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EFFECTS OF DEFORESTATION AND AFFORESTATION IN THE CENTRAL PART OF THE EAST EUROPEAN PLAIN ON REGIONAL WEATHER CONDITIONS

ABSTRACT. Forest vegetation can affect the climate and weather patterns in multiple ways. What are the main mechanisms of such influence and how the land-use and vegetation changes may affect the weather and climate conditions in different geographical regions are still not quite clear. In our study, the possible impact of land use and forest cover changes in the central part of the East European plain on regional meteorological conditions was investigated using the regional COSMO model. In our modeling experiments we used two extreme land-use change scenarios imitating total deforestation and afforestation of experimental area located between 55° and 59ºN and 28° and 37°E in the central part of the East European plain. Modeling results conducted for the year 2016 showed that deforestation results in increase of the temperature difference between summer and winter months by up to 0.6ºC and in reduction of the annual precipitation by 35 mm. On the contrary, afforestation leads to decrease of the annual temperature range by 0.3° C and to growth of annual precipitation by 15 mm. Moreover, the deforestation results in higher frequencies of stronger winds and lower number of fog events, while the afforestation leads to opposite effects. Analysis of the Khromov and Gorchinsky indexes of continentality showed that the deforestation of the selected experimental area may lead to increase of the climate continentality in the study region, whereas the afforestation results in milder climate conditions.

KEY WORDS: deforestation, afforestation, COSMO, numerical experiments, air temperature, precipitation, fog frequency

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INTRODUCTION

There are numerous factors and multiple pathways that control the interaction of forest vegetation and the atmosphere at various temporal and spatial scales. It is well known that the weather and climatic characteristics (e.g. air temperature, incoming solar radiation, latent and sensible heat fluxes, and precipitation) influence significantly the forest growth and primary production (Whittaker 1975; Woodward 1987). In turn, forests via the various feedback mechanisms (emission and absorption of CO_2, albedo, evapotranspiration, precipitation interception) affect the local, regional, and, to some extent, global weather and climate conditions (Bonan et al. 1992; Brovkin et al. 2009; Bathiany et al. 2010). Any forest disturbances can influence surface albedo, net radiation, sensible and latent heat, and CO_2 fluxes between the land surface and atmosphere, and can substantially affect climate conditions from local to global scales (Kulmala et al. 2014; Seidl et al. 2014; Mamkin et al. 2019). These feedback mechanisms were investigated over the last decades in many experimental and modeling studies (Nobre et al. 1991; Bonan et al. 1992; Carlson and Groot 1997; Pielke et al. 2007; Olchev et al. 2009; Brovkin et al. 2009; Anav et al. 2010; Bathiany et al. 2010; Kulmala et al. 2014; Mamkin et al. 2016, 2019). They showed a large diversity of feedbacks of forest and land use changes on local and regional weather conditions that could not be explained without deep understanding of all available relationships and effects arising between atmospheric and the land surface processes. For such scientific tasks, the mathematical models of different scales and complexity can be a very effective tool. The key factors influencing the accuracy of the model projections are the land surface heterogeneity, lack of necessary experimental data, and multiple simplifications still used in mathematical models in description of the land surface - atmosphere interaction. The main goal of the study is to derive the possible impact of land use and forest cover changes in the central part of the East European plain on regional meteorological conditions using the regional weather forecast COSMO model.

METHODS

General description of the COSMO model

To investigate the impact of deforestation and afforestation processes on regional meteorological conditions we used the non-hydrostatic limited area weather forecast COSMO (the Consortium for Small-Scale Modeling) model. This model is based on the key equations of hydro- and thermodynamic, allowing one to describe adequately air flows in a fully compressible, non-hydrostatic, moist atmosphere. In this assumption, the atmosphere is considered as a multi-component continuum that is composed of dry air, water vapor and water in liquid and solid states. The model is based on basic equations providing the conservation of momentum, mass and energy. These equations are written in form of budget conservation. All equations are formulated for rotated geographical coordinates. A height-based terrain-following coordinate system is also used. The model variables are staggered on an Arakawa-C/Lorenz grid with scalar defined at the centre of a grid and wind velocity components defined on the corresponded box faces (Doms and Baldauf 2018). COSMO includes subgrid-scale parameterizations of different physical processes such as atmospheric turbulence, convection and cloud formation, radiative transfer, energy and water fluxes at ground surface, heat and water exchange in different soil horizons, etc.

