Climate Change in Latvia and Adaptation to it

Editors Māris Kļaviņš and Agrita Briede

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Foreword

Climate change is happening! Of course discussion on its driving forces is continuing, but the fact itself is impossible to deny. Manifestations of climate change and climate variability might be very diverse and much should be done to identify their consequences and further to model possible changes in future. This book is an attempt to sum up research done in Latvia on climate change and climate variability character and impacts to give an contribution to understanding globally ongoing processes. However with studies of climate change and climate variability character and modelling of their character in future it is not enough. Impacts of climate change and climate variability are inevitable and the only way how to reduce adverse consequences is to adapt to climate diversity. In respect to some manifestations of climate change and climate variability adaptation need and approaches are relatively well known, as it is in case for adaptation to flood protection. For many other manifestations of climate change and climate variability adaptation solutions still have to be sought, but also dimension of ongoing climate change puts forward a need to revise existing concepts and approaches how to adapt to changes. Thus, for solving of possible and unavoidable problems a research is needed how to adapt to them. Another aim of this book is to look on ways how the adaptation to climate change and climate variability can be pursued.

Agrita Briede and Māris Kļaviņš

Climate change character

Penalty Function for Identification of Regions with Similar Climatic Conditions

Daiga Cepīte-Frišfelde, Uldis Bethers,
Juris Seņņikovs, Andrejs Timuhins
Laboratory for Mathematical Modeling of Environmental and Technological Processes,
Faculty of Physics and Mathematics University of Latvia, Zellu 8, LV-1002, Latvia
E-mail: daiga.cepite@lu.lv

Abstract
The method of defining the quantitative difference between the climates of any two points in the world is proposed. The defined quantitative distance is used to identify the regions with the present climate conditions the most similar to those expected in the territory of Latvia in the near (2021–2050) and far (2071–2100) future. The quantitative climate distance is obtained using 30-year long time series of gridded monthly average temperature and precipitation rates. As a result of using this method the regions of the globe have been identified representing the expected climate of Latvia in near and far future.

Keywords: Climate comparison, climate projections, climate models

INTRODUCTION

Experimental measurements of the last century as well as the results of global and regional climate models with a set of emission scenarios show evidence of the relatively rapid climate change all around the world. Therefore many sectors of the Latvia economy should have been interested in knowing which parts of the world are nowadays similar to the climate we expect in the future. To be able to determine that one should have reasonable future projections as well as the ability to measure the distance between two climates to determine the congruence.

The aim of the present analysis is to propose the methodology for measuring the distance between the climatic conditions of any two areas in the world and to use it for giving better impression about the future climate in Latvia.

Until now a lot of effort has been done in the number of international research projects for obtaining the climate projections of the future (ENSEMBLES members 2009). As well as the wide range of the impact studies have been done that use available results of the future climate projections. What refers to measuring the distance between climates and comparing the climates, one might notice in the scientific literature that it is done mostly to compare the model projections of the reference period with an experimental observations of the reference period. Monthly averages as well as interannual variability are the criteria considered for that purpose. These parameters can be used to build the penalty function that identifies the best performing climate model results, see Bethers and Sennikovs, 2009. In this paper we develop a similar penalty function for measuring the distance between the two climates.

METHODS

The method is applied for finding the regions around the globe with temperature and precipitation conditions nowadays similar to those Latvia is going to have in the near (2021–2050) and far (2071–2100) future. The ensemble of future climate projections of Latvia used in the study originate from the climate projections of the European Commission's 6th Framework Programs 5 year Integrated Project ENSEMBLES results (see Hewitt, 2004 for more detail of the project). The typical spatial scale of the model results analysed is around 25 km and temporal scale – 1 day. More details on the models and their performance regarding the present climate in Europe and their projections of future climate changes are analysed by (ENSEMBLES members 2009). Statistical bias correction method and data modification algorithm described by Bethers and Sennikovs 2009 are applied. Analysis performed in the presented study uses the ensemble approach for determining the future climate projections of Latvia what is preferable than using one model results only as admitted by authors of ENSEMBLES members 2009 as well as by Teutschbein and Seibert 2010. Monthly mean temperature and precipitation of the period used further in the study correspond to 50% percentile from the set of the model projections for the particular month. Contemporary climate around the globe is characterised according to ERA-40 Reanalysis data provided in ECMWF (European Centre for Medium Range Weather Forecasts) data portal.

Non-dimensional distance between the climates in any two points of the globe Δ is defined in order to analyse the distribution of climate quantitatively. It equals zero in case of the same climate and owns the maximal value 1. Monthly averages of the temperature and precipitation data series are included in the analysis of the climates equality.

The bias $\Delta T_{t_i}^k$ has been calculated to characterize the differences among the monthly average temperatures in a following way:

$$\Delta T_{t_i}^k = \frac{1}{12}\sum_{m=1}^{12}\left|T_{t_0,m}^k - T_{t_i,m}^{LV}\right| \quad (1)$$

where index k represents the point of calculation, index m – the month of the year and t_i is 30 year long period – 1961-1990 in case of t_0; 2021–2050 in case of t_1 and 2071–2100 in case of t_2. Its dimension is the same as for the average temperature – °C.

In a similar manner the bias $\Delta p_{t_i}^k$ has been calculated to characterize the differences among the monthly average precipitations rates in the control period in the point k and the monthly average precipitation rates in Latvia in the period t_i:

$$\Delta p_{t_i}^k = \frac{1}{12}\sum_{m=1}^{12}\left|p_{t_0,m}^k - p_{t_i,m}^{LV}\right| \quad (2)$$

Dimensions of $\Delta p_{t_i}^k$ equals dimension of precipitation intensity – mm day^{-1}. It should be noticed that the values $T_{t_i,m}^{LV}$ and $p_{t_i,m}^{LV}$ in formulas (1) and (2) are not unique numbers the same in all territory of Latvia but the data sets including values from all meteorological stations in Latvia. In the present paper the difference $\left|T_{t_0,m}^k - T_{t_i,m}^{LV}\right|$ has been calculated in a following way:

$$\left|T_{t_0,m}^k - T_{t_i,m}^{LV}\right| = \begin{cases} \left|T_{t_0,m}^k - \min\left(T_{t_i,m}^{LV}\right)\right| & \text{in case} \quad T_{t_0,m}^k < \min\left(T_{t_i,m}^{LV}\right); \\ \left|T_{t_0,m}^k - \max\left(T_{t_i,m}^{LV}\right)\right| & \text{in case} \quad T_{t_0,m}^k > \max\left(T_{t_i,m}^{LV}\right); \\ 0, \ \text{in } case & \min\left(T_{t_i,m}^{LV}\right) \le T_{t_0,m}^k \le \max\left(T_{t_i,m}^{LV}\right). \end{cases} \quad (3)$$

The same approach is used in calculation of $\left|p_{t_0,m}^k - p_{t_i,m}^{LV}\right|$ in formula (2). It means that zero difference is gained in case the monthly average temperature (or precipitation) is in the range between the minimal and the maximal monthly average temperature (or precipitation) of the period in meteorological stations of Latvia. The monthly averages are considered according to the 50% percentile values of the projection ensemble. The values of $\min\left(T_{t_i,m}^{LV}\right)$, $\max\left(T_{t_i,m}^{LV}\right)$, $\min\left(p_{t_i,m}^{LV}\right)$ and $\max\left(p_{t_i,m}^{LV}\right)$ are included in Table 1 and Table 2.

Table 1. **The minimal and maximal monthly average temperatures among the stations in Latvia in three analysed periods.**

m	$\min(T_{t_0,m}^{LV})$	$\max(T_{t_0,m}^{LV})$	$\min(T_{t_1,m}^{LV})$	$\max(T_{t_1,m}^{LV})$	$\min(T_{t_2,m}^{LV})$	$\max(T_{t_2,m}^{LV})$
1	−7.78	−3.29	−4.87	−0.35	−2.54	2.06
2	−6.78	−3.03	−4.95	−0.99	−2.19	1.79
3	−2.59	0.32	−0.37	2.35	2.21	4.64
4	2.90	5.56	5.00	7.29	7.19	8.74
5	8.21	12.10	10.32	13.21	12.48	14.67
6	13.09	15.71	15.03	17.37	16.79	18.48
7	15.70	17.19	16.77	18.49	18.23	19.97
8	14.72	16.34	16.24	18.23	17.64	19.66
9	10.04	12.61	11.61	14.52	13.42	16.16
10	5.17	8.40	7.34	10.54	9.06	12.19
11	−0.33	3.66	1.52	5.61	3.15	7.28
12	−4.85	−0.35	−3.00	1.75	−0.49	4.06

Table 2. **The minimal and maximal monthly average precipitation rate among the stations in Latvia in three analysed periods.**

m	$\min(T_{t_0,m}^{LV})$	$\max(T_{t_0,m}^{LV})$	$\min(T_{t_1,m}^{LV})$	$\max(T_{t_1,m}^{LV})$	$\min(T_{t_2,m}^{LV})$	$\max(T_{t_2,m}^{LV})$
1	0.89	1.71	1.08	2.02	1.24	2.30
2	0.80	1.28	1.00	1.54	1.09	1.70
3	0.86	1.50	1.02	1.62	1.16	2.02
4	1.06	1.69	1.21	2.01	1.31	2.17
5	1.10	1.75	1.25	1.95	1.55	2.19
6	1.40	2.42	1.66	2.72	1.62	2.61
7	2.02	3.05	2.47	3.45	2.44	3.37
8	2.10	3.08	2.25	3.33	2.00	3.03
9	1.83	3.04	2.03	3.50	1.96	3.40
10	1.52	3.16	1.82	3.60	1.72	3.53
11	1.50	3.39	1.64	3.73	1.84	4.10
12	1.28	2.40	1.44	2.77	1.60	2.98

Table 3. **Values of max $\Delta T_{t_i}^{k}$ and max $\Delta p_{t_i}^{k}$ used in computation of relation (3)**

Period, t_i	max $\Delta T_{t_i}^{k}$	max $\Delta p_{t_i}^{k}$
t_0	55.5	23.7
t_1	57.4	23.3
t_2	59.5	23.2

After obtaining $\Delta T_{t_i}^{k}$ and $\Delta p_{t_i}^{k}$ for each of the calculation grid points the distance between the climates that measures the effect of both temperature and precipitation differences all together is calculated

$$\Delta_{t_i}^{k} = 0.5\left(\frac{\Delta T_{t_i}^{k}}{\max\left(\Delta T_{t_i}^{k}\right)} + \frac{\Delta p_{t_i}^{k}}{\max\left(\Delta p_{t_i}^{k}\right)}\right). \tag{4}$$

$\Delta_{t_i}^{k}$ is a nondimensional number below 1 in all locations *k* in the calculation domain. To calculate the distance between the climate in Latvia and climates in the southern hemisphere six month phase shift has been used.

RESULTS AND DISCUSSION

The main result of the present study is the distribution of the distance between the contemporary climate of the world and Latvia climate projections.

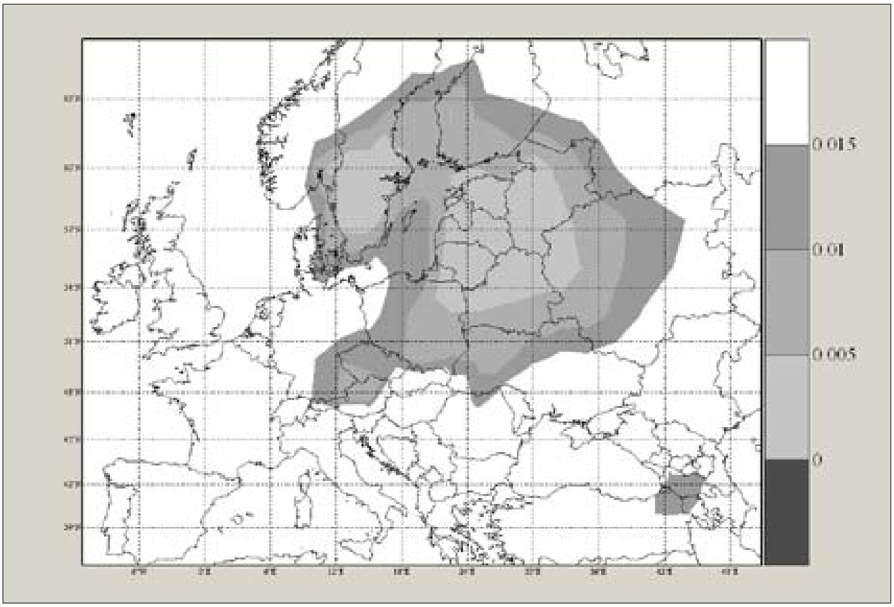

Fig. 1 **The distance between the contemporary climates of Europe and Latvia Δ_{t_0}. Regions within the distance 0 to 0.015 (0 to 1.5 %) are shown.**

shows that the closest regions to the contemporary climate of Latvia are located in the territory of Lithuania, Estonia and parts of Russia, Belorussia, Poland and Sweden as well.

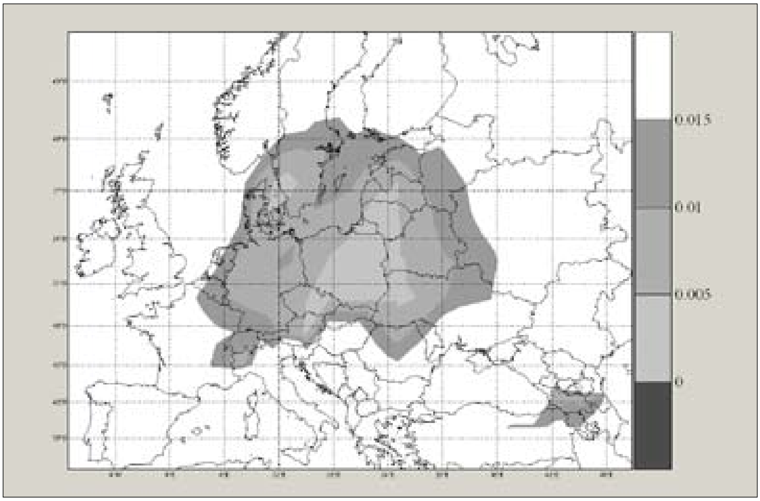

Fig. 2 **The distance between the contemporary climate of Europe and the near future climate projection of Latvia Δ_{t_1}. Regions within the distance 0 to 0.015 (0 to 1.5 %) are shown.**

demonstrates that the region of the contemporary climate that is the closest to near future climate projection of Latvia is shifted in the SW direction in comparison with the closest region shown in Fig. 1.

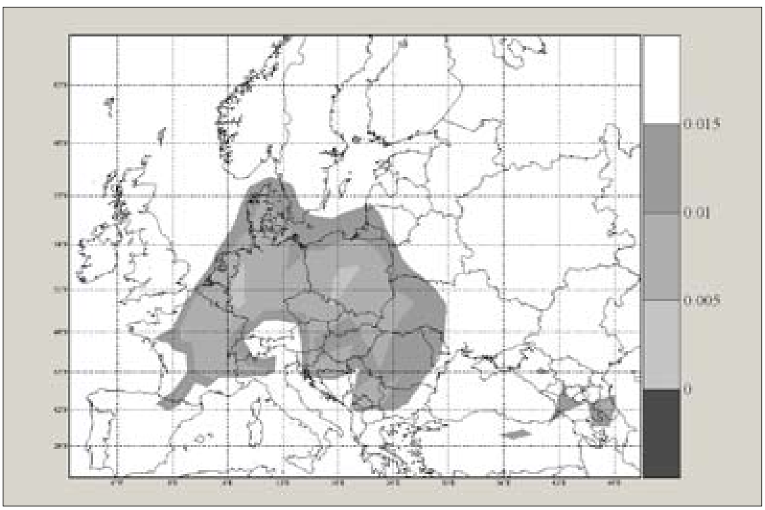

Fig. 3 **The distance between the contemporary climate of Europe and the far future climate projection of Latvia Δ_{t_2}. Regions within the distance 0 to 0.015 (0 to 1.5 %) are shown.**

confirms that the shift of the closest region in SW direction continues in case of the Latvia climate projections in the far future as well.

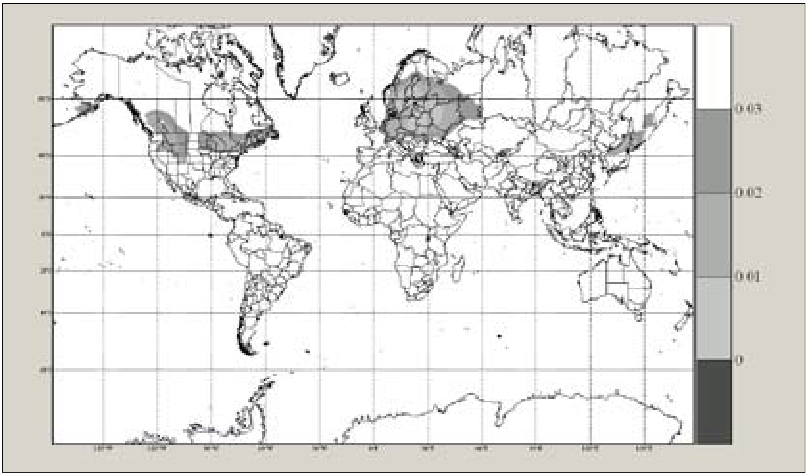

Fig. 4 **The distance between the contemporary climates of the world and Latvia Δ_{t_0}. Regions within the distance 0 to 0.03 (0 to 3.0 %) are shown.**

shows that there are regions with a distance from contemporary climate of Latvia less than 0.03 in North America and Asia. There are the regions with a distance less than 0.01 in the USA that are located in the states of Michigan, Wisconsin and Colorado.

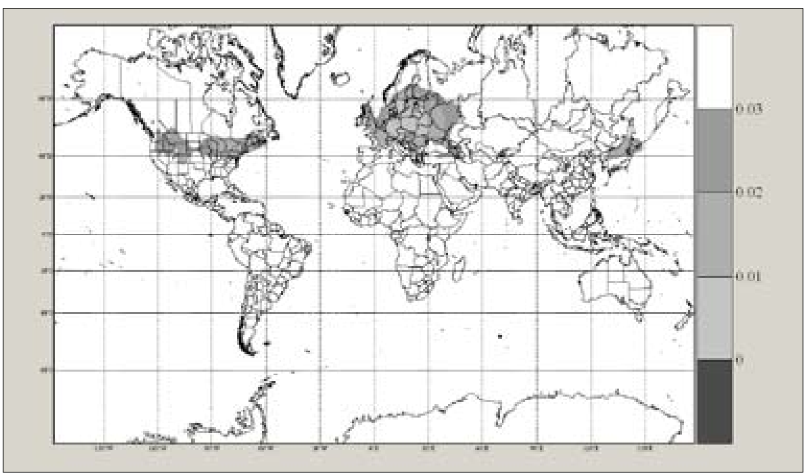

Fig. 5 **The distance between the contemporary climate of the world and the near future climate projection of Latvia Δ_{t_1}. Regions within the distance 0 to 0.03 (0 to 3.0 %) are shown.**

shows that the regions with a distance less than 0.03 could be found outside Europe in case the comparison with the near future projections of the climate of Latvia is done. There are the regions with a distance less than 0.01 in the

USA and Canada that are located in the states of Michigan, Colorado and New-York, as well as the province of Ontario. It is even more surprising to detect the close regions in Georgia, Turkey and Dagestan.

