Effects of deforestation and afforestation on regional weather conditions

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Introduction

The forests are closely interacted with weather and climate via numerous abiotic and biotic factors. Significant changes in land use and forest structure can obviously lead to changes of weather-climate characteristics at different scales. Such processes were previously investigated in studies using both experimental and modeling approaches, although the feedbacks and interaction between the forest and the atmosphere are still not reliably quantified.

The goal of study: to analyze the possible impact of land use and forest cover changes in the central part of the East European plain (with high coverage of forest) on regional meteorological conditions based on continuous COSMO-Model integrations for full year with weather conditions close to the climatic state.

Methods

- **Model:**

COSMO-CLM — Module TERRA: daily update of root depth, leaf area index (LAI)

- **Configuration:**

COSMO-Ru-NWR — Horizontal resolution ~ 6.6 km; Model domain – 1848×1452 km; Experimental area – 445×571 km

- **Period of simulation:**

1 Nov 2015 – 31 Dec 2016 — The full year + 2-month spin-up period – 'the cold start' procedure

- **Initial and boundary conditions:**

ICON (13 km grid spacing) — IC – not renewed*; BC – renewed each 3 hours

*model started once for the period of simulation

- **3 scenarios:**

Within the experimental area

Reference — The present distribution: coniferous 25.5%, deciduous 35.2%

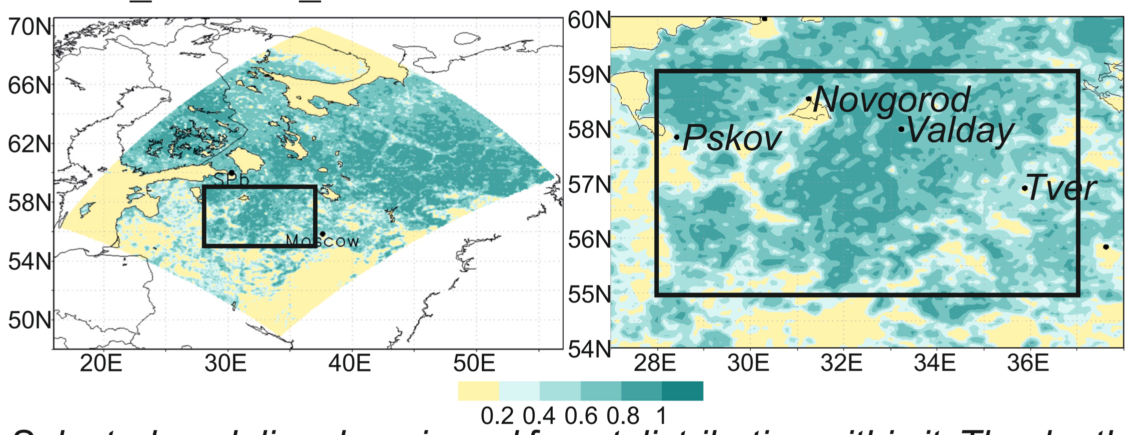
LAI and root depth are specified in dependence of forest types.
LAI: in winter 0.2–1.2, in summer 3–3.5.
Root depth: 0.3–0.7 m.

Deforestation — Total forest clearing: grass 100%

LAI: max. 2.5 (in summer).
Root depth: 0.3 m.
FOR_E = 0 (evergreen forest). FOR_D = 0 (deciduous forest).

Afforestation — Forest recovery: all areas covered in reference by grass are occupied by deciduous trees

LAI: for each day of the year is determined as a max value from all available LAI values within the modeling domain.
Root depth: the same as in ref. experiment.
FOR_E + FOR_D = 1.



Selected modeling domain and forest distribution within it. The depth of green color indicates the fraction of forest cover (both evergreen and broad-leaved tree species) in reference experiment. Black rectangle marks the boundary of experimental area.

- **Fog detection based on COSMO meteograms:**

The fog parameter given in meteograms indicates the presence of condensed water in the lowest 100–meter atmosphere level and is quantified in octs. Thus, we consider all values lower than 8 octs correspond to weather conditions that are favorable for the formation of fog, 8 octs is assumed as the prediction of fog.

- **Continentality indexes:**

1) Gochinsky *(GCI)*: $GCI = 1.7A/\sin\varphi - 20.4$,
2) Khromov (*KCI*): $KCI = (A - 5.4\sin\varphi)/A$,
where A — annual range of the air temperature, φ – latitude.
3) Selyaninov hydro-thermal coefficient (*SHTC*): $K = 10 \times P/\sum t$,
where ∑t — the sum of mean daily temperatures during the period it exceeds +10 °C, P — total precipitation amount in mm for the same period.