The weather forecast COSMO model is accepted by the Central Methodical Committee of the Russian Hydrometeorological Services as the main mesoscale regional short-range atmospheric model (up to three model days) for short-term weather prediction. The operational weather forecasts are produced for the territory of Russia with a grid spacing ranged from 1.1 to 13.2 km (Rivin et al. 2015).

The module TERRA integrated into the COSMO model is used to describe the processes at the land surface - atmosphere interface. It includes the soil module combined with a simplified heat and water transfer schemes, parameterizations of the radiation fluxes at the land surface, and the annual cycles of vegetation parameters. TERRA allows describing the rainfall and snow accumulation, dew and rime formation, evapotranspiration and surface runoff. Besides, the module includes parameterizations of water infiltration, percolation, and capillary movement in different soil layers, as well as water phase transition processes. The ground surface temperature and water content are calculated in the model for eight soil, subsoil and parent rock layers of different thickness down to the depth of 14.58 m. It is assumed that the ground surface is characterized by different morphological properties and can be roughly divided into the following types: ice, stony surface, sand, loamy sand, fertile soil, loam, clay, and peat. Each surface type is characterized by unique assemblage of specific parameters characterizing the soil physical properties, including thermal conductivity, field capacity, minimum infiltration rate, soil porosity, soil albedo, etc.

To derive the possible impact of open water reservoir on regional atmospheric processes a one-dimensional parametric fresh-water lake model, built into the COSMO model (FLAKE, Mironov 2008) is used. To adjust the water temperature and depth of mixed layer close to real values during the modeling experiment, the so-called "cold start" procedure is used. The method uses the following assumptions: no ice on the lake surface, temperature of mixed layer is equal to surface temperature that can be taken from ICON data archive, temperature of bottom layer is assumed to be equal to temperature at maximum water density (3.98°C). The "cold start" procedure is recommended to be used in spring and autumn – after the ice and snow melts, or before freezing over when the lakes have thermal stratification close to neutral. In this case, the model characteristics obtained during the "cold start" procedure would quicker come to better agreement with observational data.

External parameters describing land use and vegetation properties such as vegetation type, fraction of forest cover, root depth, maximum and minimum values of leaf area index and others, are taken from global datasets: GLOBCOVER, GLC2000 and GLCC (Asensio et al. 2018).

Thus, the COSMO model has a reasonable scheme of land surface parameterization, which is characterized by a set of key parameters for different soil and vegetation types (apart of morphometric characteristics such as coastline and surface topography) that allows to describe the possible influence of land surface on regional weather processes.

Strategy and scenarios of modeling experiments

For our numerical experiments we used the COSMO-Ru-NWR (North–West Russia) configuration of the COSMO model with horizontal grid spacing of about 6.6 km. The modeling domain (1848×1452 km) covers the entire northern part of European Russia, the eastern part of Belarus and some parts of Eastern European and Northern European countries. The central part of the modeling domain stretched from 55° to 59°N and from 28° to 37°E was taken as experimental area where the scenarios of the land surface deforestation and afforestation were simulated (Fig. 1). This area is covered with forest, which occupies up to 60.7% of the territory. At the same time, this area is covered with relatively dense network of meteorological stations, which allows analyzing the quality of our numerical experiments.

For modeling experiments, the period from November 1, 2015 at 00:00 UTC to December 31, 2016 (the full year plus two-month spin-up period) was selected to assess the impact of forest cover changes on meteorological conditions. Two-month spin-up period was used to adjust the thermal regime of big number of large (Ladoga and Onega lakes, Rybinsk reservoir) and small freshwater reservoirs that are available within the selected modeling domain.

The meteorological conditions during selected 2016 year were characterized by di-

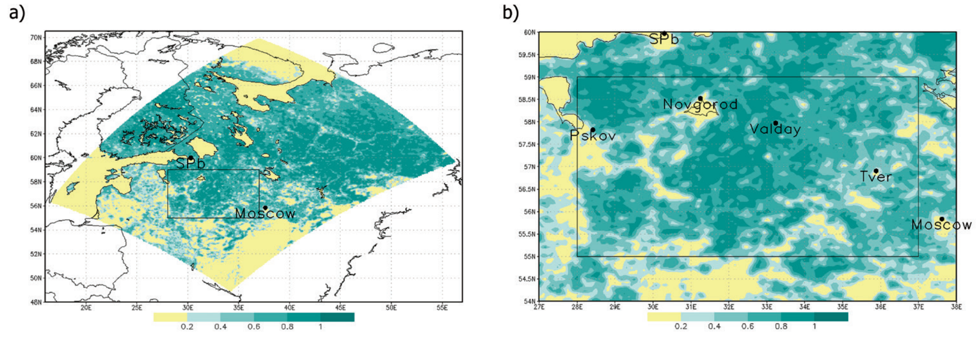

Fig. 1. The forest distribution within the selected modeling domain. The depth of green color indicates the fraction of forest cover (both evergreen and broad-leaved tree species). Black rectangle marks the boundary of experimental area