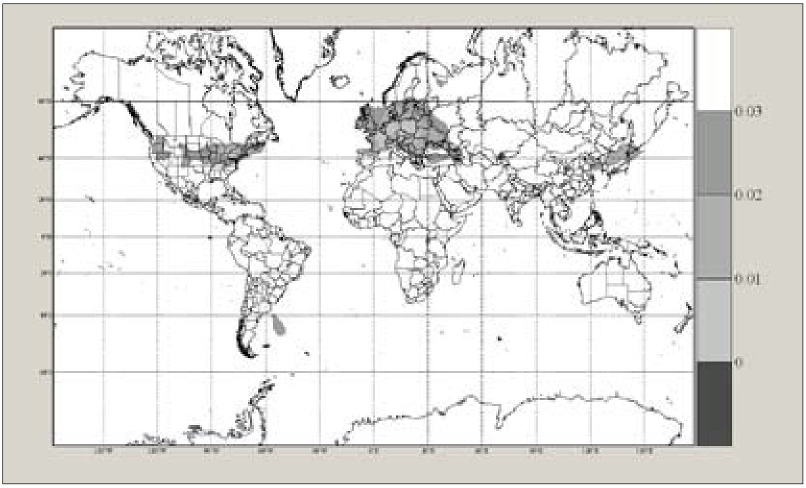

Fig. 6. **The distance between the contemporary climate of the world and the far future climate projection of Latvia Δ_{t_2}. Regions within the distance 0 to 0.03 (0 to 3.0 %) are shown.**

shows that in case the comparison with the far future projections of the climate of Latvia is done the regions within the distance of 0.01 can be found in the states of Pennsylvania and New-York, West Virginia and Ohio in the USA and in the province of Ontario in Canada. There is another close region with a distance less than 0.01 found in Dagestan on the coast of Caspian Sea.

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Data series of the contemporary climate have been downloaded from ECMWF (European Centre for Medium Range Weather Forecasts) data portal *http://data-portal.ecmwf.int/data/d/ era40_moda/*

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On Driving External Hydrological Models by Regional Climate Models

Pēteris Bethers
Laboratory for Mathematical Modeling of Environmental and Technological Processes, Faculty of Physics and Mathematics, University of Latvia, Zellu 8, LV-1002, Latvia
E-mail: peteris.bethers@gmail.com

Uldis Bethers, Juris Seņņikovs, Andrejs Timuhins
Laboratory for Mathematical Modeling of Environmental and Technological Processes, Faculty of Physics and Mathematics, University of Latvia

Regional climate models (RCMs) provide a useful source of data for assessment of climate change for hydrology. There are numerous RCMs varying in a skill regarding representation of the contemporary climate. The statistical downscaling is usually performed prior to the employment of RCM output for hydrological modelling. We found that hydrological calculations driven by bias-corrected outputs of RCMs have systematic deviations from hydrographs of Nordic rivers. The reason for this discrepancy was found in the systematic overestimation of the daily temperature-precipitation (T/P) correlation by all available RCMs. We propose to use a difference of T/P correlation values in the observations and in the particular RCM as a criterion for measurement of the skill of RCM.

Keywords: hydrological modelling, RCM, skill assessment, temperature/precipitation correlation.

INTRODUCTION

Global circulation models are widely used for the projections of the future climate. The resolution of them, however, is not sufficiently detailed to employ their results directly in the regional impact assessments. The regional climate models (RCMs) are used to dynamically downscale the GCM results to a finer scale of 25–50 km. The hydrological regime and the impact of a climate change on this regime could be assessed by either using the hydrological component of the RCMs or using external hydrological models. In the latter case, the time-series of meteorological parameters from the RCMs (temperature, precipitation, humidity etc.) are used as a forcing data for independent hydrological models. Review of the recent advances with the RCMs is given in (Rummukainen, 2010).

There are many studies of the hydrological impact of the climate change recently. Review of the recent modelling strategies estimating impact of climate change on the hydrology using RCM simulations is given in (Teutschbein and Seibert, 2010).

One of the reliability criteria of the RCMs is their ability to reproduce the various features of the present-day climate (see, e.g. Kattenberg et al., 1996). There are various studies of the model performance in the present climate (see, e.g. Jacob et al., 2007). We employ the subregional skill assessment method presented in (Sennikovs and Bethers, 2009) throughout the paper. It measures the subregional performance of RCM by comparing four parameters (monthly average temperature, precipitation, standard deviation of monthly average temperature and coefficient of variation of precipitation) between RCM data and the data from the meteorological observation stations over the particular domain of study.

The skill assessment studies show that there are biases with respect to present climate in the results of both GCM and RCM runs. Therefore, usually, the future impact is assessed by the delta-change approach, analyzing the future changes of the selected climatic variable. This approach, however, could fail in the case of hydrological studies; see the discussion in, for example, (Graham et al., 2007). It is also accepted (see e.g., Feddersen and Andersen, 2005) that RCM time-series could not be directly used to force external hydrological models prior to removing the biases. Therefore it would be useful to assess the skill of a particular RCM in respect of using its results as a forcing for the hydrological model (Lenderink et al., 2007) compared the direct forcing and the delta-change approach.

There exist methods for the bias-correction of the RCM data based on the modification of the statistical parameters of RCM data in the control period. The present paper involves the bias-correction method as described in (Sennikovs and Bethers, 2009). This bias-correction method modifies statistical distribution of daily temperature and precipitation time-series in a moving 11-day time window. The statistical moments of the temperature and precipitation distribution from the RCM data are modified to resemble that of the observed data. The method allows obtaining daily time-series of temperature and precipitation at any point throughout our domain of interest. Such time-series are employed to drive the hydrological models with the daily resolution in the present study. One may consider that skill assessment of RCM with respect of their original representation the daily temperature and precipitation is irrelevant after the bias correction due the outputs of any of RCMs might be modified to match the statistical moments of observations.

The aim of this study was to identify and demonstrate a new parameter for the skill assessment of the RCMs with respect of using their output to drive the external hydrological model. We propose such a parameter – correlation of temperature and precipitation (T/P correlation). The discrepancies of the bias-corrected RCM and observations data for the T/P correlation in the control period are analyzed, and the impact of these discrepancies on the outputs of external hydrological models is revealed.

The layout of the paper is as follows: (1) description of the hydrological models, pilot catchment and calibration, (2) description of the RCM data used to drive the hydrological models in the control period, (3) comparison of the hydrological calculations using original RCM data versus bias-corrected RCM data, (4) analysis of the discrepancies between the modelled and observed discharges, (5) analysis of T/P correlation in the RCM data versus observation data, (6) validation of the importance of T/P correlation for the reproduction of the discharges in the control period.

METHODS

Three test basins in the territory of Latvia – Bērze, Stende and Ciecere were chosen for the study (see Fig. 1). The areas of the catchments of selected rivers are, respectively, 901 km^2, 513 km^2 and 445 km^2. Monthly average observed runoff in the selected basins for the time period 1961-1990 is shown in Fig. 2. The hydrometric observation data are from (Ziverts and Strubergs, 2000). These basins have different yearly runoff patterns. The most distinct and *Nordic* feature of all of them is a well defined peak of the spring snow-melt flood; Stende basin also has an autumn rain flood peak.

Figure 1 **Area of study with the pilot basins: Bērze, Stende and Ciecere.**

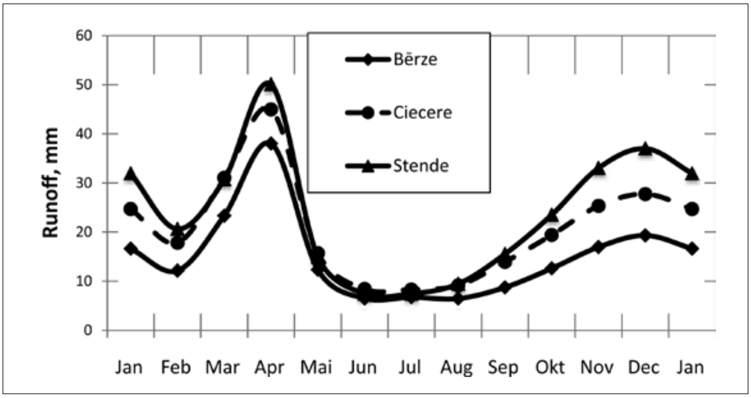

Figure 2 **Observed monthly runoff of rivers Bērze, Ciecere and Stende for years 1961-1990.**

Three hydrological models are employed in this study.

MIKE BASIN is a multi-purpose, GIS-based river basin simulation package (DHI, 2008). It is designed for analysis of water sharing problems and environmental issues at international, national and project scale. MIKE BASIN is powerful, yet simple to use, with functionality and capability of analysis for water resources engineering. It was chosen due to the fact it is simple yet could be easily calibrated to the observations. The core of the MIKE BASIN is the NAM hydrological model. The NAM model is a deterministic, lumped and conceptual rainfall-runoff model accounting for the water content in four different storages. Using this model and MIKE ZERO auto calibration module, an optimal parameter set was generated for *contemporary climate,* 1961-1990. Different sets of model coefficients were used for each of the three basins. Calibrated model parameters were not altered in the course of the project, and are the same for all model runs.

MIKE SHE (DHI, 2008) is a physically-based temporally and spatially distributed hydrological modelling system by the DHI group. It could be used in regional studies covering entire river basins as well as in local studies focusing on specific problems on small scale. The setup of MIKE SHE for the Bērze basin was coupled with MIKE 11 model for discharge routing. Two-layer groundwater model was employed. 500 m grid spacing was applied to catchment.

FiBasin (Bethers and Sennikovs, 2007) is the in-house physically-based temporally and spatially distributed hydrological model. It is based on finite volumes, and includes physically based surface flow, subsurface flow, snow and lake modules as well as dynamic flow routing through the stream channel system. We used variable element size for the Bērze basin (typically close to 2 km^2), and one groundwater layer.

Calibration of the models was performed to match the daily discharge observations in a time period 1961–1990. The observed meteorological data (temperature, precipitation and relative humidity) by Latvian Environment, geology and meteorology centre were used to drive the hydrological models in these calibration runs. The potential evapotranspiration was assumed proportional (with coefficient 0.615) to a daily averaged vapour-pressure-deficit that is calculated from the daily averaged temperature and the daily averaged relative humidity.

The performance of the calibration was evaluated by the Nash-Sutcliffe R2 criterion. Calibrating the hydrological models for the Bērze basin the R2 criterion 0.70 was reached for the MIKE SHE model and 0.69 by the FiBasin model. Calibration runs performed by MIKE BASIN represented the observations fairly good with the coefficient R2 being about 0.77 for Bērze (Figure 3), 0.79 for Stende and 0.80 for Ciecere river. All of the models provide modelled time-series of the river discharge with a daily time-step.

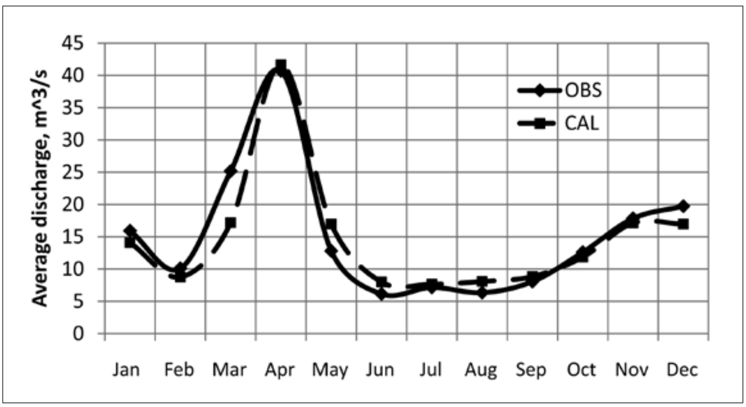

Figure 3 **Monthly mean dischange comparison of modelled calibration run (CAL), and observed (OBS) for river Berze MIKE BASIN model.**

Set of RCM model runs from the PRUDENCE (Christensen et al., 2007) and ENSEMBLES (ENSEMBLES members, 2009) project were employed in this study. All of model runs used in the study are summarized in Table 1. This table lists all of the model ensemble members showing which GCMs and RCMs where used for the run, together with the responsible institute, and the project to which the model belongs. This table also contains information of the models usage for different parts of the study, i.e. either in hydrological and T/P correlation study or in the correlation study alone. The abbreviation corresponds to the row name in Table 2, where all the monthly means of daily T/P correlations can be found.

The calculations of the discharge were performed for the control period 1961-1990. Daily time-series of temperature, precipitation and relative humidity from RCMs were used to drive the hydrological models.

Table 1 **RCM runs used in the study. X indicates the use of respective model in hydrological and/or T/P correlation study.**

Project	Institute	GCM	RCM	Abbreviation	Hydrology	T/P
PRUDENCE	CNRM	HadCM3	ARPEGE	Da9	X	X
PRUDENCE	DMI	ECHAM4/OPYC	HIRHAM	ECC	X	X
PRUDENCE	DMI	ECHAM5	HIRHAM	ECCCtl	X	X
PRUDENCE	DMI	HadAM3H	HIRHAM	F25	X	X
PRUDENCE	DMI	HadAM3H	HIRHAM	HC1	X	X
PRUDENCE	DMI	HadAM3H	HIRHAM	HC2	X	X
PRUDENCE	DMI	HadAM3H	HIRHAM	HC3	X	X
PRUDENCE	ETH	HadAM3H	CHRM	HCctl	X	X
PRUDENCE	GKSS	HadAM3H	CLM	ctl	X	X
PRUDENCE	GKSS	HadAM3H	CTL	ctlsn	X	X
PRUDENCE	HC	HadAM3P	HadRM3P	adeha	X	X
PRUDENCE	HC	HadAM3P	HadRM3P	adehb	X	X
PRUDENCE	HC	HadAM3P	HadRM3P	Adehc	X	X
PRUDENCE	ICTP	HadAM3H	RegCM	ref	X	X
PRUDENCE	KNMI	HadAM3H	RACMO	HC1	X	X
PRUDENCE	METNO	HadAM3H	HIRHAM	HADCN	X	X
PRUDENCE	SMHI	ECHAM4/OPYC	RCAO	HCTL	X	X
PRUDENCE	SMHI	HadAM3H	RCAO	HCTL22	X	X
PRUDENCE	SMHI	HadAM3H	RCAO	MPCTL	X	X
ENSEMBLES	DMI	ARPEGE	HIRHAM			X
ENSEMBLES	DMI	ECHAM5-r3	DMI-HIRHAM5			X
ENSEMBLES	ETHZ	HadCM3Q0	CLM			X
ENSEMBLES	HC	HadCM3Q0	HadRM3Q0			X
ENSEMBLES	KNMI	ECHAM5-r3	RACMO			X
ENSEMBLES	METNO	BCM	HIRHAM			X
ENSEMBLES	MPI	ECHAM5-r3	REMO			X
ENSEMBLES	SMHI	BCM	RCA			X
ENSEMBLES	SMHI	ECHAM5-r3	RCA			X
ENSEMBLES	SMHI	HadCM3Q3	RCA			X
ENSEMBLES	C4I	HadCM3Q16	RCA3			X
ENSEMBLES	ICTP	ECHAM5-r3	RegCM			X
ENSEMBLES	METNO	HadCM3Q0	HIRHAM			X
ENSEMBLES	HC	HadCM3Q16	HadRM3Q16			X
ENSEMBLES	CNRM	ARPEGE	Aladin			X
ENSEMBLES	HC	HadCM3Q3	HadRM3Q3			X
ENSEMBLES	VMGO	HadCM3Q0	RRCM			X
ENSEMBLES	GKSS	IPSL	CLM			X
ENSEMBLES	CNRM	ARPEGE_RM 5.1	Aladin			X
ENSEMBLES	KNMI	ECHAM5-r3	RACMO			X
ENSEMBLES	KNMI	MIROC	RACMO			X

Calculation of discharge using unmodified output from 19 RCMs as a forcing was performed for the Ciecere basin with the calibrated MIKE BASIN model for the time period 1961-1990 with 1-day time step. The comparison of the monthly averaged results with the discharge calculated by the same model driven by the daily meteorological observations (i.e. calibration run matching the runoff observations) is shown in figure 4. The yearly calculated average runoff varied from 4.4 m^3/s to 10.3 m^3/s in the Ciecere basin (observations show 6.7 m^3/s). The maximum of monthly average discharge in RCM-driven calculations occurs in almost any of the months, while in the observations it is due to a spring snow-melt in April. The RCM-driven calculated discharge does not represent observed seasonal changes of the river runoff sufficiently well. It means that direct employment of the RCM data as a forcing of the hydrological model is not recommended, and these calculations showed the need for the bias-correction of the RCM outputs.

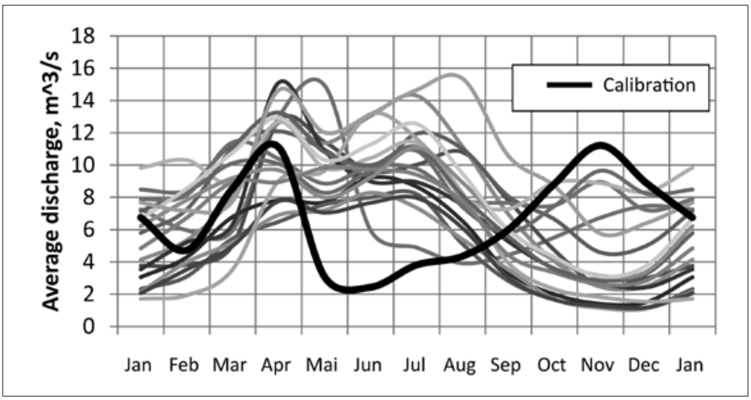

Figure 4 **Discharge calculations driven by unmodified RCM data and observed meteorological data (calibration). MIKE BASIN model, Ciecere rever, 1961-1990.**

The results of the hydrological calculations driven by the bias-corrected data for the same catchment with the data from the same 19 RCMs are shown in Fig. 5. The significant improvement of discharge signal in comparison with Fig. 4 is obvious. There are, however, clearly identifiable disagreements of the monthly discharges during both late winter and spring between the observed and calculated run-off regime. Namely, the maximum value of the observed spring peak floods is underestimated (see the month of April in Fig. 5) in the model. At the same time, the value of the observed winter low flow during February is overestimated in the model. The aim of the present paper is to identify the features of the RCM data that are responsible for the above mentioned disagreement.

