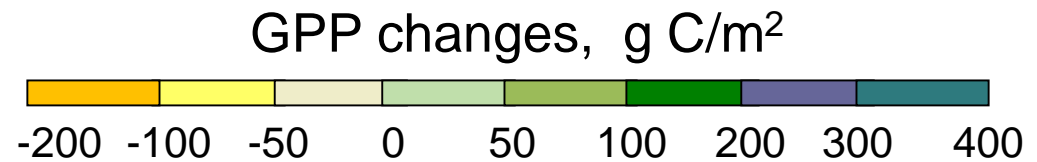
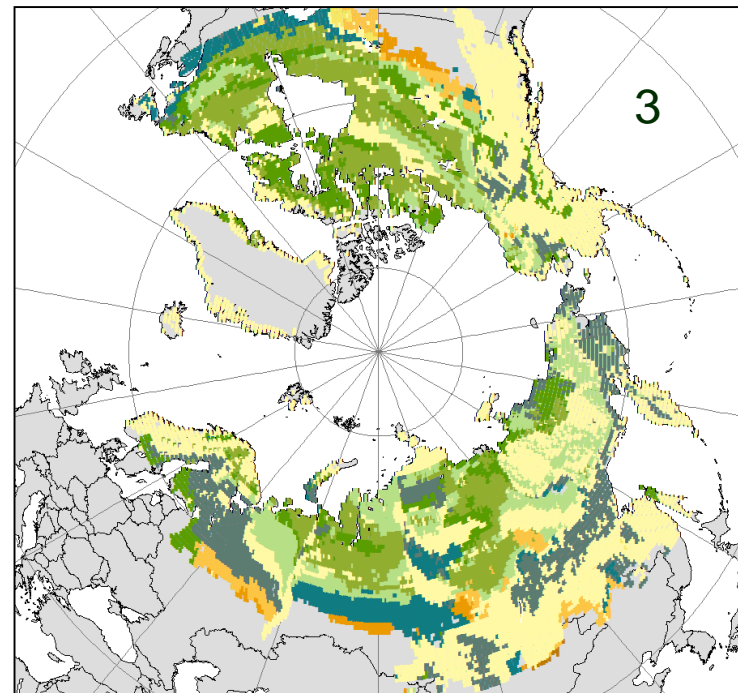
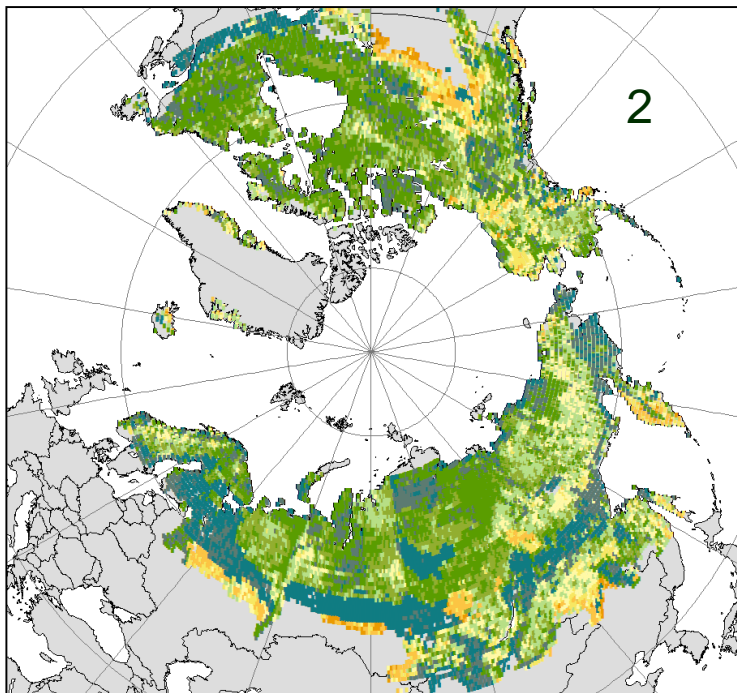
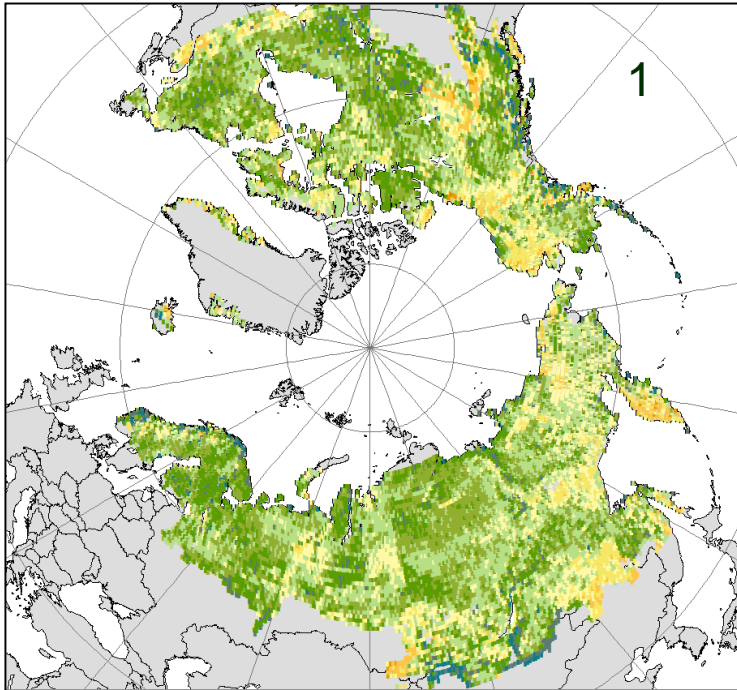
Zone	European Russia				West Siberia				East Siberia				Far East			
	2015–2045		2035–2065		2015–2045		2035–2065		2015–2045		2035–2065		2015–2045		2035–2065	
	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %	NDVI	Δ NDVI, %
2	0.180	14.6	0.205	30.6	0.228	13.4	0.256	27.4	0.216	13.7	0.239	25.8	0.316	16.2	0.367	34.9
3	0.328	9.3	0.362	20.7	0.285	14.9	0.315	27.0	0.240	10.6	0.261	20.3	0.359	17.7	0.411	34.8
4	0.358	7.5	0.386	15.9	0.329	11.1	0.354	19.6	0.295	12.2	0.327	24.3	0.339	12.3	0.388	28.5
5	0.378	6.2	0.400	12.4	0.369	9.2	0.393	16.3	0.329	9.3	0.358	18.9	0.383	11.0	0.431	24.9
13	0.38	14.8	0.426	28.7	0.357	10.9	0.385	19.6	0.351	10.0	0.378	18.5	0.387	9.3	0.429	21.2
14	–	–	–	–	0.273	11.0	0.294	19.5	0.290	11.5	0.316	21.5	0.365	12.0	0.405	24.2
15	0.259	15.1	0.290	28.9	0.251	18.4	0.281	32.5	0.199	14.4	0.220	26.4	0.267	18.7	0.306	36.0