verse weather conditions and were close to long-term climatic mean values. According to COSMO-Ru-NWR estimations, the mean annual temperature of 2016 for the selected experimental area was about 5.3°C and annual precipitation was close to 848 mm.

The initial and boundary conditions of our modeling experiments with COSMO-Ru-NWR were taken from ICON global model (13 km grid spacing) of the German Meteorological Service (DWD). In the experiments, "spectral nudging" of meteorological fields, enabled in COSMO modeling system, was not used. It allowed us to pay attention to the response of the model to change of ground surface characteristics. The boundary conditions were renewed each three hours. The initial conditions were not renewed, and the model started once for the entire period of simulation. Results of model runs were recorded with 1-hour time step.

The calculations were carried out using the climatic version of the COSMO model with daily update of key land surface and vegetation parameters such as root depth, leaf area index, sea (water reservoir) surface temperature, etc. The special software module for recalculating the current leaf area index (LAI) and root depth of different plant species from specified minimum and maximum values of these parameters depending on the day of the year were used. Three numerical experiments were conducted in our study using the configuration COSMO-Ru-NWR: reference (control) experiment describing the regional weather conditions under present land-use conditions and two experiments imitating the total deforestation and afforestation of the experimental area.

Reference experiment assumes the present distribution of broad leaved and coniferous forest types within the selected experimental area (55° – 59° N, 28° – 37° E). The present forest cover within the experimental area is about 60.7%. The fraction of coniferous forests is 25.5% and deciduous species is 35.2%. LAI is specified in dependence on different forest types. It is assumed that it is varied in winter between 0.2 and 1.2 m^2m^{-2}, and in summer – between 3 and 3.5 m^2m^{-2}, respectively. Root depth is specified for each vegetation types and ranged from 0.3 m to 0.7 m.

Deforestation experiment imitates the total forest clearing at entire experimental area. We assumed that all cleared areas are covered by grassy vegetation. Their LAI in the area reaches maximum values in summer months and do not exceed 2.5 m^2m^{-2}. The root depth of grassy vegetation is assumed to be 0.3 m.

Afforestation experiment assumes complete cessation of agricultural and industrial activity in the region and widespread forest recovery. Taking into account a very slow regeneration rate of coniferous tree species we assume that all areas previously covered with grassy vegetation are completely occupied with deciduous trees. LAI value for each day of the year is determined as a maximum value from all available LAI values within the modeling domain. The plant root depth is assumed to be the same as in the reference experiment.

Data analysis

To derive the possible effects of forest cover changes on regional weather conditions we analyzed the difference between monthly mean values of the key meteorological parameters predicted for scenarios imitating total deforestation and afforestation and monthly values obtained for reference experiment assuming the present land use and forest structure.

To estimate effects of deforestation and afforestation on regional patterns of wind speed and fog occurrence we analyzed the temporal variability of these parameters for all available meteorological stations situated within the experimental area.

To estimate the climate continentality in our study we used two indexes (*CI*), suggested by Khromov and Gorchinsky (Khromov and Mamontova 1974; Kireeva-Ginenko et al. 2017). The index of continentality suggested by Gorchinsky is calculated as:

$$K = 1.7\,A / \sin\varphi - 20.4$$

According to Khromov *CI* can be calculated as:

$$K = (A - 5.4\sin\varphi) / A$$

where, *A* is annual range of the air temperature, and φ is latitude. The annual range of the air temperature is calculated as a difference of monthly mean air temperatures in July and January. Since the experimental area has a long north-to-south extension we used for our calculations the latitude of the parallel crossing the central part of our experimental area (57° N).