Table 2 **Monthly means of daily T/P correlations for observation data (Obs) and all RCMs used in the study. 1961-1990, Riga.**

	HCTL	HCTL_22	MPICTL	3003	HADCN	KNMI_ HC1	Ref	adeha	adehb	adehc	DA9	HCctl
Jan	0.40	0.39	0.37	0.29	0.41	0.37	0.32	0.37	0.37	0.35	0.37	0.36
Feb	0.37	0.40	0.35	0.31	0.38	0.40	0.33	0.31	0.31	0.28	0.33	0.38
Mar	0.21	0.23	0.29	0.19	0.25	0.26	0.21	0.20	0.20	0.18	0.27	0.21
Apr	-0.02	-0.01	0.05	-0.02	0.01	0.09	0.14	0.14	0.04	0.09	0.12	0.03
Mai	-0.10	-0.10	-0.03	-0.06	-0.08	0.04	0.13	-0.01	0.00	0.00	0.08	0.06
Jun	-0.13	-0.17	-0.12	-0.03	-0.11	-0.04	-0.01	-0.03	-0.04	0.03	0.01	0.02
Jul	-0.22	-0.27	-0.19	-0.10	-0.15	-0.12	-0.10	-0.11	-0.13	-0.12	-0.04	-0.03
Aug	-0.24	-0.27	-0.18	-0.21	-0.21	-0.14	-0.15	-0.16	-0.15	-0.15	-0.06	-0.06
Sep	-0.19	-0.20	-0.03	-0.13	-0.13	-0.06	-0.10	-0.13	-0.09	-0.17	0.08	-0.04
Oct	-0.01	-0.01	0.09	-0.04	0.01	0.08	0.03	0.00	0.00	-0.09	0.20	0.17
Nov	0.15	0.19	0.26	0.07	0.21	0.21	0.21	0.07	0.16	0.13	0.18	0.26
Dec	0.30	0.31	0.30	0.20	0.31	0.34	0.27	0.23	0.28	0.29	0.32	0.30

	CTL	CTLsn	ECC	ECCtrl	F12	F25	HC1	HC2	HC3	DMI- HIRHAM5	DMI- HIRHAM5	ETHZ- CLM
Jan	0.33	0.35	0.39	0.41	0.40	0.39	0.41	0.36	0.38	0.23	0.26	0.34
Feb	0.36	0.39	0.33	0.35	0.40	0.37	0.35	0.32	0.28	0.21	0.26	0.31
Mar	0.19	0.25	0.10	0.29	0.17	0.16	0.13	0.10	0.07	0.17	0.17	0.25
Apr	0.07	0.07	-0.15	0.05	-0.04	-0.04	-0.05	-0.05	0.04	0.05	-0.08	0.05
Mai	-0.11	-0.08	-0.12	-0.03	-0.05	-0.05	-0.05	-0.03	-0.05	0.00	-0.10	-0.11
Jun	-0.20	-0.18	-0.16	-0.09	-0.05	-0.01	-0.05	-0.13	-0.13	0.01	-0.09	-0.16
Jul	-0.23	-0.22	-0.27	-0.04	-0.13	-0.21	-0.21	-0.24	-0.23	-0.04	-0.17	-0.27
Aug	-0.26	-0.23	-0.18	-0.13	-0.23	-0.22	-0.27	-0.24	-0.24	-0.11	-0.16	-0.16
Sep	-0.12	-0.09	-0.17	-0.03	-0.12	-0.11	-0.14	-0.13	-0.15	-0.12	-0.05	-0.10
Oct	0.13	0.18	0.10	0.16	0.13	0.12	0.09	0.03	0.07	0.08	0.06	0.06
Nov	0.22	0.26	0.27	0.34	0.27	0.28	0.26	0.23	0.23	0.16	0.15	0.23
Dec	0.30	0.34	0.39	0.36	0.36	0.36	0.37	0.32	0.38	0.22	0.29	0.27

	METO-HC HadRM3Q16	KNMI-RACMO2	METNO-HIRHAM	MPI-M-REMO	SMHIRCA	SMHIRCA	SMHIRCA	C4IRCA3	ICTP-REGCM3	METNO-HIRHAM	METO-HC_ HadRM3Q0
Jan	0.31	0.28	0.29	0.22	0.33	0.29	0.37	0.33	0.26	0.30	0.29
Feb	0.25	0.27	0.32	0.25	0.36	0.31	0.34	0.31	0.24	0.29	0.30
Mar	0.12	0.25	0.19	0.16	0.26	0.25	0.29	0.25	0.19	0.23	0.21
Apr	0.02	0.04	-0.01	-0.11	0.10	0.11	0.19	0.13	0.03	0.05	0.10
Mai	-0.08	-0.11	-0.09	-0.19	0.01	0.05	-0.01	-0.01	-0.07	-0.08	0.07
Jun	-0.03	-0.07	-0.18	-0.13	0.01	0.03	-0.09	-0.04	-0.10	-0.09	-0.01
Jul	0.00	-0.23	-0.25	-0.22	-0.07	-0.02	-0.10	0.04	-0.15	-0.14	-0.07
Aug	-0.14	-0.10	-0.18	-0.15	-0.02	-0.02	-0.10	0.05	-0.05	-0.11	-0.05
Sep	-0.08	-0.07	-0.14	-0.14	0.15	0.01	0.07	0.01	0.01	0.10	-0.01
Oct	0.16	0.16	0.00	0.02	0.19	0.19	0.23	0.18	0.18	0.15	0.09
Nov	0.31	0.17	0.22	0.10	0.26	0.23	0.26	0.31	0.23	0.21	0.28
Dec	0.34	0.27	0.28	0.21	0.29	0.28	0.38	0.34	0.30	0.33	0.28

	CNRM-RM5.1	METO-HC_ HadRM3Q3	VMGO-RRCM	GKSS-CCLM4.8	CNRM-RM4.5	KNMI-RACMO2	KNMI-RACMO2	Obs
Jan	0.33	0.25	0.39	0.30	0.32	0.30	0.34	0.21
Feb	0.27	0.27	0.29	0.30	0.24	0.28	0.27	0.19
Mar	0.11	0.18	0.23	0.23	0.11	0.17	0.13	0.12
Apr	0.00	-0.01	0.06	0.06	0.05	0.11	0.00	-0.09
Mai	-0.02	-0.11	0.00	0.02	0.03	-0.01	-0.05	-0.06
Jun	-0.15	-0.21	-0.05	-0.18	-0.01	-0.16	-0.21	-0.01
Jul	-0.26	-0.21	-0.15	-0.23	-0.04	-0.09	-0.20	-0.16
Aug	-0.13	-0.09	-0.09	-0.11	-0.01	-0.07	-0.05	-0.14
Sep	0.01	0.05	-0.01	0.07	0.14	0.15	0.23	-0.13
Oct	0.14	0.20	0.17	0.10	0.12	0.20	0.21	0.05
Nov	0.25	0.29	0.34	0.25	0.30	0.30	0.30	0.08
Dec	0.32	0.40	0.35	0.18	0.35	0.35	0.33	0.10

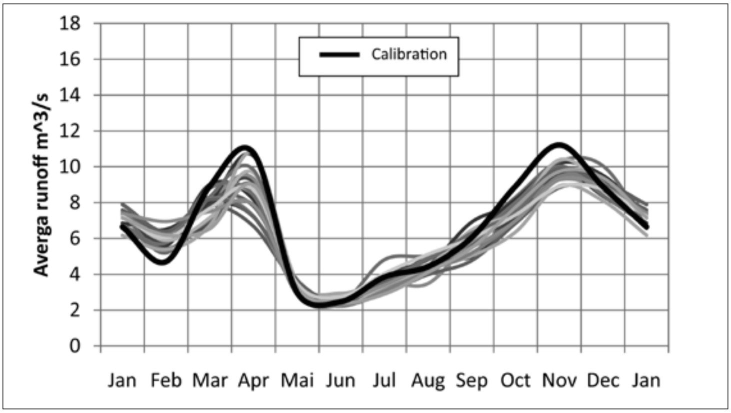

Figure 5 **Discharge calculations driven by modified RCM data and observed meteorological data (calibration). MIKE BASIN model for river Ciecere, 1961-1990.**

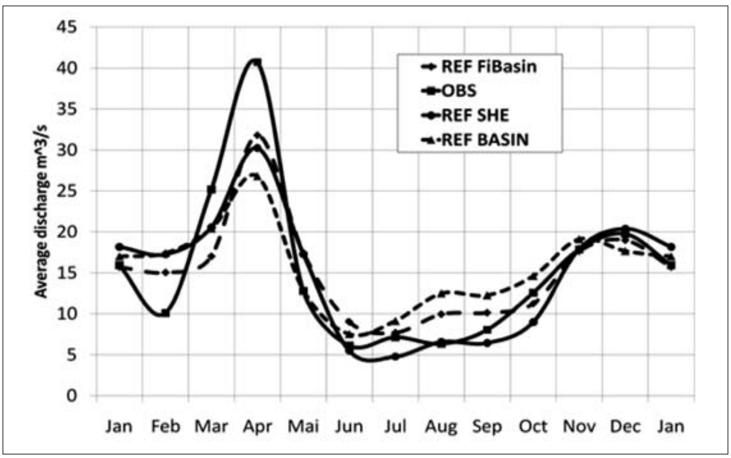

Figure 6 **Discharge of river Berze, observed and calculated, using different hydrological models driven by modified RCM HCctl data, 1961-1990.**

Calculations with three different hydrological models for the same catchment (Bērze) driven by the bias-corrected meteorological data from arbitrary RCM were performed to show that the problem of the representation of the spring flood maximum and winter flow minimum is not a model (MIKE BASIN) specific. Figure 6 depicts calculations of the flow with the bias-corrected RCM data with calibrated MIKE BASIN, MIKE SHE and FiBasin models for the Bērze basin. The SMHI RCAO HCCTL_22 model run data from PRUDENCE project was used as a source of forcing data in this comparison. Although there are differences in the results provided by different models, the above mentioned deviation of winter and spring hydrograph from the observations can be clearly seen in the all three simulations.

RESULTS

The employed bias-correction method could not correct the temperature - precipitation correlation (Sennikovs and Bethers, 2009). The monthly averaged values of daily T/P correlations in Riga from an ensemble of bias corrected RCM results are summarized in Table 2 and Fig. 7 for the winter and spring months. Values of the T/P correlation calculated from the observation data are shown in the same Fig. 7. All models show an excessive correlation during the winter months ranging from average monthly values of 0.36 to 0.21 as opposed to the average correlation 0.15 in the observation data. Such a large difference is only found in the winter months whereas for the rest of the year (Table 2) the monthly correlation in RCM data ranges from –0.10 to 0.08 (the observed value being –0.05). This clearly indicates a principal problem of the whole family of regional climate models – a model inability of correct representation of the precipitation/temperature interrelation during the cold part of the year. All RCMs show significantly stronger positive correlation between the precipitation and temperature during the winter months. Physically it means more precipitation in the warm winter days and less precipitation during the severe cold periods. It leads to an artificial decrease of the precipitation fraction that falls out as snow, subsequently reducing the accumulated snow amounts, and, as an effect to hydrology – reduction of the spring flood maximum. On the other hand, another consequence of the same effect is the increased fraction of rain during the winter, which artificially increases the winter runoff. Thus, the inadequate model representation of the winter T/P correlation might be the main source of the systematic deviations of the modelled hydrographs from the observed ones identified in the previous section (Fig. 5).

The hypothesis that T/P correlation during the winter months in the RCM data might be a measure of the ability of an external hydrological model (driven by the respective RCM output) to represent the observed spring snow-melt flood maximum was proposed. To verify this hypothesis we performed a series of 30-year (1961–1990) calculations by MIKE BASIN model for Ciecere basin with daily time step. We used a set of bias-corrected 19 RCM outputs for model forcing. For each model run we calculated the sum of absolute differences between the monthly mean calculated and observed discharges. These sums for considered models are shown as a function of T/P correlation during winter months (Nov, Dec, Jan and Feb) in Fig. 8. Fig. 8 clearly shows that the ability to reproduce an annual hydrograph decreases with the increase of the T/P correlation in the particular RCM used for a forcing of the hydrological model. We applied a linear regression model ($y = ax + b$) to T/P correlation for winter months and discharge differences; yielding $b = -0.004$ and $a = 29.9$. Standard deviation for a is 12.3. The parameter a is significant within 97% confidence level (Fisher, 1954).

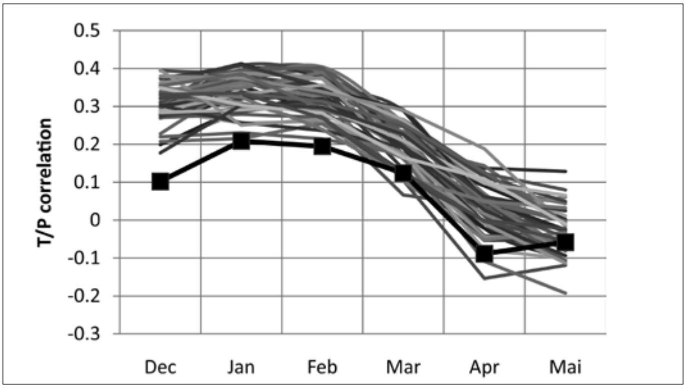

Figure 7 **Monthly means of daily T/P correlation in observation data and RCM data for in the winter/spring minth, 1961-1990.**

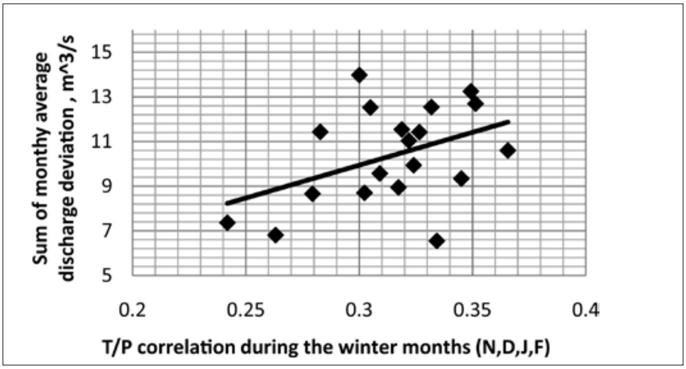

Figure 8 **T/P correlation inpact on the ability to represent the hydrological cycle. Ciecere basin, 1961-1990.**

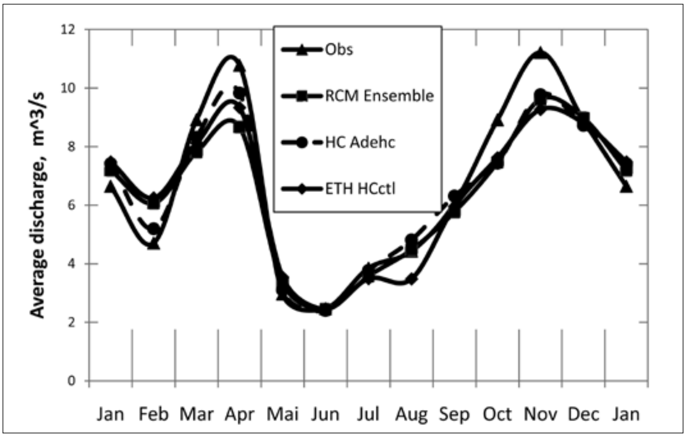

Figure 9 **Comparison of monthly mean discharges of river Ciecere,1961-1990. Observations and MIKE BASIN calculations (a) mean values of ensemble of RCMs, (b) driven by HC Adehc model, (c) driven by ET HCctl model.**

We assume that this analysis is a sufficient proof that T/P correlation of RCM data during cold part of the year determines the skill of RCM in representing the winter and spring hydrograph via external hydrological models. In such a case this T/P correlation may be used for skill assessment of RCM instead of the method proposed in (Sennikovs and Bethers, 2009). Indeed, the previous skill assessment might be irrelevant for selection of the most skilful model due to the bias correction (Sennikovs and Bethers, 2009) removes the skill differences between the models.

The illustration of the skill of different models in representing the annual hydrograph is shown in Fig. 9 – all calculations by MIKE BASIN model, Ciecere basin, years 1961–1990. The following graphs of monthly mean discharges are compared: (1) the observed values, (2) the ensemble mean of the hydrological modelling results forced by the whole set of RCMs, (3) the values of the hydrological calculations forced by the most skilful RCM according to the proposed T/P correlation criteria (HC Adehc), (4) the values of the hydrological calculations forced by the most skilful RCM ETHC HCctl according to the criteria in (Sennikovs and Bethers, 2009). One may consider that the new skill assessment criterion indeed provides a better match of observed and calculated hydrographs.

INTERPRETATION AND DISCUSSION

The study presented in this paper allows drawing the following conclusions:

1. The usage of outputs from an ensemble of regional climate models for the forcing of external hydrological models once again confirmed conclusion that RCM outputs should be additionally processed for achieving adequate hydrological response.
2. The bias-correction of RCM outputs by the method proposed in (Sennikovs and Bethers, 2009) provides a reasonable data set for employment with hydrological models.
3. The usage of the corrected ensemble of data sets from RCM for the forcing of external hydrological models revealed the systematic overestimation of the modelled winter discharge and underestimation of the spring snow-melt floods.
4. The calculation exercise with different hydrological models allowed conclusion that these systematic deviations are inherited from the RCM data structure rather than from the properties of a particular hydrological model.
5. The skill assessment of RCMs based on their agreement with the meteorological observations during the control period (1961–1990)

becomes irrelevant after the bias correction due all models become equally skilful in this respect.

6. The systematic overestimation of the correlation between the temperature and precipitation in the winter period was found for all members of RCM ensemble. The reason of this feature of RCM is unknown for the authors, and up to our knowledge is not addressed in the literature.
7. The logical considerations and calculations in this paper demonstrate that the overestimation of the T/P correlations for the cold part of the year in the RCM outputs leads to both systematic deviations of the hydrograph calculated by models driven by RCM data from the observed hydrograph, namely overestimated winter and underestimated spring discharge.
8. We propose the use of the temperature-precipitation correlation as the measure of the skill of regional climate models if the output of RCM has to be used for forcing of external hydrological models.

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Using Digital Repeat Photography in Phenology: Case Study in Riga

Evita Groza
Latvijas Universitāte
Ģeogrāfijas un Zemes zinātņu fakultāte
Raiņa bulv. 19, Rīga, LV-1586
E-pasts: evita.groza@gmail.com

Maija Dragiļeva
Latvijas Universitāte
Ģeogrāfijas un Zemes zinātņu fakultāte
Raiņa bulv. 19, Rīga, LV-1586
E-pasts: maija.dragileva@gmail.com

Māra Bitāne
Latvijas Universitāte
Ģeogrāfijas un Zemes zinātņu fakultāte
Raiņa bulv. 19, Rīga, LV-1586
E-pasts: mara.bitane@gmail.com

Abstract
Digital repeat photography is a modern and easy method for observing and detecting phenological events as well as documenting changes in phenological patterns.
Urban phenology, the new field of phenological studies, is fast developing because heat island phenomena associated with urban areas provide possibilities to study the local effect of warming on phenology in great details. In this study we analyzed digital photographs in order to compare phenological phases at different areas in Riga city, Latvia. This is a first attempt to make a research in urban phenology using digital photography.
The spring phenological stages of Norway maple *Acer platanoides*, silver birch *Betula pendula* and bird cherry *Prunus padus* in period 2009–2011 are studied. The objective of this study is to compare observed spring phenophases in four different areas of Riga city using digital repeat photography. Main tasks were to collect digital images with various phenological phases at different areas in Riga city and to compare those phases emphasizing the conditions influencing plant phenology in urban environment.