Results

The influence of forest cover change on the air temperature and precipitation

Deforestation processes result in lower winter and spring temperatures and in higher summer ones, afforestation processes result in opposite effects. Although the intermonth differences over the year are quite expressed, the forestry does not influence significantly the annual average air temperature at 2m. Deforestation results in an increase of the annual air temperature range (+0.6 °C), whereas afforestation leads to its decreasing (-0.3 °C).

Precipitation changes are characterized by uniformly distributed negative trend in case of deforestation and positive trend in case of afforestation during the entire year.

Deforestation slightly increases the climate continentality, whereas afforestation leads to milder climate conditions.

In January the air temperature difference is predominantly manifested within the experimental area only. In July, the change of the air temperature is evident within the entire modeling domain. Analysis of the influence of afforestation on the spatial temperature pattern indicates the similar features. The most significant changes are observed in the central (in July also in eastern) part of the experimental area. The temperature changes observed outside of the experimental area border are mainly influenced by prevailing wind directions in lower and middle troposphere.

Precipitation differences are characterized by very mosaic spatial patterns both within and outside of the experimental area. In January the maximum precipitation changes are concentrated within the experimental area, whereas in July they are spread over the entire modeling domain. The similar features are observed in the case of afforestation.

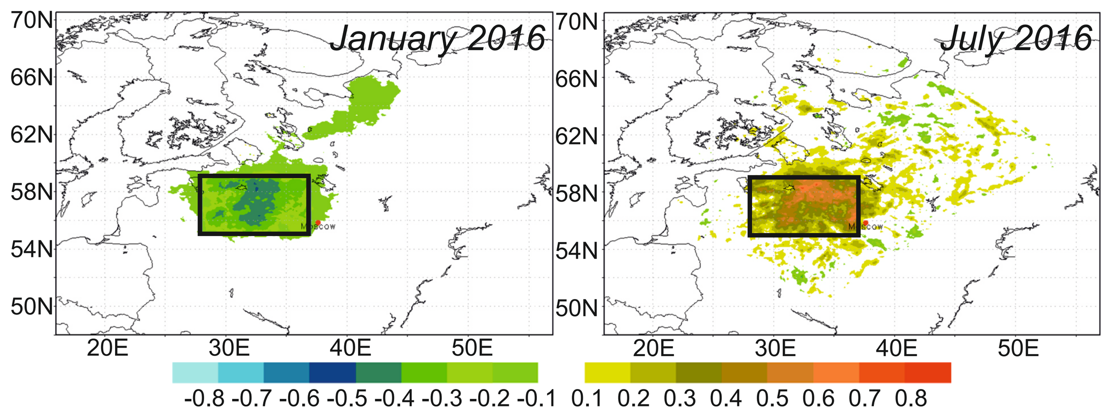
In 2016 the obtained SHTC ranges for our region between 1.0 and 2.5 that corresponds to moderately wet moisture climate conditions. The response of SHTC is observed over the entire modeling domain. The deforestation lead to increase of dryness, whereas the afforestation — to the opposite effects. The difference of SHTC values between deforestation and afforestation scenarios reaches -0.4, and in some regions even -0.6.

Monthly air 2m-temperature and precipitation (experimental area)