To analyze the surface moisture conditions we used the hydro-thermal coefficient (HTC) suggested by Selyaninov (Selyaninov 1928; Khromov and Mamontova 1974). It is calculated as:

$$K = 10 \times P / \sum t$$

where ∑t – the sum of mean daily temperatures during the period when it exceeds +10°C, *P* – total precipitation in mm for the same period. Under very wet surface moisture conditions *K* is higher than 2.0. When *K* is varied between 1.0 and 2.0 the surface moisture conditions can be classified as moderately wet. The moderately dry surface moisture conditions are characterized by *K* below 1.0, and very dry – by *K* below 0.4.

RESULTS AND DISCUSSION

The results of conducted numerical experiments showed significant influence of forest cover changes on regional and local weather conditions within both the selected experimental area and the entire modeling domain. It is traced in changes of spatial patterns of the air temperature, precipitation rate, wind speed, fog intensity and frequency.

The influence of forest cover change on the air temperature

Effect of forest cover change on the air temperature is determined by various factors including surface albedo, roughness, net radiation, evapotranspiration rate, etc. Their aggregated influence leads to opposite trends of the air temperature changes for cold and warm seasons of the year. Results of the modeling experiments show that deforestation processes result in lower winter and spring temperatures and in higher summer temperature (Table 1). The largest difference in mean monthly air temperature (at 2 m) between scenarios imitating forest cover changes and the reference experiment was detected in spring. In March the temperature difference between reference and deforestation experiments was -0.6° C (averaged for entire experimental area), whereas the temperature difference between reference and afforestation experiment was positive and some smaller in absolute range – +0.3°C. Such difference is most likely could be explained by various surface albedo and different rates of snow melting at open and forested areas. Whereas the air temperature in January for experiment imitating total deforestation was 0.4°C lower than for the reference experiment, the air temperature in July under the same scenario was already 0.3°C higher than the temperature in the reference experiment.

Afforestation processes result in opposite effects: the air temperature of January was 0.2°C higher, and in July 0.1°C lower than in the reference experiment, respectively.

The obtained results also show that the deforestation results in an increase of the annual air temperature range (+0.6 °C), whereas afforestation leads to its decreasing (-0.3 °C). Analysis of continentality indexes shows that deforestation slightly increases the climate continentality, whereas afforestation leads to milder climate conditions (Table 2).

Similar numerical experiments provided using the COSMO model to derive the air temperature responses to forest cover changes for the same experimental area during the warm period of 2010 (Kuz'mina et al. 2017a, b; Olchev et al. 2018) showed that deforestation leads to much higher increase of the air temperature in summer months. It was shown, in particular, that the total deforestation of experimental area under weather conditions of July 2010 resulted in increase of the mean monthly temperature up to 1.6°C. The total afforestation under weather conditions of 2010 resulted vice versa in temperature decrease by about 0.7°C (Kuz'mina et al. 2017a, b). We can expect that such strong temperature response to forest cover changes might be explained by anomalously hot and dry weather conditions observed in the European part of Russia in summer 2010.

Comparisons of obtained results with similar numerical experiments provided using other models showed their good agreement. In particular the similar temperature trends were detected during the modeling experiments imitating complete deforestation of the large forest areas situated north of 45°N with the earth system model of the Max Planck Institute for Meteorology (MPI-ESM) (Bathiany et al. 2010).

Table 1. Mean monthly air temperature at 2 m and total precipitation within experimental area modeled for control experiment and experiments imitating total deforestation and afforestation

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)

Table 2. Continentality index for the experimental area calculated using Khromov's and Gorchinsky's equations for reference experiment and experiments imitating total deforestation and afforestation

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

The spatial pattern of the air temperature changes due to forest cover change is influenced by an ensemble of different factors including local land use properties and regional circulation processes. Figure 2 shows examples of the spatial patterns of the air temperature changes that can be detected in the case of total deforestation of experimental area in January and July 2016. In January, the air temperature difference between deforestation and reference experiments is predominantly manifested within the experimental area only. Such tendency can be mainly explained by influence of deforestation on surface albedo as well as by weak circulation activity observed within the modeling domain during the second half of winter. In July, the change in air temperature is evident within the entire modeling domain that is mainly governed by high cyclone activity and high intensity of meridional and zonal air mass transfer. Analysis of the influence of afforestation on the spatial temperature pattern indicates the similar features.

It is noteworthy that the most significant changes of surface air temperature caused by forest cover changes are observed in the central part (in July - in the central and eastern parts) of the experimental area. The temperature changes observed outside of the experimental area borders were influenced mainly by prevailing wind directions in lower and middle troposphere.