Keywords: phenological phases, urban phenology, Latvia

INTRODUCTION

The importance of phenology in global change studies has increased last few decades due to the fact that phenology is an excellent instrument to detect and measure the impact of climate on vegetation (Roetzer et al., 2000; Neil and

Wu, 2006; Ide and Oguma, 2010). Phenology can be defined as "the study of the timing of recurring biological phases, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species" (Linderholm, 2006, p. 2).

The influence of climate changes on vegetation can be examined by using the annual variation of starting dates of phenophases like the leaf unfolding, the beginning of flowering or other (Roetzer et al., 2000). Urban phenology has some specific features that differ from common phenology. Effect of increased temperature in urban territories known as urban heat island is one of the factors influencing microclimate in cities and other urbanised areas (Lu et al., 2006).

Terrestrial observation studies in Europe, e.g. by Roetzer et al. (2000), Lakatos and Gulyás (2003) and Mimet et al. (2009), as well as studies in North America (e.g. Zhang et al. 2004) or Asia (e.g. Lu et al. 2006; Luo et al. 2007) confirm an earlier plant development in urban areas (Jochner et al., 2011). The urban heat island effect, classically associated with high impervious surface area, low vegetation fractional cover and high land surface temperature, has been linked to changing patterns of vegetation phenology, especially spring growth – that means the dates in early flowering species advance more quickly than in late flowering species (Lu et al., 2006; Gazal et al., 2008). Therefore plants located in urban areas have to cope with warmer conditions compared to plants growing in rural areas. In addition, the phenological differences can be observed in the city too.

The city itself represents a modified ecological environment for plants in many aspects (urban heat island phenomenon, high building density, air pollution, soil sealing and pollution, water balance) so pattern of phenological data represents mainly ecological-microclimatic structures of urban area (Lakatos and Gulyás, 2003). There are enough factors, such as the distribution of buildings, closeness of streets with heavy traffic, vegetation zones and many more that are influencing urban vegetation and phenological events.

Digital repeat photography has became one of the most easy, inexpensive and modern method for phenological observations (Crimmins and Crimmins, 2008; Ide and Oguma, 2010). Recently the number of studies using digital images from standard ground-based RGB (red, green and blue) cameras for vegetation studies has increased (Ahrends et al., 2008; Crimmins and Crimmins, 2008; Graham et al., 2009). Despite this pioneering work, the application of digital image analysis in vegetation phenology is still a new field.

Repeat photography offers some advantages compared to other methods that are used for phenological data obtaining. Once the camera is installed at the field, time series of images could be collected automatically at any intervals. Even archived time series of digital images, which were not used previously, could be widely available for future analysis. Another advantage is the high resolution in time and space as well. Phenology can be observed at a wide range of spatial scales, from a species to a local ecosystem, depending on both the resolution of the camera and the distance to the target (Ide and Oguma, 2010). In addition, photo time series can capture traditional phenologic measurements, such as first flowering date and budburst as well as quantitative changes in plant phenology over time, including increases and decreases in greenness and shifts in the abundances of flower blooms. Finally, repeat photos have great value for public outreach. Changes in phenology are easy to visualize using repeat photographs and scientists and volunteers of all skill levels can be engaged in data collection and interpretation using this method (Crimmins and Crimmins, 2008).

Previous studies mainly documented the conceptual use of area-integrated digital camera images (Hall, 2001; Borman and Chamberlain, 2004) or photo-monitoring for historical and ecological purposes (McDougald et al., 2003; Lassoie and Comba, 2006; Myron, 2008). Digital photography also can be used in agricultural industry to observe the health of the plants and growing conditions (McDougald et al., 2003; Borman and Chamberlain, 2004; Mobasheri et al., 2008). Spatial and temporal uncertainty of digital images for continuous objective monitoring of phenological processes is still largely unknown. The digital images can be used in urban territories as well as in rural areas.

The objective of this study is to compare observed spring phenophases in four different areas of Riga city using digital repeat photography. Main tasks were to collect digital images with various phenological phases at different areas in Riga city and compare those phases emphasizing the conditions influencing plant phenology in urban environment.

MATERIALS AND METHODS

Study area

The study area where photographic samples were taken is Riga which is the capital of Latvia and also the largest city (about 300 km^2) in the country. Riga is situated near the Baltic Sea, approximately 15 km south from it. It is located at 56°56' N and 24°6' E at 6 m a.s.l. on the average. The country's largest river Daugava passes through Riga and flows into the Baltic Sea (Turlajs, 2007).

Overall four sites were studied in Riga city in order to analyze and compare spring phenological events of 52 trees: 32 silver birches, 19 Norway maples and one bird cherry. All trees were observed and photographed twice per week by ourselves with the exception of plants in Botanical Garden, where the automated digital camera is located taking images automatically and sending them to the server. The investigated areas were Riga city centre (with 2 maples and 2 birches), Dārzciems (1 maple and 7 birches), Dzirciems (15 maples and 22 birches) and Botanical Garden (1 maple, 1 birch and 1 bird cherry).

The map with observation sites in Riga city (Fig. 1) is created using programme *ArcGIS Desktop 10*. The data layers from GIS database developed by Faculty of Geography and Earth sciences (University of Latvia) are used. The whole map of Latvia is taken from the enterprise *Grupa93* homepage (http://www.grupa93.lv/?fl1m58i2). The maps showing observation points in the city centre and Dārzciems (Fig. 2) are based on the digital map of Map Publishers "Jāņa Sēta" Ltd. (http://rigas-centra-karte.zl.lv/). For pointing to observation sites the Microsoft Windows programme *Paint 6.1* is used.

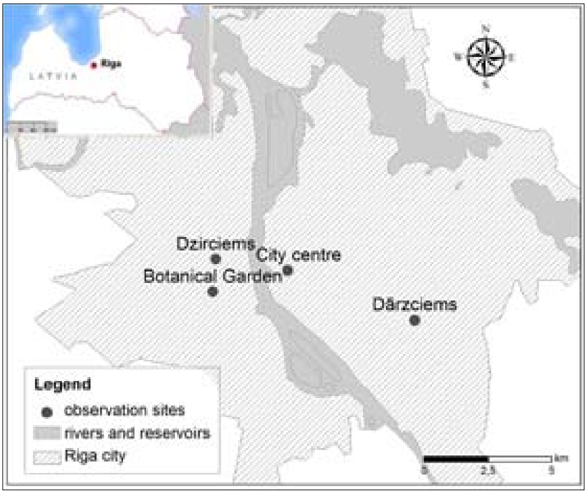


Fig. 1. **Observation sites in Riga city.**

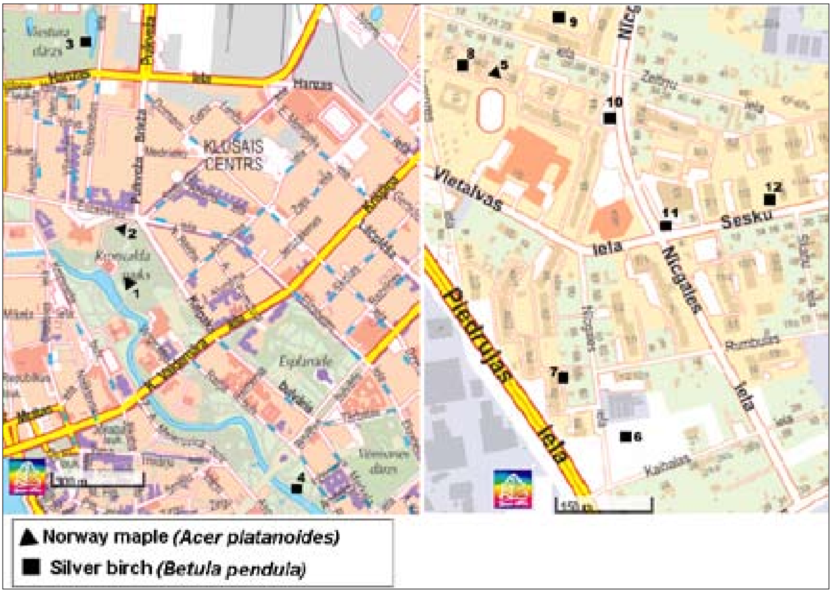


Fig. 2. **Observation points in Riga city centre (left) and Dārzciems (right) during the period of April 10 to May 12 year 2011.**

The map with included observation points in Dzirciems (Fig. 3) is based on the orthophoto layer with resolution 0.5 m from database developed by University of Latvia, Faculty of Geography and Earth sciences (http://kartes.geo.lu.lv/). The map is created using programme Quantum GIS version 1.6.0.

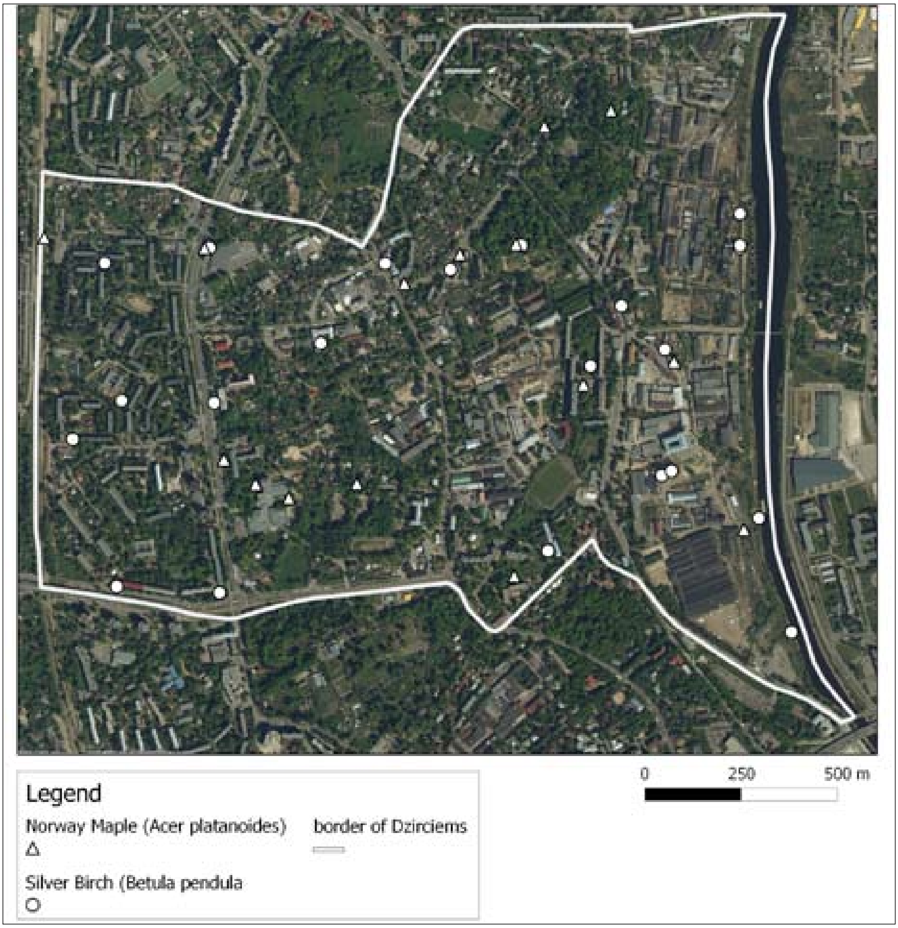


Fig. 3. **Observation points in Dzirciems.**

METHODS: DIGITAL IMAGES

The digital images have been collected at different parts of the Riga city (Fig. 1). One of the sites is Botanical Garden of University of Latvia where the commercial web camera *StarDot NetCam* is located taking several digital photos per day from the beginning of spring in 2009. Field observations include three other investigated areas where we have taken photos by ourselves twice per week. These areas are Riga city centre and two districts - Dārzciems and Dzirciems. The investigated species were Norway maple *Acer platanoides*, silver birch *Betula pendula* in the city centre, Botanical Garden and both districts and bird-cherry *Prunus padus* only in Botanical Garden. A *Nikon D70* digital single-lens reflex camera and *Canon 400 D* camera were used to capture images. All images were analysed visually.

Digital images from Botanical garden were used to analyse and compare phenological stages in order to show the difference between starting dates of spring phases for observed tree-year period. The starting of such following spring phenological phases as bud swelling, bud burst, leaf unfolding and flowering was observed in Botanical Garden for 2009–2011 period.

The digital images at Dzirciems were taken on April 25 in 2011 and phenological events were investigated for 37 trees (Fig. 3.), 22 silver birches and 15 Norway maples. The main task was to compare phenological observations of both species at the same day, as well as all trees were divided into five groups, depending on location of the surrounding buildings and environmental conditions. First group contained trees that grow on the side of the street. Second group encompassed trees growing in the yard of multi-storey buildings. Third included parks, in this case it was Dzegužkalns. Fourth group contained trees near canal. Finally, fifth group was made of trees that grew in open area. These groups were established to make comparison between observed conditions of phenological stages according to different growing environment.

Overall 205 digital photographs were shot taking photos twice per week in year 2011 from the period covering April 10 to May 12 at twelve separate locations in Riga city centre and Dārzciems (Fig. 2). Bud swelling, bud burst, leaf unfolding and flowering were the easily identified stages in the photographs. Development of mentioned phenological stages and differences in their progress amongst selected locations were captured. Due to close up images of selected branches the phenological stages were easily detected. This was not possible only assessing photographs of a whole tree.

RESULTS

Comparison of spring phenological stages in Riga city centre and Dārzciems

Overall 205 digital photographs were analyzed from the period covering April 10 to May 12 in 2011. Digital images shot twice per week at twelve separate locations in Riga city centre and Dārzciems (Fig. 2) enabled studies of the development of bud burst, bud swelling, leaf unfolding and flowering phases and differences in their progress amongst selected locations.

Norway maple *Acer platanoides*

Evaluating images from the period April 25 – May 12 it was established that leaf unfolding, leaf expansion and flowering started earlier in the city centre. Emerge of flowerheads from buds was observed in the city centre at

April 25, whereas in Dārzciems buds were still closed (no bud burst) (Fig. 4). No significant differences were detected between locations in the city centre. Flowering evened up in all locations by May 2, but leaf development continued to be delayed in Dārzciems until full leaf expansion. Accordingly, at April 28 in Riga centre leaves were unfolded and began to expand, at the same time in Dārzciems unfolded leaves were barely visible. At May 9 in the city centre most of the leaves reached full size, while in suburban location it was not yet observed.

Silver birch *Betula pendula*

Fig. 4. **Acer platanoides bud development in the city centre (right) and in Dārzciems (left) on 25.04.2011.**

Fig. 5. ***Betula pendula* leaf unfolding in the city centre at location #4 (top left) and in Dārzciems at location #12 (bottom left), #10 (top right), #8 (bottom right) on 25.04.2011.**

Evaluating digital photographs of silver birch it was found out that 4 locations (2 in Riga centre and 2 in Dārzciems) showed earlier development of spring phenological stages and 5 locations (all in Dārzciems) delayed development (locations #6, #7, #8, #9, #10). Thus bud breaking was observed at April 12 in the first group and at April 18 in the second. Leaf unfolding and expansion was observed at April 25 in the city centre and Dārzciems locations #11, #12 (see Fig. 2), while at the rest of locations only green tips on buds were visible (Fig. 5). By April 28 expansion of leaves was observed at 6 locations (#3, #4, #8, #9, #11, and #12) and leaf unfolding phase at three sites (#6, #7, and #10). Thereby, only three suburban locations showed the distinct delay of spring phenological stages comparing to the city centre.

The comparison of phenological characteristic for Norway maple and silver birch in Dzirciems

The digital images from Dzirciems were taken on April 25 in 2011 and phenological patterns and differences were investigated for 37 trees: 22 silver birches and 15 Norway maples (Fig. 3), comparing phenological observations of both species at the same date and dividing all plants into five groups, depending on environmental conditions.

Comparing silver birches growing on the side of the street, mostly the leaf unfolding was observed as well as the late bud burst stage also was detected for some trees. The end of bud swelling mostly was observed for Norway maple.

Most of those silver birches, growing in the yard of multi-storey buildings on the April 25, had beginning of leaf unfolding. Nevertheless some of trees still had bud burst stage. Observing the Norway maple, the end of bud swelling stage was determined.

In the park territory (the hill of Dzegužkalns) the early leaf unfolding of silver birch was detected due to the tree location on the southern slope of Dzegužkalns. We observed earlier spring phenological stages for maples located on the southern slope of hill compared with those trees growing on the northern slope. There was bud burst observed on the southern side, while on the northern side there still was bud swelling stage.

As regards the group of silver birches growing nearby the canal, mostly the late bud burst phase was observed and also early leaf unfolding phase for some trees. There were no Norway maples nearby the canal. All silver birches located in open areas had early leaf unfolding phase, and the bud swelling stage was detected for Norway maples.

Annual variations of spring phenological phases in Botanical Garden

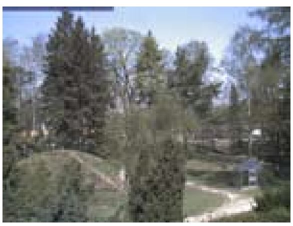
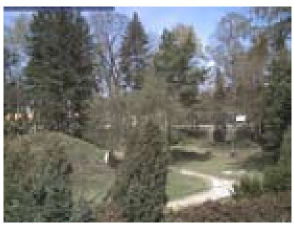
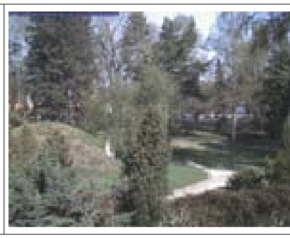
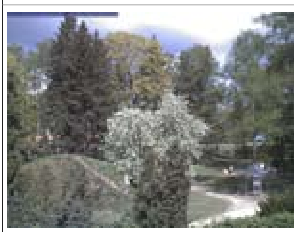
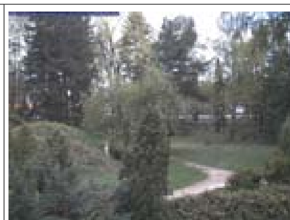
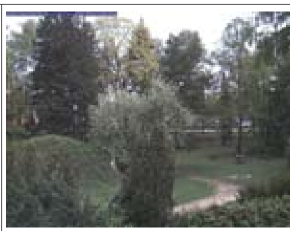
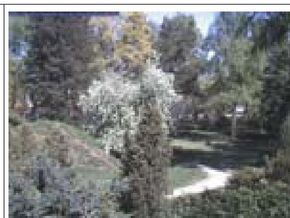
2009	2010	2011
02.03.		
		