Projected NDVI changes

Projected by 2050 GPP changes

(Anisimov et al. 2017)

- 1 – fixed vegetation zones;
- 2 – adjusted vegetation zones;
- 3 – difference (2)-(1)



Projected biome areas and GPP changes

Veg. Zone	Baseline 1982 - 2014		Mid-21 st century projection		
	Area 10 ⁶ km ²	C, Pg/y	Fixed VZ	Adjusted VZ	
			C, Pg/y	Area 10 ⁶ km ²	C, Pg/y
2	0,775	0,097	0,108	0,097	0,009
3	2,007	0,472	0,564	0,304	0,061
4	1,331	0,445	0,531	1,36	0,386
5	1,878	0,74	0,847	0,931	0,344
6	2,427	1,257	1,399	2,048	1,035
7	3,502	2,11	2,3	2,964	1,757
8	2,926	1,969	2,122	2,781	1,898
9	5,043	3,048	3,371	7,297	4,769
10	3,369	1,095	1,226	2,122	0,718
11	1,316	0,285	0,345	0,307	0,068
12	0			2,348	2,456
15	0			0,362	0,323
16	0			1,246	0,708
17	0			0,407	0,235
All	24,57	11,518	12,813	24,57	14,767

Conclusions

1. NDVI data indicate general rise of the biome productivity in the extra-tropical zone of the Northern Hemisphere with positive trends up to 10% per decade in the tundra area.
2. NDVI changes correlate with climate predictors, such as summer temperature sums and precipitation.
3. By mid-21st century biomes are likely to shift northward in response to climatic change.
4. Projected increase in GPP is estimated at +1.3 Pg C/y for the fixed distribution of the vegetation zones and at +3.2 Pg C/y for the adjusting vegetation zones.
5. Photosynthetic carbon uptake due to increasing GPP and northward advancement of the productive biomes is likely to fully compensate the projected increase in carbon emission.