Effects of forest cover change on precipitation

The influence of forest cover change on precipitation is characterized by very mosaic spatial patterns both within and outside of the experimental area (Fig. 3), as well as by uniformly distributed trend of precipitation changes throughout the entire year (Table 1). In January, maximum precipitation changes are detected within the experimental area, while in July they were spread over the entire modeling domain. The difference between annual precipitation for scenario imitating the total deforestation of experimental area and the reference experiment is -35 mm (precipitation decreased from 848.0 to 813.3 mm and the difference does therefore not exceed 5% of annual precipitation amount). Vice verse, in the case of afforestation experiment precipitation is higher than in the reference experiment in all months of the year. Absolute range of the changes is some smaller than for deforestation scenario not exceeding 15 mm.

a)   b)

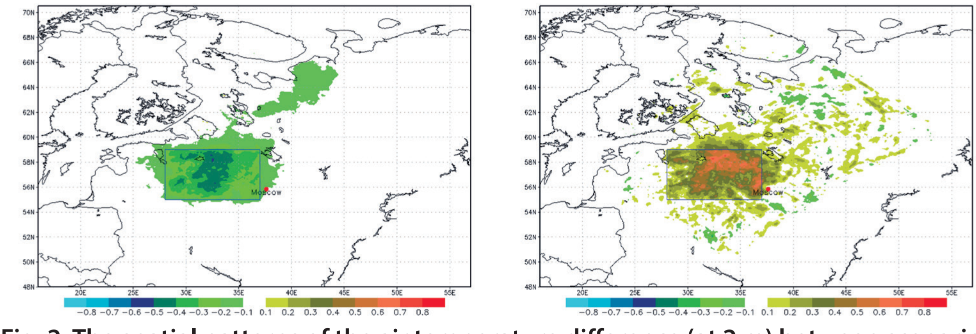

Fig. 2. The spatial patterns of the air temperature difference (at 2 m) between scenario imitating total deforestation of the experimental area and the reference experiment in (a) January and (b) July of 2016

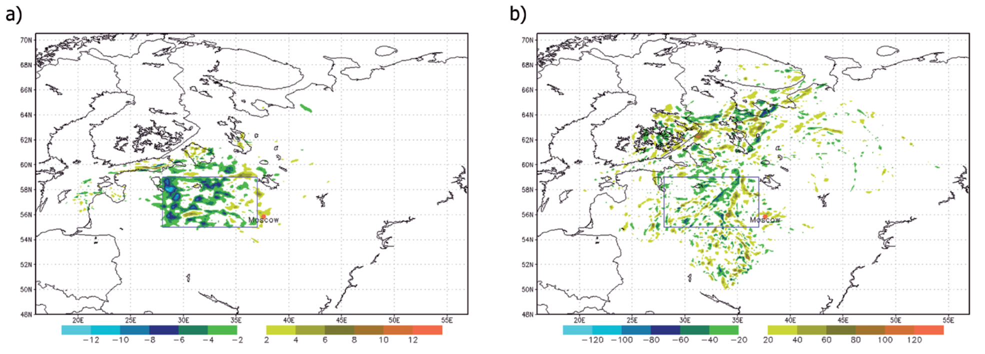

Fig. 3. Differences in precipitation amount between scenario imitating the total deforestation of the experimental area and the reference experiment in January (a) and July (b) 2016

Analysis of surface moisture conditions within the modeling domain using HTC index showed that in 2016 it ranged within the experimental area between 1.0 and 2.5 that corresponds to moderately wet moisture conditions (Fig. 4).

The response of HTC index to forest cover change is observed over the entire modeling domain (Fig. 4b), and in different regions this response has the different signs. Despite of a variety of HTC responses to forest clearing, at local scale the deforestation processes lead to increase of surface dryness, whereas the afforestation results in opposite effects. The difference of HTC values between deforestation and afforestation experiments reaches -0.4, and in some regions even -0.6. The highest changes of HTC are observed in the central and northern parts of the modeling domain, whereas in its western part the projected changes are relatively small.

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

Forest cover change and wind speed

To derive the possible effects of forest cover changes on regional weather conditions we also considered the possible changes of wind speed pattern and the frequency of high wind speeds due to deforestation and afforestation taking into account their significant influence on regional agriculture, forestry and population.