16.04		
		
28.04.		
		
05.05.		
		
11.05		
		

Fig. 6. **The comparison of spring phenological phases using digital images taken at Botanical Garden in period 2009–2011.**

Several dates in spring season for the period 2009–2011 were chosen to evaluate and compare phenological events in Botanical Garden of University of Latvia (Fig. 6). Three tree plant species were studied: silver birch *Betula pendula*, bird cherry *Padus racemosa* and Norway maple *Acer platanoides*.

On May 2 2009 snow cover was thinner than in 2010 and 2011. Dormant bud phase have been observed for all three years and for all studied plant species.

Snow melting speed was similar in the last decade of March, although in 2009 snow completely melted couple days earlier because winter was warmer in 2009 than in 2010 and 2011. In 2010 snow completely melted on March 31 but in 2011 it happened three days later on April 3.

Digital photos taken on April 16 show that in 2009 bird cherry *Padus racemosa* already had leaf unfolding and it was continuing for 10 days. In 2010 and 2011 leaf unfolding was enduring for 6 and 4 days. In all three years silver birch and Norway maple both have bud burst on April 16.

Bird cherry flowering was observed on April 28 in 2009, comparing with the year 2010 when flowering was not observed. The flowering phase also was detected in year 2011. In all three years on the same date (April 28) Norway maple had stage of flowering and leaf unfolding. In year 2009 leaf unfolding and flowering had continued for two days, but in 2010 and 2011 these phases were just begun. In 2009 leaf unfolding for silver birch was detected, comparing with year 2010 and 2011, when bud swelling was observed.

On May 5 in 2009 the flowering of bird cherry was determined, and this phase was very well observable in the digital images, but on May 5 in 2010 flowering was not yet started. On the contrary, in 2011 digital images showed that flowering has just begun. On May 5 in 2009 and 2011 the flowering and early leaf unfolding of Norway maple lasted already for week, but in 2010 it has just begun. In all three years the early leaf unfolding of silver birch was observed.

On May 11 in all studied period the flowering stage of bird cherry was established. Only one difference was observed: in 2009 bird cherry started to shed its blossoms, but in 2010 and 2011 the beginning of flowering was detected. As regards silver birch, it already had green leaves.

CONCLUSION

Earlier leaf unfolding and flowering of Norway maple are observed in the city centre compared with Dārzciems. Meanwhile, in case of silver birch the distinction between mentioned regions was not so apparent. This can be explained by the fact, that only one Norway maple specimen, but a total of seven silver birch trees were selected in Dārzciems. This creates greater diversity in case of silver birch and thus a greater impact of small-scale factors.

Comparing both species from Dzirciems study in every group, the timing of phenological stages was quite similar. Norway maple had earlier spring phenological stages in all groups comparing with silver birch. Greater difference of phenological stages in Dzirciems was observed for silver birch; on April 25 in all area of Dzirciems various phenological phases of birch was detected from bud burst to first leaves. Norway maple had only bud swelling stage.

Comparing phenological phases in Botanical Garden in years 2009, 2010 and 2011, there was observed that in 2009 phenological events occurred earlier. In 2010 and 2011 the starting and duration of phenological phases were similar, though in 2011 they started about couple of days earlier.

Using digital photos in phenology is a good alternative to daily observations. It can be successfully used to describe phenological differences in Riga.

Observations in Botanical Garden are the first attempt of using digital photos in phenological studies in Latvia. The survey is made since year 2009 and it is going to be continued.

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Unusual Weather Conditions in Latvia (900–1860)

Guntis Eberhards
University of Latvia, Faculty of Geographical and Earth Sciences,
Raiņa Blvd. 19, LV 1586, Rīga, Latvia

The historical sources that describe weather conditions in the Baltics and Latvia over a period of more than 900 years – which are to a certain extent summed up in this work – provide an insight into unusual winters, springs, summers and autumns; catastrophic floods in the Daugava River and other rivers; high heat and unimaginable drought, when rivers and wells dry up, forests and swamps burn out; steady rain going on for months; winter snow and blizzards continuing for 1–2 months; situations when all sowings wither in spring or early summer around the solstice, or are flooded up by the summer and autumn rains, resulting in long-term hunger without bread throughout the Baltics; when the Baltic Sea (not to mention the Gulf of Riga) freezes up in particularly severe winters several times in a century, and people from Denmark, Germany and Poland travel back and forth to Sweden and Finland, and also to the Baltics on foot or by sleigh, because it is easier to move over ice than through snowbound fields and forests.

Key words: climatic extremes, history, climate change,

INTRODUCTION

What we are witnessing today and in recent decades is neither unusual, nor unprecedented. In the second half of the 20th century and early 21st century, there have been no such extraordinary years, when rye could be reaped already in June or cherries could be picked already in May. Nor there have been years in which, in late spring frosts or even around the Midsummer Day in June, when the last night frosts occasionally occur in Latvia, all crops and vegetable gardens had perished (with cold), resulting in food shortage. Unusual, extreme weather conditions are yet to come. To have an idea of what has been and, perhaps, of what we can expect in the near or distant future, let us take a look at the events of the remote past, their descriptions found in various historical sources, such as chronicles, annals, newspapers and monographic materials.

Unusual winters

Information about the earliest known harsh winter in 991 is found in the newspaper *Latviešu avīzes* (Latvian Newspapers) (28, No. 22). According to the ancient archive data, the winter in the Baltics was very severe: everything was destroyed by frost, including crops, and there was a famine.

In 1172, in contrast, as written in the *Latviešu avīzes* (28, No. 47) on the basis of archival data, the winter in the Daugava River basin was so warm that trees sprouted buds and birds started to build nests. The Chronicles of Livonia, in turn, report that in 1214 and 1216, winters again were so severe that the Gulf of Riga was covered with ice so thick that a large army of Rigans could freely move over it, marching out in a campaign against the Livs of Vidzeme and Latgallians. Also in 1219, when traffic between Riga and Estonia took place over the ice of the Gulf of Riga, it was so cold that masses of wayfarers had face, feet, joint and nose frostbites and were forced to turn back. Their old, frost-bitten skin peeled off and new skin appeared, as the Chronicle of Livonia describes (6).

It is also written in the Chronicle of Livonia (6) that Bishop Albert with his army went in a campaign from Riga to Saaremaa across the Gulf of Riga in 1225 and 1227, when the winters were harsh and the gulf was frozen. The noise caused by the moving army was like thunder: weapons clanging, sleds colliding, people shouting, people and horses falling and getting up on the slippery ice. Similar campaigns and travels over the frozen Gulf of Riga from Livonia to Estonia took place also in 1228, 1260–1261 and 1269–1270.

The *Latviešu avīzes* provided information according to the chronicle data that there was no winter at all in 1289. In Christmastime, young women adorned themselves with violets coming into flower in the fields (28, No. 4).

Then comes the beginning of the 14th century – the years 1315 and 1316/1317 – when winters were extremely cold in the Baltics and Russia. All crops were destroyed by frost and famine followed (13, 16, 26, 28, 30). Bread and other foodstuffs in Livonia were as expensive as never before. Hundreds of people died of hunger. The famine lasted for three years, as rye and barley sowings were frost-bitten each year (13).

The winters were harsh again in 5 years (1322 and 1323). The Baltic Sea was frozen for 7 weeks. Wayfarers from Germany and Sweden made their way to Riga by ice. So wrote the *Latviešu avīzes* in 1868 (28, No. 9). However, referring to the archive data, the same newspaper (28, 1873, No. 4) wrote that the winter was particularly warm in 1341: cherries blossomed in March and were ripe already in May!

A harsh winter again in 1345, and the Baltic Sea froze over. The weather conditions were similar also in the early 15th century (the years 1408, 1418 and 1426). Extremely cold and snowy winters also in 1432, 1433 and 1434: "The winters were very severe; once it was snowing steadily for 40 days and nights in a row," so says the *Latviešu avīzes* in 1876 (28, No. 22).

Relying on archival materials, the *Latviešu avīzes* wrote in 1873 (28, No. 4) that the winter was very warm in 1538: gardens were in blossom already in December and January.

Several sources (13, 15 and 17) reported unusually harsh weather conditions in the autumn and first half of winter in 1576. Storms like no one had seen before raged all autumn until the New Year. People died in the thick snow. The strong wind bent down the rooster on the steeple of St. Peter's Church in Riga on the 2nd of October. Terrible winds razed over the sea. In Revel (Tallinn), no one could remember before this occurrence a storm toppling down a bell-tower and the waves and wind in the port of Revel smashing and sinking loaded ships and boats in the course of one autumn (13).

In contrast, the winter in the Baltic States in 1617 was very warm and rainy, without snow. The wind blew from south-east and it rained all January, grass grew, flowers opened and cherries started to blossom. There was snow only in February, when it was possible to make sledge routes just for one and a half week (31).

There was a similarly warm winter again in 7 years, in 1624. In December 1623, there was frost about 2–3 weeks before Christmas. On 18 March 1624, the spring high water started in the Daugava River, and in April it was as warm as around the midsummer. On the 15th of April, cherries were in blossom. So wrote J. Brotze (17).

The winter of 1636 was severe, the Baltic Sea froze over, while the winter of 1666 was so cold that peasants froze to death while riding in sleigh, remaining in a sitting position as if alive (31).

A. Sapunovs (14) writes that the winter in 1696 was again so warm that the Daugava River did not freeze up all year round.

Many historical sources report a very severe and snowy winter in Latvia and Russia in 1709. The *Latvijas avīzes* inform that the soil froze 9 feet deep (2.42 m), the Baltic Sea froze over completely, while ice thickness in the Daugava River reached 2.5 arschines (1.73 m). Catastrophic floods followed in Riga afterwards (31).

In 1722, the winter was again warm in Latvia, and there was little snow. Trees were in leaves already in February. The winter was dry and warm in most of Europe (28, 1873, No. 4). The winter was warm in the Baltics also in 1741. January, February and March were rainy with thunder. The summer was also rainy (23). 3 years later, in 1744, as reported in many sources, the winter was extremely cold. In 1814, the newspaper *Rigasche Stadt-Blätter* noted that the ice cover thickness in the Daugava River was two times the height of a man (31). Then great floods followed in Riga.

In 1760, the winter in the Daugava basin area was long and cold, the snow cover depth reached 1–2 arschines (> 1 m). There were no thaw days throughout the winter (32). Conditions were similar also in 1789: a severe winter was followed by a beautiful spring and very hot summer with good hay crops.

The winter of 1823 was severe not only in the Baltics but also in England, Germany and even in the Crimea on the Black Sea. The air temperature fell below –30 degrees. Many people got frostbites and died of cold. On the 23rd of February, a strong thunderstorm moved from the West across the Daugava River in the direction of Vitebsk, causing great damage to the local population. A nasty thunderstorm with lightning started at 10 o'clock in the morning, followed by warm rain already in 20 minutes. The rain was particularly heavy in the vicinity of Krāslava. The temperature fell below zero again in 2 hours (28). The spring was long and cold.

The winter in 1835 was even milder than that of 1831/32. The air temperature did not fall below –8 degrees, there was only little snow, and livestock could be let out for grazing the whole winter (27).

The snow cover in Latvia was exceptionally thick in 1835, reaching 1.8–2.1 m (27). Snowfalls started from the New Year, getting especially heavy in March. In April, the sun and rain quickly melted the snow, and massive flooding began. The ice cover on rivers reached the thickness of the height of an adult man (31).

The winter of 1844 was unusually rich in snow in Courland. There were just a few days without snowing (27).

In the 50s of the 19th century, the press wrote about an unusual winter in Latvia in 1850 (28, 1850, No. 16). It started with extreme frost and lots of snow. In January, there was a snowstorm going on for 2 weeks in a row, and it was so heavy that no one could leave their houses. All roads were totally snowbound. In February, in turn, it rained for 2 weeks, melting all the snow. The waters of the rivers rose, then the temperature fell below zero again, up to –12 degrees, and everything froze over.

In contrast, the winter of 1859 was particularly mild. The newspaper *Latviešu avīzes* wrote (21) that such a warm winter has not been seen for a long time. In January and February, the average monthly temperature was between +0.5 and –0.5 degrees (the norm is between –4.9 and –4.5 degrees), and orchards started to bloom. Then, on the 13th of March (25), lots of snow fell, but the rain melted it down soon – on the 16th of March (28).

Unusual summers and autumns

Hot and dry summers

M. Bogolepov writes that the year 1170 was extremely hot and dry throughout Europe (2). The soil cracked and there were so much dust and such a haze in the air that one could hardly see the road in front of one's feet, causing many people trip and fall. Similar drought occurred in 1173. It is reported about the unusual summer of 1223 that exceptionally hot weather lasted for a long time (6). There were a lot of people and livestock in the castle, and they started losing weight from hunger and thirst (6). Plague broke out in the castle from the horrible stench, coming from the dead animals and humans.

After a turbulent winter in the Daugava basin in 1368, a dry and hot summer set in. Based on the annals, A. Gacisskiy (5) described the events as follows: the sky was sometimes blood-red, sometimes black, haze persisted for 3 months. These were hard and distressed times for people. The fish died out in the rivers.

There was extreme drought in the summer of 1431, which is described as follows (3, 4): "Dry land and swamps were on fire, haze in the same summer stood for 6 weeks, the sun was not visible, the fish in the water died and birds were not seen flying, as they had fallen on the ground" (1). Also in 1473, there was a big drought in Lithuania, West Poland and the rest of Europe. Forests, villages and cities were on fire (4, 30). Similar situation was in 1533 (1).

The year 1679. Dry and hot summer with severe night frosts in June. All cereal sowings had been destroyed by frost (23).

Dramatically changeable weather conditions along the seasons were in 1708. After a harsh winter, there were very heavy rainfalls in the summer, at the end of June. The water level in the Daugava rose so high that all the surrounding gardens were flooded for 4 weeks. After that, the summer was hot and dry, followed by heavy rains again in November and bitter cold in December (18, 23).

After a snowy and cold winter, the summer of 1745 was dry, with the dominating wind from the East. The water level in the Daugava River was so low that the cannons that had been sunk by the Saxon troops in 1701 were found and taken out of the dry river bed in the surroundings of Koknese (23).

The summers of 1748, 1749 and 1750 also were dry and hot, with extensive forest fires. Also in 1776, as shown by entries in the parish chronicles of Courland, a moderate winter was followed by a dry summer with fires everywhere for 6 weeks (27).

Quite unusual events were observed in Riga in the summer of 1795. On the 10^{th} of June, a whirlwind with heavy hail was raging over the city, causing major damage in a 2 km-wide and 160 km long area. Hailstones were of the size of eggs. The thermometer in the Riga Dome Church wall at a height of 170 feet (51.9 m) showed a temperature between –3 and –4 degrees on the Réaumur scale; at a height of 4 feet (1.22 m) – +16 – + 18 degrees Réaumur (19).

In 1819 in Latvia, there was hot weather nationwide from May to September. The air temperature reached +25 ... +27 degrees in the shade for many consecutive weeks. Rain showers were rare. There was no drought though (27).

The year 1826 came with a very hot and dry summer. Throughout the summer, fires broke out in forests, peatlands and heaths, as they were very dry. There was a horrible drought. Watermills stopped working without water (27). The average air temperature was +18.9 in June, +22.5 in July and +20.7 in August.

The year 1827, especially the summer, was very unusual in Courland. According to the data of the Courland parish chronicles (27), the summer set in very early: rye was harvested already at the end of June (i.e., for more than a month earlier than now –around the first half of August). The autumn was also warm and dry.

The summer was very hot and dry also in 1834. There was absolutely no rain in June, July and August. The Daugava River was so shallow that it could be easily forded in some places, and barges could be pulled with great difficulty even downstream, as they rubbed against the river bottom. Forest fires were everywhere. Swamps dried out to such an extent that hunt birds perished of thirst. It was a disastrously dry year, witnessed by a number of sources (27, 28, 1834, No. 45).

There was a dry and hot summer without rain for 10 weeks (two and half months) also in 1855 (27, 28, 1855, No. 35).

Wet, rainy, chilly summers

In different historical sources, there are less data about particularly rainy and chilly than extremely hot and dry summers. It is understandable, since heatwaves and drought bring great disaster to people and natural world. There is lack of water for plants, animals, birds and humans; forest and bog fires rage; in calm weather conditions, vast areas are covered with smog.

The first recorded facts, indicating a very rainy and wet summer, are from the year 1370. Weather conditions were so unfavourable, with prolonged rains and high air humidity, that the army of the Riga Order could not embark on any campaigns (33).

In 1579, the summer in the Baltics was so rainy that there had been no three days without rain, which continued day and night. The rain was so long-lasting that soldiers' uniforms started to rot while being worn (13).

The year 1679 was also referred to as very rainy in Latvia. Incessant rain continued throughout the summer and autumn. It rained for 14 weeks (three and a half months) in a row in the autumn (23).

In 1746, there were very unstable weather conditions in the Baltic States: 106 rainy days per year; snow fell on the 15th of October (23).

The year 1838: May and June were quite dry, with low precipitation; then it started to rain and continued for 2 months, causing great flood in rivers. Even more terrible conditions followed already in 2 years. It was raining throughout the spring, summer and autumn. The weather was chilly, and there was not a single hot day. Over the period from the beginning of the winter until the 17th of October, rivers went out of their banks 4 times, causing major damage.

The *Rīgas avīzes* and other newspapers report about an even more horrible summer in 1844 (22, 27, 28). The *Rīgas avīzes*: "Rain and flooding here. Not a single dry day since the Trinity Sunday. There were only 15 days without rain within a 12-week (3-month – G.E.) period. We didn't see even two consecutive days with no rain, and there were no perfectly clear days at all. It rained even more in July. Meadows and lowland fields were more flooded than in spring.

Moreover, roads and bridges were also flooded. Rain poured non-stop for more than two months; all trenches turned into rivers, rivers – into large water streams, meadows – into lakes. Bridges, dams and a number of watermills were ruined, and roads became impassable" (28, 1844, No. 35). Similar weather conditions were also in Russia.

The year 1849 was also unusually rainy.

Grouping by centuries (Table 1) the yearly data of unusual winters and summers published by E. Moskovkina (10), we see a distinctive picture. According to the data of chronicles, annals and other sources, the highest numbers of extremely severe and severe winters were recorded during the period from 1200 to 1500 and also in the 18th century, whereas the highest number of particularly warm winters – during the 13th and 18th centuries.

Table 1 **Grouping of unusual winters and summers**

Years	1000–1099	1100–1199	1200–1299	1300–1399	1400–1499	1500–1599	1600–1699	1700–1799	1800–1864
Severe and extremely severe winters	2	2	**17**	11	**15**	4	10	**15**	6
Particularly warm winters		3	1	**8**	4	2	4	5	**22**
Hot and extremely hot summers	3	2		2	2	4	7	**14**	5
Chilly, cold and rainy summers	1	1	3	1	2	4	7	3	**9**

The table has been composed according to E. Moskovkina's (10) estimated data by years.