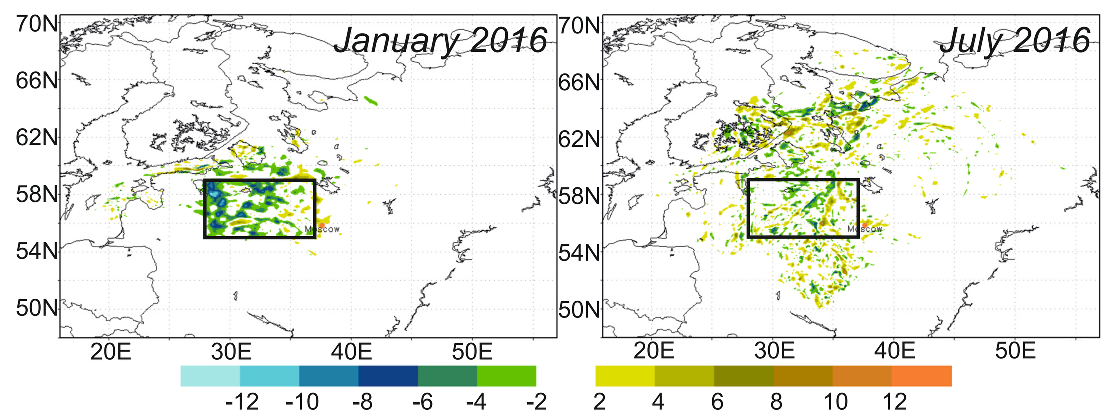
Month	Air temperature at 2 m (°C)			Precipitation (mm month^{-1})		
	Reference	Deforestation	Afforestation	Reference	Deforestation	Afforestation
1	-10.6	-10.9 (-0.3)	-10.4 (+0.2)	76.4	74.4 (-2.0)	77.6 (+1.2)
2	-2.1	-2.3 (-0.2)	-2.0 (+0.1)	57.4	53.2 (-4.2)	59.4 (+2.0)
3	-2.2	-2.8 (-0.6)	-1.9 (+0.3)	46.2	43.1 (-3.1)	48.1 (+1.9)
4	5.2	4.8 (-0.4)	5.3 (+0.1)	73.0	69.7 (-3.3)	74.4 (+1.4)
5	13.6	13.8 (+0.2)	13.5 (-0.1)	50.2	48.3 (-1.9)	50.7 (+0.5)
6	17.2	17.8 (+0.6)	17.0 (-0.2)	61.7	57.4 (-4.3)	63.0 (+1.3)
7	19.0	19.3 (+0.3)	18.9 (-0.1)	138.5	133.5 (-5.0)	140.0 (+1.5)
8	17.1	17.2 (+0.1)	16.9 (-0.2)	83.5	81.3 (-2.2)	84.4 (+0.9)
9	11.2	11.2 (0.0)	11.1 (-0.1)	40.2	39.1 (-0.3)	40.7 (+0.5)
10	2.5	2.5 (0.0)	2.5 (0.0)	69.3	67.4 (-1.9)	70.1 (+0.8)
11	-3.6	-3.7 (-0.1)	-3.5 (+0.1)	97.2	93.7 (-3.5)	99.0 (+1.8)
12	-4.0	-4.1 (-0.1)	-4.0 (0.0)	54.6	52.2 (-2.4)	56.0 (+1.4)
Year	5.3	5.2 (-0.1)	5.3 (0.0)	848.2	813.3 (-34.9)	863.3 (+15.1)

Continentality indexes GCI and KCI

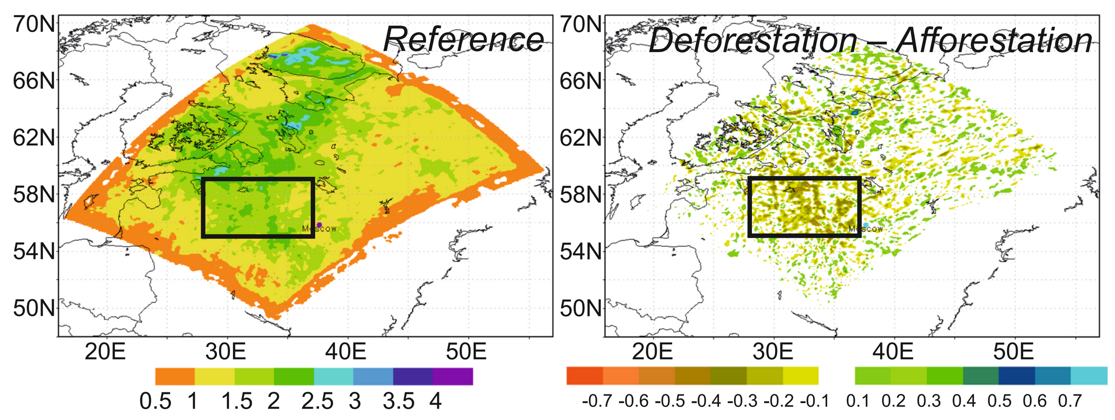
	Reference	Deforestation	Afforestation
Gorchinsky CI	39.62	40.84	39.01
Khromov CI	0.847	0.850	0.845



The spatial patterns of the air temperature difference (at 2 m) between experiments: Deforestation – Reference



Differences in precipitation between experiments: Deforestation – Reference



The spatial pattern of Selyaninov hydro-thermal coefficient, HTC (Selyaninov, 1928) for year 2016