Numerical experiments showed that deforestation results in significant growth of the mean wind speeds and the number of days with strong wind speed (>8 m/s) within the experimental area (Table 3). In particular, under scenario imitating the total deforestation of experimental area the number of the days with strong wind speed is increased in Valdai station from 1 to 35. Afforestation vise versa leads to decrease of the mean wind speeds and number of days with strong wind.

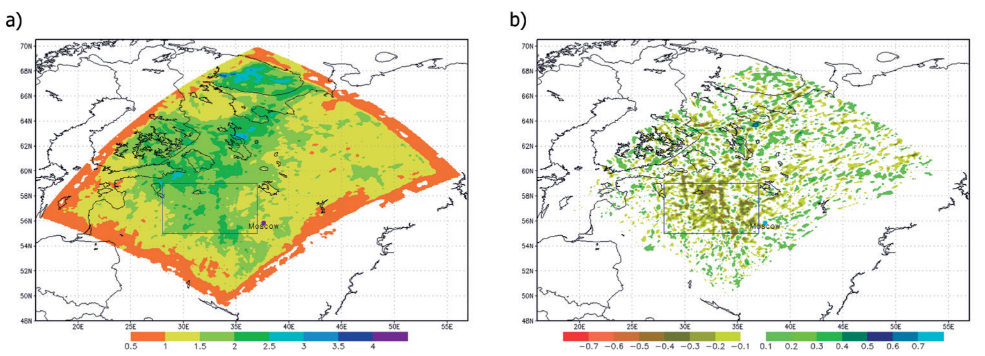

Fig. 4. The spatial pattern of Selyaninov hydro-thermal coefficient, HTC (Selyaninov, 1928) in reference experiment for year 2016 (a) and the difference between HTC values estimated for deforestation and afforestation scenarios (b)

Table 3. The number of days with strong wind speed (> 8 m/s) for 4 stations within the experimental area for the reference, deforestation, and afforestation experiments for the period from May to September of 2016. The differences between the deforestation/afforestation and reference experiments are shown in brackets

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)

Forest cover change and fog occurrence

To analyze the main features of fog formation under land-use and forest cover changes, in the first step we compared the dew point variability for reference and deforestation/afforestation scenarios. Results showed that the changes of monthly mean dew point values are quite similar to variation of precipitation rate (Table 4). 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. Analysis of the spatial patterns of dew point differences between the reference and forest cover change scenarios showed significant heterogeneity for the coldest and warmest half of the year. The changes projected for winter months are significantly higher than the changes of dew point in summer months (Fig. 5). It can be also pointed out that the dew point changes during the summer months are spread into the entire modeling domain and characterized by mosaic structure with positive and negative deviations whereas the changes of dew point in winter months are always negative and manifested mainly within the experimental area.

Table 4. Monthly mean dew points at 2 m within the experimental area in the reference experiment and in the experiments imitating total deforestation and afforestation

Months	Dew point at 2 m level		
	Reference	Deforestation	Afforestation
1	–12.3	–12.7 (–0.4)	–12.1 (+0.2)
2	–3.0	–3.3 (–0.3)	–2.9 (+0.1)
3	–3.6	–4.3 (–0.7)	–3.3 (+0.3)
4	3.0	2.6 (–0.4)	3.1 (+0.1)
5	7.5	7.5 (0.0)	7.6 (+0.1)
6	10.7	9.9 (–0.8)	10.9 (+0.2)
7	15.3	15.1 (–0.2)	15.4 (0.1)
8	13.6	13.5 (–0.1)	13.7 (+0.1)
9	7.9	7.9 (0.0)	7.9 (0.0)
10	1.0	0.9 (–0.1)	1.0 (0.0)
11	–4.5	–4.7 (–0.2)	–4.4 (+0.1)
12	–4.8	–5.0 (–0.2)	–4.8 (0.0)
Year	2.6	2.3 (–0.3)	2.7 (+0.1)