Very warm, hot and extremely hot summers frequently occurred in the 17th century (14 summers mentioned). Particularly cool, also extremely rainy summers most frequently occurred in the 16th and 18th centuries.

Extreme spring high waters and floods in the Daugava and other rivers

The first scientific study on weather conditions in the Baltics and Latvia and on river runoff and flooding, based on historical evidence (chronicles, annals, church books) from a period of a thousand years is E. Moskovkina's book (10) *Pavodki na reke Daugava* (Floodings on the Daugava River). According to the descriptions by years given in the appendix to the book, the author has grouped the spring high water levels as follows: catastrophically high, high, above average, close to average, below average, low and catastrophically low. The overview table composed by centuries according to the yearly descriptions (Table 2) shows the main characteristics.

Table 2 **The spring high water levels on the Daugava River in Riga**

Years	1000–1099	1100–1199	1200–1299	1300–1399	1400–1499	1500–1599	1600–1699	1700–1799	1800–1870
Catastrophically high	1		3	2	3	3	3	**6**	**5**
High	1	7	3	6	**13**	3	**15**	**11**	**8**
Above average		3	**11**	7	**15**	8	**11**	**12**	6
Close to average			2	4	3	7	6	**19**	**21**
Below average		3	1	4	3	7	2	**10**	5
Low			2	4	6	3	4	**12**	**26**
Catastrophically low				2		1			2

Over a period from the year 1000 until the second half of the 19th century, especially catastrophic spring floods on the Daugava River occurred in 23 years, most often from 1600 to 1860, 4-6 years per century.

The rise of catastrophically high water levels from 1600 to 1700 can be explained for the most part by the fact of rapid deforestation, land cultivation and reclamation relating to the increase in population, development of agriculture, construction of buildings in cities and countryside, building of ships, also exports of timber, production of coal and extraction of tar. As we know, snow melts faster and water drains to the rivers quicker in woodless than in wooded areas.

It should be noted that the characterisation of spring high waters in the Daugava River until 1871 provided by E. Moskovkina is based on historical observations as well as on P. Stakle's estimates of spring high water levels on the Daugava River in Riga. Only starting from 1871, the yearly water levels were determined in accordance with official water level measuring points, with exact absolute height marks. Therefore, the data on the spring flood water levels in Riga until 1871, especially according to P. Stakle's estimation, should be regarded as quite approximate. Only the level of the disastrous flood that occurred in 1709 is accurate, because the correct absolute height in accordance with the Baltic height system was later determined by the mark left on the Dome Church wall.

The first reports of large, catastrophic floods in the Daugava River in Riga appeared in written historical documents around the mid-14th century. So, several sources reported on the catastrophic floods on the Daugava River in 1358. The newspaper *Rigasche Stadt-Blätter* wrote on the basis of annals that water stood above man's head in the Riga Dome aisle. To revive a memory of this event, an iron cross was mounted to the church building's wall (31). Later on, J. Brotze (17) also wrote that the Daugava River had catastrophically flooded the Riga Dome Church, although the wall-mounted iron cross was no longer there at that time. P. Stakle (24), estimating the likely water level of the Daugava River in the year 1358, concluded that it rose about 5.5-6 m above the summer water level.

Multiple sources (22, 24, 29) report that the spring flood levels in the Daugava were catastrophic also in 1578, when vast areas around Riga had been submerged, causing huge damages. On April 14, according to P. Stakle's estimation, the water level could have possibly risen by 5-6 m.

Great floods caused by spring high water occurred in Riga in the years 1589 and 1597, when the water level rose by 5.5–6 m (P. Stakle's estimation). In 1810, the *Rigasche Stadt-Blätter* (31), referring to archive data, wrote that, on 18 April 1597, the ice broke through the embankment (rampart) near Jacob's Gate in Riga, roads were washed off, buildings were ruined, and ships sunk in the Daugava River. Many people and livestock were drowned. The city incurred massive losses.

Catastrophic floods caused by the spring high water occurred in Riga again in 1615. A huge ice jam (dam) formed by the former Bisenieki Isle, causing a rapid rise in water level upstream of it. The water washed down and flooded the embankments in the area of Mārstaļu Street, running through the rampart towards the Riga Castle. Ch. Kelch (26) wrote about this disaster that such an unprecedented rise in the water level began on the Daugava River by Riga that the water not only flooded the city surroundings but also broke into the city behind the gates, so that many buildings stood in water. According to P. Stakle's estimation, the maximum water level reached 5.5–6 m on the 7th of April.

Multiple sources (17, 26, 31, 1812) write about a fierce storm and flooding in Riga in 30 May 1626. Large masses of sea water were driven into the Daugava River (presumably with northwest winds – G.E.) from the Gulf of Riga, which, together with the spring flood waters of the Daugava, made the water level rise unusually high. The entire city and pastures were submerged, many buildings were ruined, the wind downed lots of trees, a lot of people and livestock perished. This natural disaster was caused by simultaneous action of two elements: water and storm. Although there are no data on the maximum water level, it is possible that it reached 4-5 m.

Disastrous spring floods with large piles of ice on the Daugava River occurred again in 1649 (138, 149, 150). According to P. Stakle's estimation (24), the water level reached 5.8–6 m on the 11th of April. The city ramparts by the gates of Jacob's and Smil u Streets were washed off by the forceful flow, just as the Hincene dam by Latgale Street and about a half of Kube Hill (dune – G.E.) (17), many buildings were destroyed and people killed. The strong northwest wind brought water in the Daugava River also in autumn, and the high water level caused wide flooding with significant damages for the second time in the same year (22, 24).

There were heavy storms in the sea in November and December 1704. The northwest and north winds drove the sea water and ice into the Daugava

River up to Katlakalns and the Lucavsala Island. The areas by the Grēcinieku Street gate in Riga as well as the Klīversala Isle were flooded. Many houses were carried out into the sea (18). Also in late June 1708, there were big rainfalls in Latvia and flooding in the Daugava River. The water level in Riga rose by 4.5 m (P. Stakle's estimation). Gardens were submerged in the vicinity of Riga for 4 weeks. All plantations and sowings perished.

The year 1709. After a particularly harsh winter, when the Baltic Sea froze over and ice thickness in the Daugava reached 1.7 m, ice started drifting on the 6th of April. Since the Gulf of Riga was still covered with thick ice, the ice pieces carried by the river flood waters were piled on the isles and shores of the Daugava River. The water level rose catastrophically, reaching the absolute height mark of 4.68 m on the 16th of April. To leave a proof of this disastrous flood, a cross was carved in the Riga Dome Church wall. According to J. Brotze's records (20), the water in the city reached the depth of human height. All isles and the valley of the other side of the Daugava were flooded, whereas the water on the right side of the river reached Kube Hill and the Citadel. Since the ice blocked free water outlet from the Daugava into the sea, part of the water diverted to the Lielupe River (the current Buļļupe River – G.E.) and another part – to the sea across the Mangaļsala peninsula in the area of Vecāķi.

Compiling the historical data, P. Ludvigs (9) wrote that the most terrible flood ever seen in Riga occurred in 1709. The author describes the overall situation as follows: "They (the flooding and the subsequent disaster-causing events – G.E.) began in the autumn of the previous year. In November, an exceptionally strong storm raged, tearing down the roofs not only of many buildings but also partly of the Riga Dome Church. The storm-blown water flooded the Daugava River banks and isles, washing away houses, livestock and people. Several ships were smashed and cast ashore. The storm was followed by severe frosts, which persisted almost continuously throughout the winter. The ice cover on the Daugava River reached the thickness of 1.5 m, so that in some places the river was frozen to the bed. 22 ships were stranded in the ice. In that winter, almost all fruit trees were frostbitten. When the spring thaw began, the stream brought the ice from the Daugava upriver downwards, while the ice at the downriver did not break, remaining where it was. Consequently, a huge ice dam was formed. The water then broke two new outlets to the sea, flooding Pārdaugava and isles of the Daugava. The ice-bound ships could not be salvaged anymore, and they were crushed, destroyed and carried into the sea, along with large quantities of timber and several houses with their inhabitants. The Zaķusala Island alone lost 52 houses. Situation in Riga was even worse. The masses of ice and flood waters broke through the Riga city gates, flooding the streets, buildings and cellars. Water in the Dome Church rose up to the altar. Pews, coffins and corpses floated in a jumble inside the church" (pp. 230–231).

Like in the year 1709, also in 1744, when the ice thickness in the Daugava River was twice the height of a man after a harsh winter (31, 1814), ice started drifting at the beginning of April. The drifting started in the morning, and at four in the afternoon the water has already reached the Dome Church. A few days later the ice forced the Šabļi Street gate, and the old town was submerged subsequently. Pews floated around the Dome Church aisles. Johan's dam was also destroyed, and the outskirts were flooded, with the exception of Lielā Smilšu Street and Kube Hill. The maximum water level was reached on the 10th of April, though it was lower than in the year 1709. Water in the city washed away many houses and bridges.

Catastrophic flooding caused by the spring high waters in the Daugava River occurred in Riga also in 1770, with the maximum water level on 11 April.

After the snowy winter in the Daugava basin, ice drifting and catastrophic flooding started in Riga at the end of April 1771, reaching the peak level on the 26th of April (around 5.5-6 m according to P. Stakle's estimation). At that time, the Daugava River mouth and the Gulf of Riga were still covered with ice. The waters of the Daugava broke through Catherine's dam, and a large part of the city, wide surroundings and the isles flooded. Countless houses with people floated together with ice from the direction of the upriver toward the sea. Townspeople could do nothing except helplessly watch from higher places the doomed people drifting by on their houses and ice floes. P. Sapunov has so described the tragic scenes (14).

During the disastrous spring floods, when large ice jams built up by the upper end of the Dole Island and on the small islands in the Main Daugava, in the years 1615, 1771 and 1867, the waters of the Daugava River, bypassing ice jams (piles) in the Main and the Dry Daugava, ran over the old river-bed (the Brek upe River), past the Church of Salaspils (located on an elevation formed by the old isle – G.E.) to Ulbroka, finding its way to Lake Jugla through the valley of the Pičurga Creek.

There were great flood damages in Riga also in the spring of 1783, when dams were washed out and broken in 11 places (11). There was a catastrophic flooding with ice drifts in Riga also after the harsh winter in 1795. J. Brotze (19) wrote that the lower houses, that the residents left, were in water up to roofs, whereas the newspaper *Rigasche Stadt-Blätter* wrote in 1825 that the flood level caused by spring high water exceeded the level of 1744 in Riga on April 13. There were high flood levels also in the spring of 1807, when the waters of the Daugava River broke the dams and flooded the city's canals and the Citadel and carried away bridges.

The catastrophic flooding on 12 April 1814 was conduced by the thick cover of sludge and ice. A big flood occurred again in 2 years (in 1816), when large ice jams formed opposite to Catherine's dam in Riga. The waters of the Daugava River ruptured the dam and flowed through the present

Sarkandaugava distributary. All the bigger islands of the river's lower reaches of that time, such as Ķīpsala, Bieķēnsala and Mazā Kliversala were submerged, along with parts of Iļģuciems and the Moscow Vorstadt, as well as Pārdaugava (from the present Torņakalns railway station downwards, including Uzvaras Square and the Agenskalns bight).

After 13 years, in 1829, after a harsh winter without thaws, ice drifts started on the 9th of April in the Daugava River in Riga. As usual, ice piles formed on the many low isles and banks. The river bed was obstructed, and the water level rose rapidly upstream of the jam. The low flood-land of the Daugava valley in Pārdaugava up to Māra's Pond Mills, Catherine's dam, Sarkandaugava and St. Petersburg's suburbs were submerged. The old town was saved with great efforts (28, 1829).

in 1837, catastrophic spring floods with ice drifts took place in rivers throughout Latvia. Damages in Riga were not as big as in previous years, unlike in Dinaburg (Daugavpils) and especially in Slobod on the Courland coast side, where the water rose so quickly (due to a large ice jam) that poor people were able to save little, trying to save themselves on the rooftops. The Daugava River flooded the entire wide valley, and the city looked like a big lake (28, 1837, No. 20). 190 families suffered losses during the spring flood of the Daugava River. There were very high levels of flood water also in the Lielupe, the Abava and other river valleys (28, 1837).

In 1844, there was a late spring after a snowy winter. Ice drifting started in the Daugava by Riga in mid-April. On the 18th of April, a huge ice jam formed in the river downstream in Mīlgrāvis, by the White Church on the right bank of the Daugava River. The water level rose by about 4 m. The Moscow Vorstadt was submerged because the water broke through the protecting dam. Other low flood-land areas were also submerged.

Also the next year, 1845, a big pile of ice formed again on the left bank of the Daugava River by Riga, opposite to Tsar's Garden (now Viestur's Garden). The water level rose rapidly on the 16th and 18th of April. Then a large part of the ice with flood waters found a new outlet across the grasslands of Spilve to the sea (31, 1845). Opposite to Rīnūži, the forceful flow of the river washed off a 500 metres long bank section with three peasant houses, forming a new 4-6 m deep riverbed (7).

Even greater flooding and devastation took place in Riga after 10 years. On 11 April 1855, after a snowy winter without thaws, ice breaking and drifting towards the sea started in the Daugava River. The ice stalled in the river by the White Church in Vecmīlgrāvis, since the ice cover was still firm on the river mouth. Huge piles of ice formed by Podrags. On the 12th of April, the water rapidly rose and flowed over the protective dam, submerging the entire lower flood-land on the left bank, the area of Ganību dam on the right bank, a large part of the Moscow Vorstadt and the isles of the Daugava River. Houses on the isles were in water up to roofs (8). Bypassing the ice jam, the ice and waters of the Daugava made a new way across the grasslands of Spilve, carrying away 2 houses and other structures. On the 14th of April, the water level began to subside.

According to A. Sapunov's estimation (14), the maximum spring high water level in Riga was 8.24 m higher than the water level during the summer low flow, whereas P. Stakle estimated the level at 5.5–6 m.

The end of the year 1856 also came with major floods on the Daugava River and other rivers of Latvia and water devastation in Riga. Bitter frost started already in September and continued through November, followed by a deep thaw and major floods at the end of November. During the disastrous flooding of the Daugava River, the outskirts of Jelgava (on the left bank of the river – G.E.), the Moscow Vorstadt, the isles and many streets were flooded, since several dams had been destroyed. Bridges had been carried away. In St. Petersburg's suburb, the first floors of buildings were in water. The maximum water level in the Daugava was only for 1.22 m lower than in 1855 (31, 1862). Ice drifting and congestions also occurred on the Lielupe and Venta Rivers, whereas the Gauja River overflowed its banks. In the Bārta River, there was the largest flood in 50 years (31, 1862).

Big floods ravaged Riga also in 1865, when a large ice jam formed on the Daugava River and the water level rose by 4.56 m. The city canal and aqueduct, Parade Square, Kārļa Street and Vērmaņdārzs Park overflowed. The water flow washed out a large hollow on Suvorov's Street, while the Tsar's Garden was in 1 m deep water. All houses on the Zaķusala Island were in water up to the roofs, while in Pārdaugava the water flooded the entire vast lowland territory (including today's Victory Park – G.E.) up to Torņakalns (28, 1865; 31, 1865). After such spring floods, warm and dry weather continued until August (28, 1865).

Unusual, unprecedented floods struck the city of Riga at the beginning of March 1871. The strong wind from the sea forced large amounts of ice from the Gulf of Riga into the Daugava River mouth, making ice piles as high as never seen before. Their height reached 70 feet (21.35 m!) and width – around 20–30 m. The length of ice ranges reached 2–3 versts (2.12–3.18 km!). The ice piles reached the river bottom, which was said to have been more than 5 m deep. However, the ice piles did not stay for long in the Daugava River, since intense ice drifting started on the 17th of April. The piles were carried into the sea. Therefore, there was no major flooding, except in the low Pārdaugava (24).

At the beginning of the last century, the largest flooding in Riga related to ice jams occurred in 1917. The ice that was carried downstream by the Daugava River current jammed between the Zaķusala Island and the Zvirgzdi Isle. Large piles of ice were driven onto the river banks by the Moscow Vorstadt up to the tramway rails, toppling on their way several cast iron poles. The water stream running from the Lucavsala Island and Zaķusala Island washed off large plots of land. Several small ships were cast ashore. In the river basin upstream of the jam, the water level rose by 5.18 m (!).

Serious flooding occurred also in the years 1924 and 1929.

To sum up, over the period of almost 600 years, from the 14th century until the early 20th century, Riga and its inhabitants endured devastation of more than 20 cases of catastrophic flooding caused by ice jams: in the years 1358, 1363, 1587, 1589, 1597, 1615, 1618, 1643, 1709, 1727, 1744, 1770, 1771, 1783, 1795, 1807, 1814, 1829, 1837, 1912, 1917, 1924 and 1929.

Daugavpils also sustained damages caused by spring high waters a number of times. The worst floods in Daugavpils occurred in the 18th century (1702, 1709, 1723, 1729, 1735 and 1739), the most devastating – in the year 1709, when Riga also was catastrophically flooded.

In 1729, the spring flood waters also rose so high that Daugavpils resembled Venice (9, p. 232). In order to protect the city from similar floods, a 6 km long protective dam was built along the right bank of the Daugava River. The protecting structure was completed in 1841. The Riga–Daugavpils–Krāslava motorway runs over this dam. However, during the great flood in 1922, when the maximum water level in the Daugava reached 9 m, the dam breached, flooding the lower part of the city.

Today, just as before, the flood risk area encompasses the Daugava valley from Daugavpils to Līvāni (including) and Jēkabpils, where the flood risk is particularly high after the Pļaviņas HPP reservoir has been created.

Jaunjelgava also incurred significant damages in the floods of 1740, 1743, 1773, 1924 and 1929. In the year 1773, this small town on the Daugava bank was almost completely erased from the face of the Earth. Around 100 houses were ruined. Also in 1924, during the spring flood, the Daugava waters carried away 4 and damaged several other buildings (9). After the construction of Ķegums HPP had been complete, the flooding risk for Jaunjelgava increased, as the reservoir's backwater level reached quite far upstream of the town. The situation was similar to that of Jēkabpils and Pļaviņas now, after the formation of Pļaviņas HPP reservoir.

A protective dam was built along the Daugava River bank for the purpose of protecting Jaunjelgava. After putting Pļaviņas HPP into operation, regular spring floods is no longer a threat for Jaunjelgava, as Ķegums HPP regulates the water level, and the large masses of ice remain in the reservoir of Pļaviņas or, in smaller quantities, go into Ķegums Lake through the hydropower plant's floodgates.