The influence of forest cover change on wind speed and fog frequency

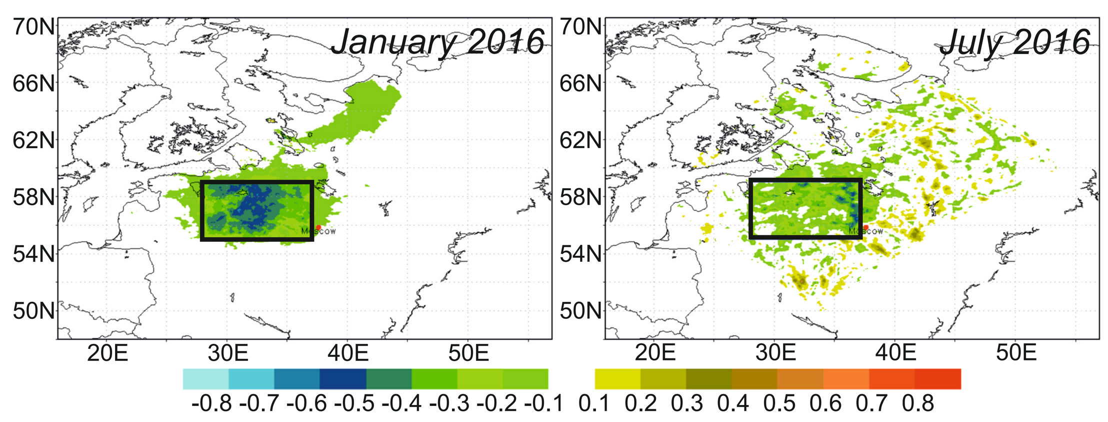
Deforestation results in significant growth of the mean wind speeds and the number of days with strong wind speed (> 8 m/s). Afforestation vise versa leads to decrease of these parameters.

The changes of monthly mean dew point values are quite similar to variation of precipitation rate. Under deforestation conditions during all months of the year 2016 dew point tended to decrease, whereas under afforestation scenario it increased, and these changes were some lower than in the case of deforestation scenario. Spatial patterns are characterized by significant heterogeneity: the changes projected for winter months are significantly higher than the changes of dew point in summer months.

During the warm period (May – September) in deforestation scenario the frequency of favourable conditions for fog formation is decreased, whereas in afforestation it is increased. The same tendency is observed for fogs of maximum intensity (equal to 8 octs).

Number of days with wind speed > 8 m/s

Station	Reference	Deforestation	Afforestation
Valdai	1	35 (+34)	1 (0)
Novgorod	9	29 (+20)	1 (–8)
Pskov	5	25 (+20)	3 (–2)
Tver	5	16 (+11)	0 (–5)



Difference of monthly mean dew points: Deforestation – Reference

Station	*Number of favorable situations for fog formation*			*Number of fogs (8 octs)*		
	Reference	Deforestation	Afforestation	Reference	Deforestation	Afforestation
Valdai	73	69 (–4)	91 (+18)	21	16 (–5)	20 (–1)
Novgorod	58	41 (–17)	72 (+14)	9	7 (–2)	10 (+1)
Pskov	32	25 (–7)	50 (+18)	7	5 (–2)	15 (+8)
Tver	34	30 (–4)	51 (+17)	7	5 (–2)	8 (+1)

Conclusion

The numerical experiments provided with COSMO-Ru-NWR for the period from January to December 2016 showed significant influence of regional forest cover changes on meteorological conditions. It was shown that deforestation results in decrease of the air temperature in cold half of the year and in increase – in summer time. The afforestation results in opposite effects. An increase of annual temperature range in the case of deforestation is about 0.6°C and it can lead to small increase of climate continentality, whereas the decrease of annual temperature ranges by 0.3°C in the case of afforestation and promotes the milder climate conditions. Analysis of precipitation changes showed that deforestation leads to small decrease of the annual precipitation amount by 35 mm (about 4%) , whereas afforestation leads to increase of precipitation amount by 15 mm (less 2%).The precipitation changes are concentrated in the experimental area for winter months and are disseminated for modeling domain for summer conditions. This permits to suppose that in the case of deforestation for more wide area the response in the precipitation fields will be greater due to the additional influence of 'forsing' (superposition) of the neighboring regions.The numerical experiments showed that deforestation processes lead to higher frequency of the days with strong wind speed and lower frequency of fog events. In case of afforestation, the number of days with high wind speed changes insignificantly, whereas the fog frequency is significantly grown. These results (concerning the tendencies of regional changes of forestation) could be taking into account in the planning of economical development of regions, for example, construction of objects, roads etc.

References

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