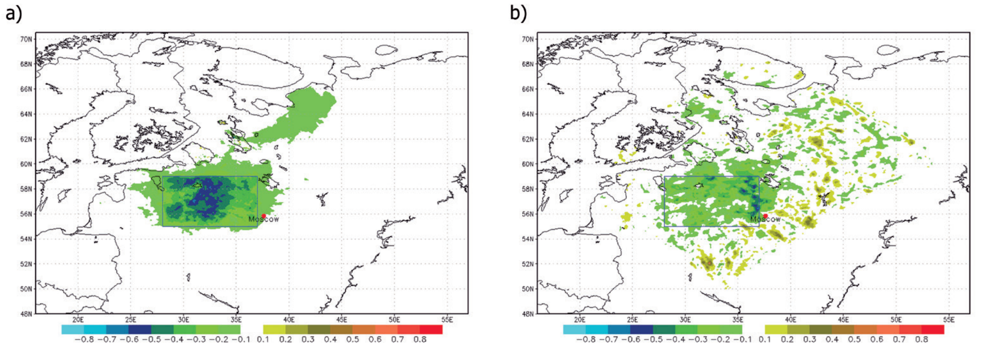

Fig. 5. Difference of monthly mean dew points at 2 m between deforestation and reference experiments in January (a) and July (b), 2016

The results of dew point analysis can be effectively used to explain the changes of spatial pattern of fog occurrence caused by deforestation and afforestation processes. The COSMO model assumes that the fog can occur if the cloudiness sinks in the lowest model level, and its intensity is quantified in octs ranging from 0 to 8. Relative humidity in the corresponding atmospheric layer is considered as a criterion to quantify the fog intensity. It is assumed that all values lower than 8 octs correspond to weather conditions that are favorable for the fog formation. The intensity of fogs equal to 8 octs is assumed as the maximum probability of fog events with the highest intensity. During the warm season of 2016 (from May to September) in deforestation experiment the frequency of favorable conditions for fog formation is decreased, whereas in afforestation experiment – it is increased. The same tendency is observed for fogs of maximum intensity (equal to 8 octs).

Taking into account the main features of the trend for fog number of maximum intensity (8 octs), reproducing by the model for different forest cover change experiments for all months of 2016 (Fig. 6), it is very important to point out that the dependence of the dense fog probability on relative humidity looks a little bit ambiguous. It is obvious that accurate prediction of fog intensity requires accurate description of all key processes influencing fogging processes and it is clear that it cannot be reduced by a direct dependence on relative humidity only. Thus, Fig. 6 shows that in all months of the cold period of 2016 there is no pronounced increase in fog numbers under afforestation experiment in respect to the experiment imitating total deforestation, while the number of simulated fogs in both experiments noticeably increased in relation to the warmest half of the year. The latter indicates an increase in the frequency of weather con-

Table 5. Number of favorable conditions for fog formation for four meteorological stations situated within the experimental area in the reference experiment and in the experiments imitating afforestation and deforestation during the period from May to September, 2016. In the brackets the fog number differences between the deforestation/afforestation and the reference experiments are shown

	Number of favorable situations for fog formation			Number of fogs (8 octs)		
Station	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)

Fig. 6. Number of modeled fogs (8 octs) at meteorological stations within the experimental area (indicated by station indexes) in the deforestation (red color) and afforestation (green color) experiments for different months of 2016

ditions that are favorable for fog formation in the winter period. It can be also resulted from, for example, an underestimation of the surface air temperature, leading to the occurrence of radiation fogs, or an increase in the number of advective fogs. However, these hypotheses require further aggregated studies using both experimental data and modeling experiments.

CONCLUSION

The numerical experiments conducted with the COSMO model for experimental area situated in the central part of the East European plain for the reference period from January to December 2016 showed significant influence of forest cover changes on regional 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 total deforestation of experimental area is about 0.6°C and it can lead to small increase of climate continentality. In the case of afforestation the decrease of annual temperature range is about 0.3°C that promotes the milder climate conditions. Analysis of changes in precipitation under different forest cover change scenarios showed that deforestation leads to relatively small decrease of the annual precipitation by 35 mm, whereas afforestation leads to increase of precipitation by 15 mm. It can be expected that deforestation leads to drier climate conditions that in the long-term perspective can influence the rate of forest recovery, species composition and biodiversity.

It is very important to mention that the forest cover change influences a broad spectrum of meteorological conditions. The numerical experiments showed that deforestation processes lead to higher frequency of the days with strong wind speed and lower frequency of fog events especially of the highest intensity. In the case of afforestation, the number of days with high wind speed is changed insignificantly, whereas the fog frequency is significantly grown.

It should also be pointed out that all obtained results are well agreed with a number of numerical experiments conducted using global scale models (e.g. Brovkin et al, 2009). At the same time, it is obvious that such studies should be continued using the models of different scales and complexity as well as using experimental data to derive the whole spectrum of possible responses of regional and global weather conditions on forest cover changes.

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