In some years, major floodings occurred also in the Venta River downstream, by Nabes Lake, Zlēkas and Piltene.c P. Ludvigs (9) wrote about an unusually high, catastrophic flood on the Venta River by Kuldīga in 1615: "Then the spring flood waters (presumably due to an ice jam, G.E.) rose so high that the town of Kuldīga was submerged. They (the waters) also entered into the castle yard. The chain bridge mounted on the stone piers at the times of the German order – linking the two banks of the Venta River opposite to the Castle gate – was then destroyed and carried away. A new bridge across the Venta by Kuldīga (downstream of the Kuldīga Falls) was built only in 1874 and is still there" (p. 126).

The main cause for the disastrous floodings on the Daugava River in Riga over a period of more than 750 years since the founding of the city until the Ķegums HPP was built was the wide and shallow bed of the Daugava River with many larger and smaller isles and sandbars, often changing their location and size. The river washed away some isles during flood, some isles formed anew elsewhere. The sandy, gritty and pebbly material carried from the river sections with rapids from Pļaviņas to the downstream end of the Dole Island accumulated in the river within the city limits of Riga and was partly washed into the sea. During the spring high water, the ice-drifts, from the upper reaches of the river piled on sandbars and isles, completely damming up the river with huge ice jams. Upstream of the congestions, water levels were rising fast, flooding vast areas of the Daugava valley and the city of Riga, which some 500-600 years ago – especially the territory that presently is the city centre with multi-storey dwellings – was about 2–3 m lower. During the last centuries, especially beginning with the demolition of the city ramparts, the territory was banked and elevated up to 5-5.5 m above the sea level to avoid flooding. The 5-8 m thick cultural layer is the evidence for this fact.

The present-day topographic maps of Riga that show the parts of the city that were often submerged during last centuries effectively demonstrate the extent of floods (Figure). If, in some distant future, wind-caused water run-up in the Gulf of Riga and the coastal area rose for 4–5 m, then the scene would be similar to that 400–500 years ago.

In some years, when the Gulf of Riga and the Daugava were under ice cover, the strong north-western storms drove large masses of ice from the gulf into the river mouth, forming large ice piles, which caused flooding in the city. Beginning with the 80s of the 19th century, when the Daugava riverbed deepening and straightening works, building of dams – which direct the river's flow into its main watercourse – as well as removal of certain isles and sandbars commenced, the risks of ice jams and devastating floods in the city decreased. The situation was also improved by building ramparts along the city, stop gates at the ends of streets leading to the river and water-gates on both ends of the city canal, as well as by elevating the ground surface in lower built-up areas, using debris as a material for banking. In the 19–20th centuries, iceboats were started to be used for breaking ice in the Daugava River before the spring high water season. Construction of the Ķegums HPP prevented the ice jam formation in the city.

Nevertheless, in our day, in autumns and winters, when violent storms rage in the Baltic Sea, and SW, W winds drive large masses of water from the open sea into the Gulf of Riga, and then the wind turns from NW, the threat of flooding increases in the low built-up areas of the city, situated on the Daugava valley. In such circumstances, the water level in the Daugava, the Lielupe and the Gauja downstream rises for about 1.5–1.8 m. In the devastating storms of 1969 and 2005, the water level in Riga reached an absolute height mark of 2.1–2.15 m, and large vacant and built-up city territories were flooded. As the climate becomes warmer and storms increase in power, the water level rise caused by wind-driven water run-ups in the peak of the Gulf of Riga and in Riga might in the near future reach a 2.5–3 m mark.

We can only guess what was the actual height of the ground surface above the summer low flow level of the Daugava in the 12–13th centuries, when Riga was founded. Nowadays, the data of excavations made during the Town Hall restoration, as well as the data of many geological and engineering-geological exploration drillings in the central part of the city show that, as a result of making banks for centuries (cultural layer), the city area has been elevated for about 3–6 m. In many places, the former high floodplains of the Daugava valley – from Ķengarags to the Academy of Sciences multi-storey building, including the areas of Central Market, Railway Terminal, Vērmaņdārzs Park and the Freedom Monument – have been banked and built up. Initially these areas could have been only 2–3 m above the summer level of the Daugava River.

In the excavation made during the restoration of the Riga Town Hall, a massive oak tree trunk with roots was uncovered by the building foundations. Apparently, it was brought there together with ice during the spring high water when the city was flooded. The natural (unbanked) ground surface height mark on the building foundation, in accordance with the geological exploration drilling data, corresponds to "0" in the Baltic height system. Of course, neither the Dome Church, nor the Town Hall, could be built in places, the altitudes of which were close to the summer water level of the Daugava River, but, in all probability, at least 2.5–3 m higher. This factor allows for a possibility that the average water level in the Gulf of Riga and the Baltic Sea (and also in the Daugava River downstream) have risen by at least 2–3 m over the last 800–850 years. The data obtained from long-term observation of the average sea level changes over the past more than 120 years in the Daugava River mouth show that it has risen for 0.25–0.30 m. Sinking of the Earth's crust – even if only 1 mm per year (totalling to 80–90 cm) – soil compaction and settling under buildings and artesian water withdrawal can be mentioned as the side factors which all together cause lowering of the Earth's surface.

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Heat Waves in Latvia: Occurrence, Impacts and Consequences

Māris Kļaviņš, Zanita Avotniece, Valērijs Rodinovs
University of Latvia, Faculty of Geographical and Earth Sciences,
Raiņa Blvd. 19, LV 1586, Rīga, Latvia

Extreme climate events occurring due to climate change and natural climate variability are increasingly recognized as a threat to human health, agriculture, forestry and other sectors. To assess the occurrence and impacts of extreme climate events on human health, we have investigated the changes of indexes characterizing positive temperature extremes and trends of extreme temperature indicators as well as spatial heterogeneity of extreme temperature events in Latvia. The impact of extreme heat events on human health has been studied through analysis of medical emergency calls. Although cold weather conditions prevail with respect to adverse effects on human health, extreme heat events also have significant health consequences and, considering the trend of their growing occurrence, may pose threats in the future, thereby requiring adaptive actions.

Key words: temperature extremes, climate change, atmospheric circulation, mortality, human health

INTRODUCTION

Over the last decades, there has been a growing interest in the connection between climate and health, largely due to the potential impacts of climate variability and change on human health (Epstein, 2002; Haines and Patz, 2004; Patz and Kovats, 2002). It is expected that climatic changes associated with global warming will have a serious impact on human beings (Kalkstein and Smoyer, 1993). Among the potential direct risks that global warming presents to human health is the increase of heat-related deaths during intermittent hot weather, as predicted by WHO. An increase in mortality related to heat waves has been reported from various industrialized countries (Dessai, 2002; Diaz et al., 2006; Robine et al., 2008; D'lppoliti et al., 2010). However, much remains unknown about the links between climate and a variety of health outcomes. This is of concern as climate variability and change health impact assessments need to be based on plausible and well-established climate and health impact links, which could also be applied to health forecasting (Thomson et al., 2003) and development of adaptation strategies and actions.

The studies of the impacts of the so-called "heat waves" – periods when the temperature has reached extremely high values for a long-lasting period – have been comparatively extensive (Diaz et al., 2006; Alberini et al., 2008; Ha et al., 2011). Most of such studies have been carried out in regions where the regular temperature is comparatively high, especially during summertime; while there have been fewer studies of the impact of heat waves in more temperate climatic conditions. Among the main climatic factors of concern, temperature and its variability, air pressure and the amount of atmospheric precipitation can be considered. The changing human mortality can be influenced not only by positive temperature anomalies (heat waves) but also by negative anomalies, because extremely cold weather is a risk factor for acute complications of ischaemic heart disease (e.g., myocardial heart attack and cardiac arrhythmia). Year-to-year variations of the level of mortality may be partly determined by inter-annual variations in winter climate.

The aim of the study is to analyse trends of extreme heat events, factors and processes influencing them and impacts of positive temperature extremes on human health indicators in Latvia.

MATERIALS AND METHODS

Daily data on all-cause (total) mortality and, separately, mortality due to the circulatory system diseases in Latvia were obtained from the State Agency of Health Statistics and Medical Technologies over the period of 2000–2004. All medical certificates of death were compiled by medical professionals (in the majority of cases by general practitioners and also by specialists in pathology or in forensic medicine). Since the 1st of January 1996, the 10th revision of *International Classification of Diseases and Related Health Problems* (ICD-10) has been introduced in Latvia. The statistical coding of the causes of death and their accountancy was performed by health statistics specialists in accordance with the rules described in the 2nd volume of ICD-10. Excess daily mortality was established by calculating deviations of the observed number of deaths from the expected number of deaths for each day of the examined period. Daily data of emergency ambulance calls for the summer 2010 in Rīga were obtained from the Emergency Medical Aid Service.

Daily climate data were provided by 23 meteorological observation stations in Latvia. Variable data obtained from the Latvian Environment, Geology and Meteorology Centre included maximum, minimum and average daily temperatures recorded by the weather stations. For the determination of the impacts of meteorological factors on human health in Rīga during the summer 2010, we also used the values of daily relative air humidity (maximum changes within 3 and 6 hour periods, maximum relative humidity during daytime and nighttime), daily mean atmospheric pressure on the station level as well as variables representing the air quality – maximum daily ozone and NO_2

concentrations. Heat waves can be defined as consecutive periods of at least 3 days, during which the daily maximum temperature is higher than or equal to 30 °C (Kysely 2002; Huynenet et al., 2001). In this study, an alternative definition of heat waves was applied, defining them as summer periods of 3 or more consecutive days with the mean daily temperature by 12.5 % higher than in the reference period (1960–1990), which leads to the same number of heat waves being observed in the analysed period.

Ensemble climate change indices derived from daily temperature data, describing changes in the mean indices or extremes of climate, were computed and analysed. The indices follow the definitions recommended by the *CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices* (ETCCDI 2009), with a primary focus on extreme events (Table 1).

Table 1. **List of climate indices used in this study**

Index name	Explanation	Unit
TX	Daily maximum temperature	temperature value
TG	Daily mean temperature	temperature value
TR	Tropical nights (number of days TN > +20°C)	number of days
SU	Summer days (number of days TX > +25°C)	number of days
CSU	Maximum number of consecutive summer days (TX > +25°C)	number of days

Trends in the meteorological event time series were analysed, using the non-parametric Mann-Kendall test (Libiseller and Grimvall, 2002). The Mann-Kendall test was applied separately to each variable at each site at a significance level of $p \leq 0.01$. The trend was considered as statistically significant if the test statistic was greater than 2 or less than –2.

RESULTS AND DISCUSSION

Climate in Latvia is influenced by its location in the northwest of the Eurasian continent (continental climate impacts) and by its proximity to the Atlantic Ocean (maritime climate impacts). A highly variable weather pattern is determined by the strong cyclonic activity over Latvia.

The overall results of trend estimates for 10 meteorological observation stations in Latvia (the spatial location of the meteorological observation stations can be found in Figures 7–9) with the longest data series are summarized in Table 2. The mean daily mean temperature showed a statistically significant increasing trend at 8 of the 10 meteorological observation stations (except for Stende and Ainaži, where the increasing trend was of no statistical significance) covered by the study, while there has been a significant increase in the mean daily maximum temperatures in all of the meteorological observation stations. The extreme values of air temperature have been increasing along with the increase in the mean values, as there has been an increase in the number of days with extremely high temperatures. There has been an increase in the number of summer days (TX > + 25°C), tropical nights (TN > + 20°C) and in the length of prolonged heat events – the number of consecutive summer days. For the annual number of tropical nights, the trends of changes were statistically significant for a half of the stations (5 stations), while in respect to the annual number of summer days and consecutive summer days, the trend was of a statistical significance only in some meteorological observation stations (Figure 1). At the same time, other studies confirm that, in the period from 1946 to 1999 in Europe, the number of summer days has increased by 4.3 days (Klein Tank, 2004) and that the overall warming tendency is more evident in the central part of Europe, in the mountainous regions and in the north-eastern part of Europe (Olsen et al., 2008).

Table 2. **Long-term trends in extreme heat events (Mann-Kendall test statistics)**

Weather observation stations	**Indices of extremely high air temperatures**				
	TG	**TX**	**SU**	**TR**	**CSU**
Liepāja (1923–2010)	**4.13**	**4.67**	0.78	1.59	2.96
Ventspils (1923–2010)	**3.09**	**2.31**	0.55	**3.47**	0.74
Kolka (1925–2010)	**2.46**	**2.94**	1.17	0.06	1.44
Mērsrags (1927–2010)	**2.18**	**4.36**	**4.13**	1.75	4.17
Stende (1924–2010)	1.13	**3.14**	1.43	0.99	1.36
Rīga (1923–2010)	**3.62**	**3.72**	2.19	3.11	1.67
Ainaži (1927–2010)	2.23	**2.52**	0.42	**3.13**	0.92
Rūjiena (1927–2010)	**2.92**	**3.12**	1.64	**2.32**	2.41
Priekuļi (1923–2010)	**3.13**	**4.18**	1.92	**3.09**	2.33
Gulbene (1924–2010)	**3.07**	**3.11**	**3.10**	0.53	1.11

TG, mean daily mean temperature, °C; TX, mean daily maximum temperature, °C; SU, summer day (TX > +25°C), days; TR, tropical night (TN > +20°C), days; CSU, maximum number of consecutive summer days (TX > +25°C), days.

Human health status in Latvia is relatively poor and mortality indicators are high, especially in comparison to similar indicators in other EU Member States, probably due to reasons related to the heritage of the socialist regime and change of the social structure (excess of forced deaths among young adults, high prevalence of unhealthy lifestyle, low accessibility of medical services etc.). To add to that, meteorological processes also have a definite impact on human mortality, first of all, the air temperature. In Figure 2 one can see that the relative mortality is inversely proportional to the monthly mean air temperatures – during months with a lower air temperature, the relative mortality is exceeding the mean mortality of the period.

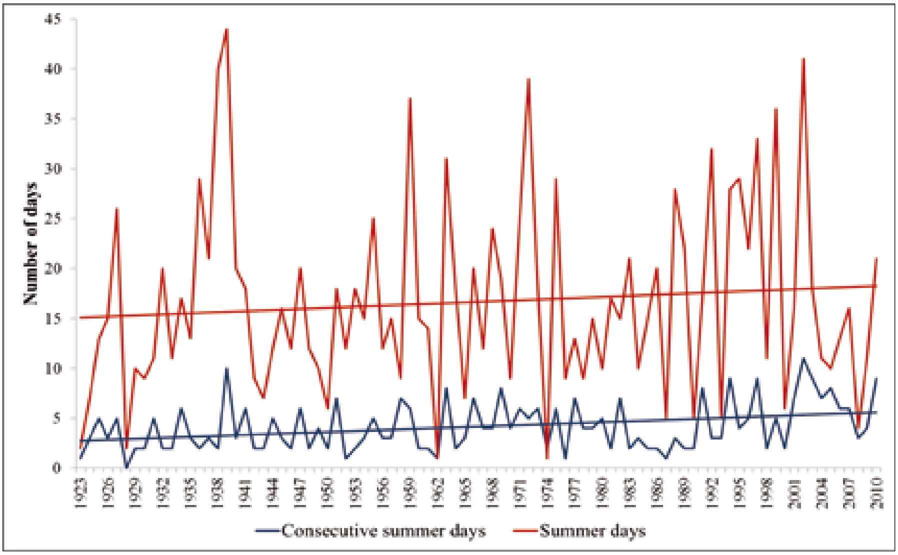

Figure 1. **Trends in the annual number of summer days (TX > +25°C) and consecutive summer days in Liepāja for the period from 1923 to 2010**

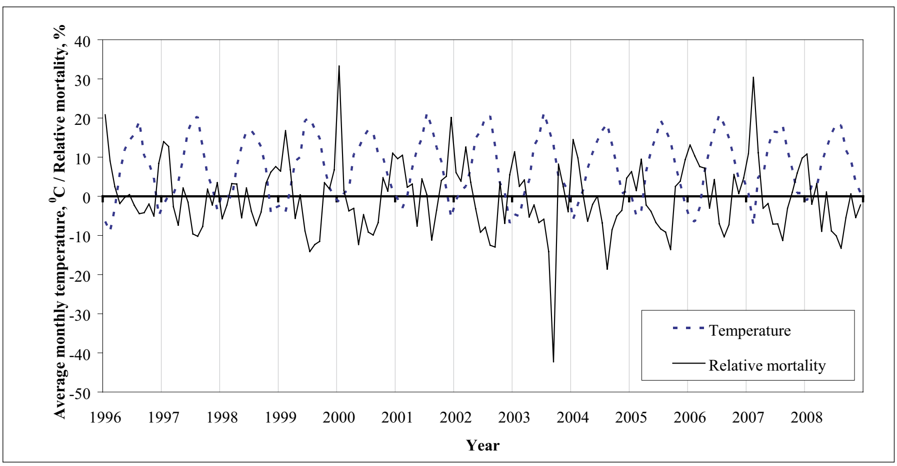

Figure 2. **Consecutive data for average monthly temperature and relative mortality (% above/below the 1996-2008 mean) in Rīga for the period from 1996 to 2008**

The changes of air temperature and extreme values of air temperature can also be related to changes in human mortality. At first we considered the mortality caused by ischaemic heart disease and other conditions of the circulatory system (Fig. 3, 4), and the possible adverse impacts of prolonged increase of average daily temperature on elderly people.

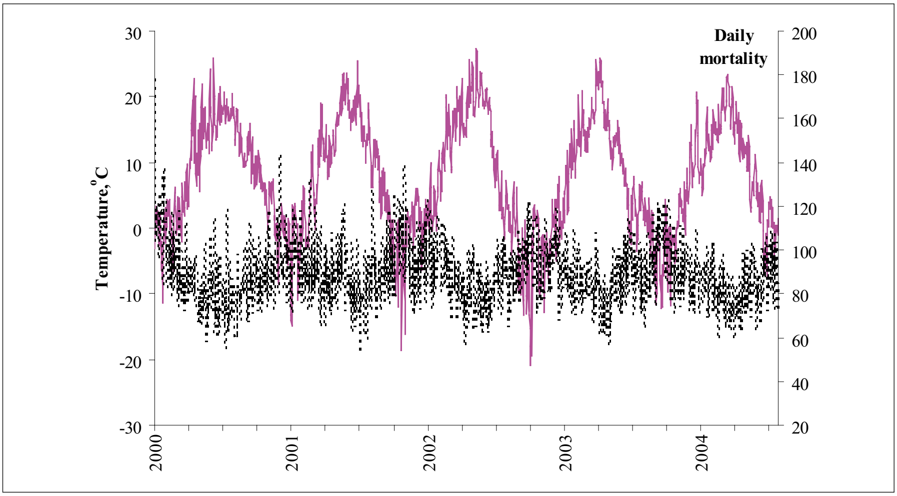

Figure 3. **Daily mortality in absolute figures (— overall in Latvia) and the mean daily temperature (— in Rīga)**

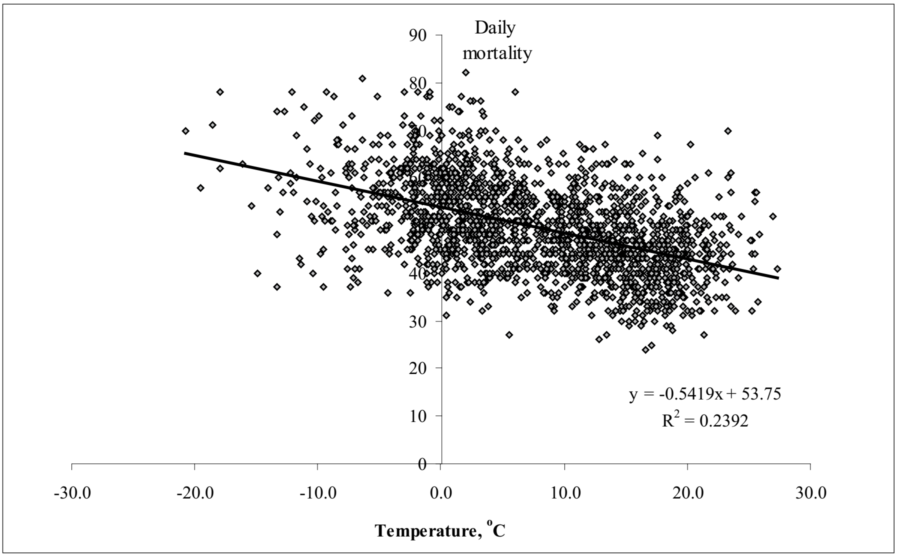

Figure 4. **Correlation between the daily mortality in Latvia and the mean daily temperature in Rīga (2000-2004)**

Unless the correlation between the mean air temperature and mortality (Fig. 4) is insignificant, the overall trend of their relation is evident, indicating an increased mortality in wintertime – as it has also been found in other countries of Central and Northern Europe (Lloyd, 1991; Keatinge et al., 1997; Healy, 2003; Mercer, 2003). The fact that the period of observations in the study was comparatively short may be a reason why no stable general trends were observed.

Insofar as climate change impacts can be associated with "heat waves", we have analysed the possible impacts of prolonged periods with increased air temperature on mortality for the period 2000-2004. Most of the studies of heat wave impacts have been conducted in hot climate regions (France, Spain, Portugal, South China, etc.). In comparison to these studies, the absolute temperature values of our study, performed in Latvia, cannot be considered as pertaining to hot climate study proper, because such values of air temperature have not been reached in Latvia even in the hottest summers on record. In this study, the situation has been considered as a "heat wave" if, for at least 3 consecutive days, the mean daily air temperature was by 12.5 % higher than in the reference period (1960–1990).

As it can be seen in Figure 5 and has also been confirmed by other studies in several European countries (D'lppoliti et al., 2010), the increased incidence of mortality can be associated with the increasing temperature. Although the temperature increase in our study is not considered to be extremely high compared to the cases of heat waves observed in countries with warmer climate, still, the increase in temperature coincides with the increase in mortality.

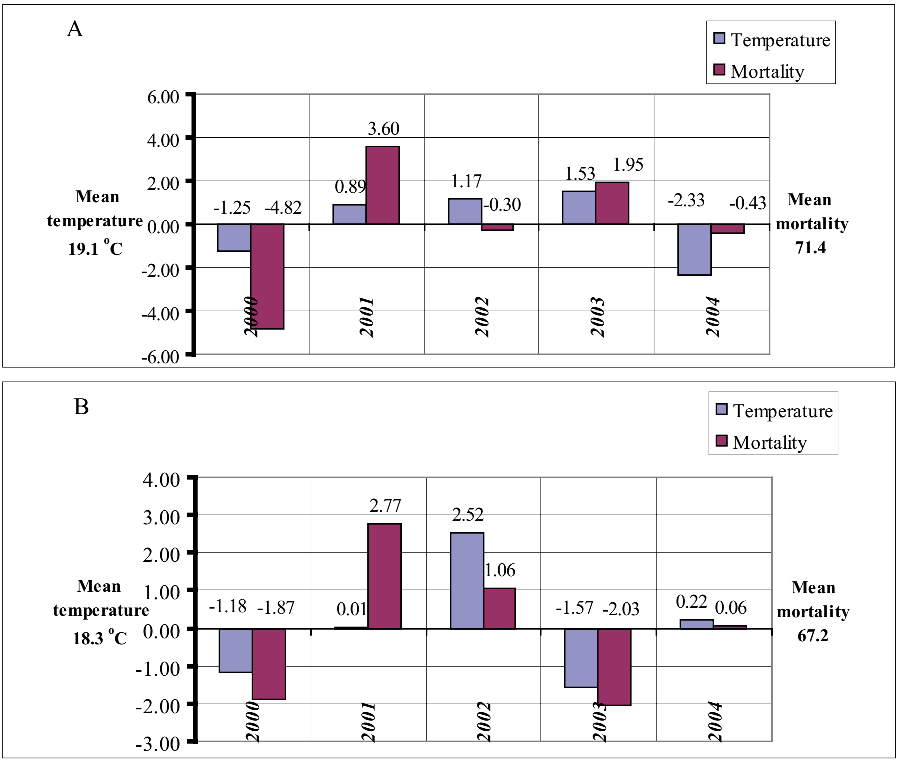

Figure 5. **Changes of temperature and mortality in July (A) and August (B) in respect to the mean values of air temperature (1960–1990) and mortality (2000–2004)**

According to the analysis of the World Meteorological Organization (WMO, 2010), the year 2010, along with the years 2005 and 1998, globally has been the hottest year since the beginning of the instrumental meteorological observations in 1850. In Latvia, due to the extremely low wintertime temperatures, the average air temperature of the year 2010 was close to the reference (+5.6°C), ranking the year as the coldest of the 21st century, even if during the summer the air temperatures were extremely high, the excessive heat lasted for a long period of time, and in most of the meteorological observation stations of Latvia the maximum air temperature records were broken. Such extremely hot conditions were observed due to a south-easterly air flow that was established over the area for a prolonged period of time (Deutscher Wetterdienst, 2011).

Figure 6 shows the maximum air temperatures of the summer 2010 recorded in 23 meteorological observation stations in Latvia, and one can see that in all meteorological stations, except Kolka, the maximum air temperature exceeded +30°C. The pattern of the maximum air temperature distribution was not directly related to geographical factors, such as the distance from the Baltic Sea or the Gulf of Riga – due to prevailing south-east winds the highest air temperature of +34.83°C has been observed in Ventspils.

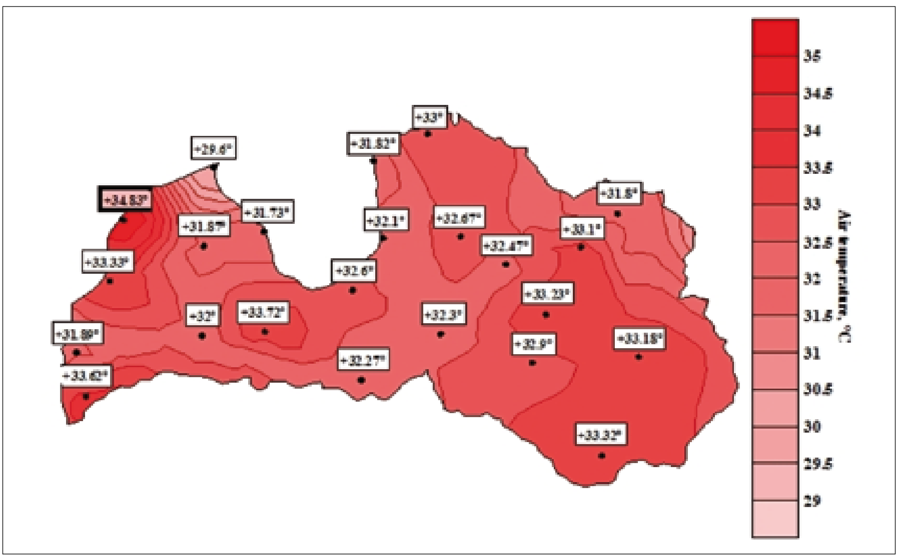

Figure 6. **Maximum air temperatures of the summer 2010 (the spatial location of the meteorological observation stations the same as in Figures 7–9)**

Overall during the summer 2010 there have been up to 17 days with the maximum air temperature exceeding +30°C, with the most of the exceedances observed in the south-eastern part of Latvia (Figure 7). The period of excessive heat lasted for a relatively long period of time, and the number of consecutive days with the maximum air temperature exceeding +25°C in the territory of Latvia varied from 5 days in the meteorological stations situated near the coast of the Baltic Sea up to 15 days in the central part of Eastern Latvia (Figure 8).

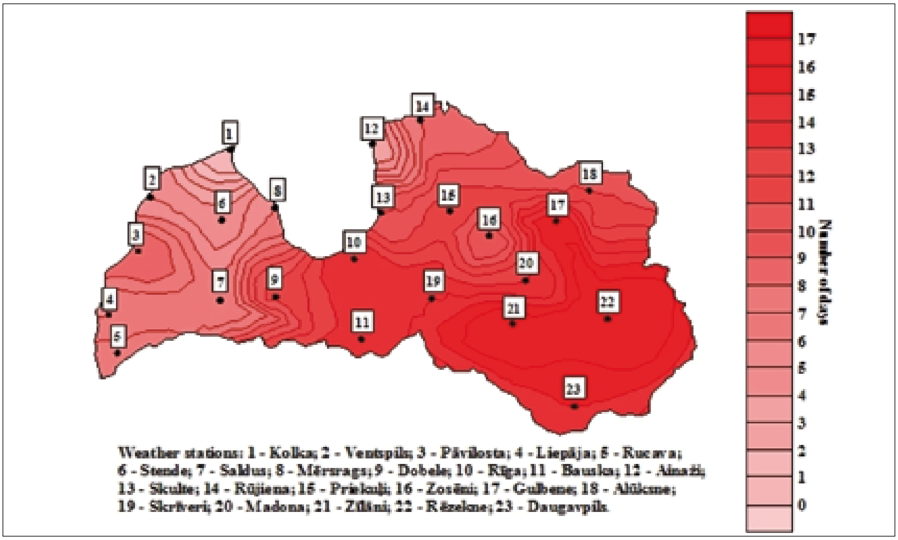

Figure 7. **The number of days with TX ≥ +30°C in the summer 2010**

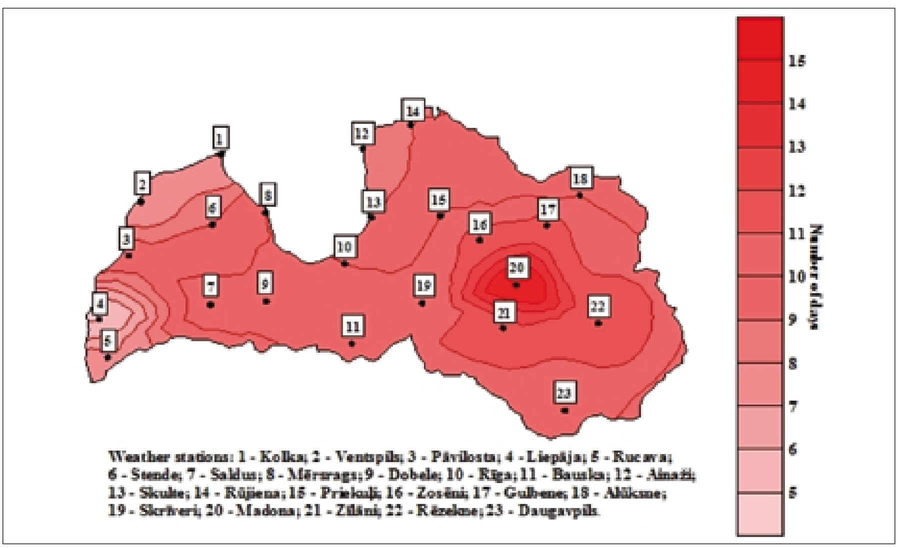

Figure 8. **The number of consecutive days with TX ≥ +25°C in the summer 2010**

The excessive heat lasted not only during the daytime; the air temperatures also remained very high during the nights. Figure 9 shows the number of tropical nights (TN > +20°C) observed during the summer 2010. A clear increase in the number of tropical nights can be seen in and around the capital city of Rīga, where, probably due to the urban heat island impacts and the urban climate specifics, the number of extremely hot nights reached 14 – the greatest number of tropical nights ever observed in Rīga and Latvia overall.

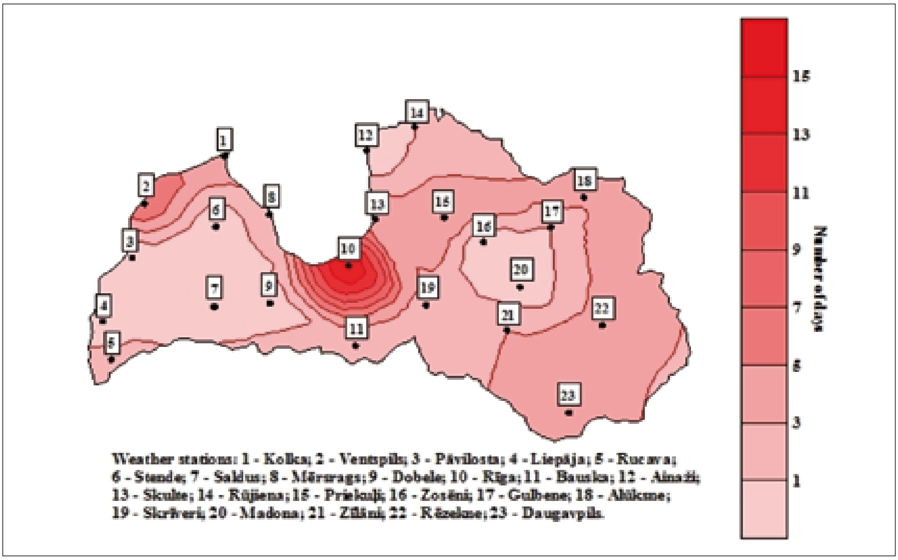

Figure 9. **The number of tropical nights (TN > +20°C) in the summer 2010**

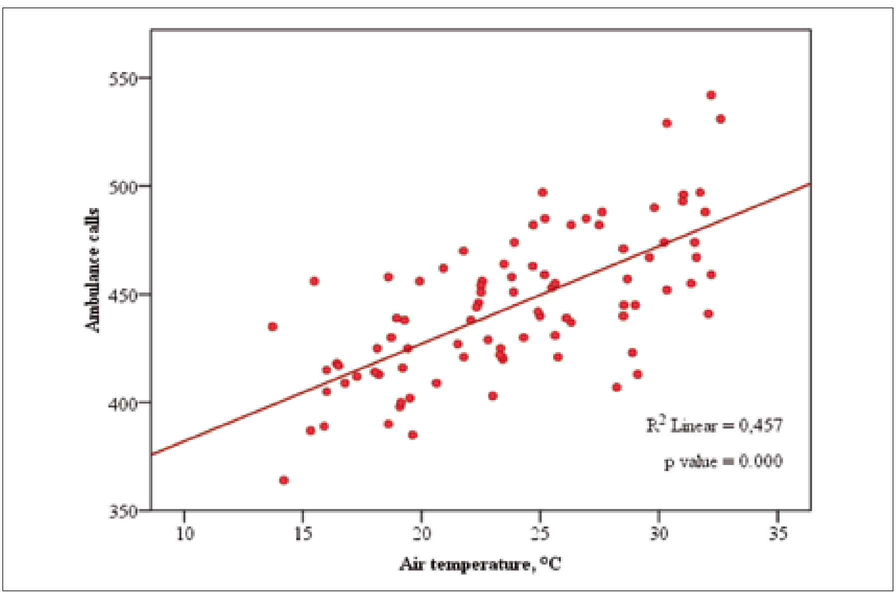

Figure 10. **The relation between the daily number of emergency ambulance calls and maximum air temperature in Rīga in June-August 2010**

Several studies worldwide have reported that extreme air temperatures are consistent with the increase in morbidity (Ma et al., 2011; Nitschke et al., 2011). The excessive heat of the summer 2010 in Latvia also showed impacts on human health. The relation between the daily maximum air temperatures and the number of emergency ambulance calls in the capital city Rīga (Figure 10) evidently shows an increase in the necessity for emergency medical assistance during the days with extremely high air temperatures. The effect of the urban heat island should also be taken into consideration (Burkart et al, 2011; Gabriel and Endlicher, 2011).

Likewise, the temporal development of heat wave during the summer 2010 can be illustrated with a growing number of emergency calls proceeding in line with the increase of maximum, minimum and mean air temperatures (Figure 11) and correspondingly decreasing after ceasing of the heat wave.

The reasons of emergency calls were diverse health problems, such as sunstroke and heat stroke, hypertensive diseases, acute cardiovascular diseases, pneumonia, bronchial asthma and intestinal infections. The following meteorological factors affecting human health during the heat wave for the study period were selected: 24 hrs average atmospheric pressure, maximum changes in the values of atmospheric pressure within 3 hrs, maximum changes in the values of atmospheric pressure within 6 hrs, relative air humidity during nighttime, relative air humidity during daytime, maximum concentration of ozone, maximum concentration of NO_2.

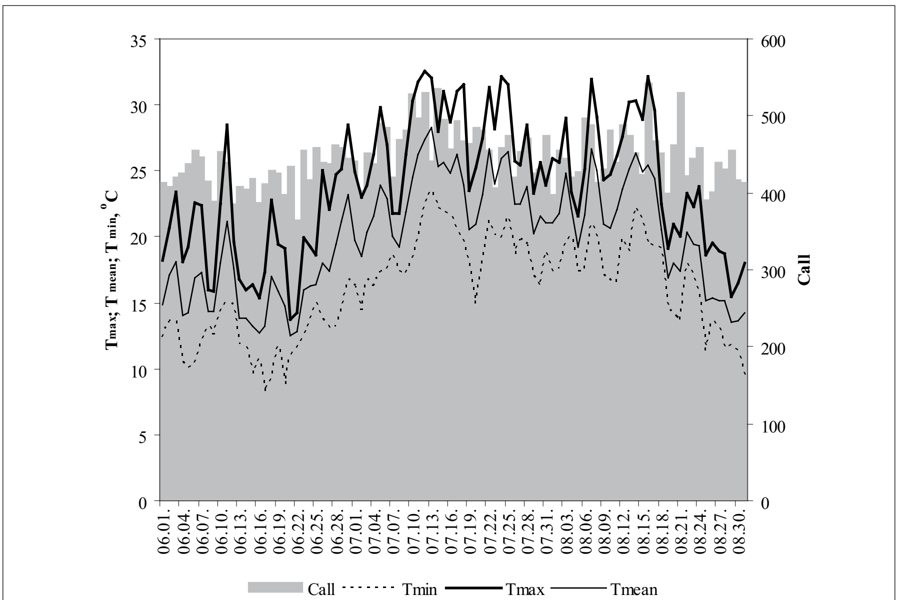

Figure 11. **Changes in the number of emergency ambulance calls (Call) and maximal, mean and minimal air temperature in Rīga in June-August 2010**

The number of emergency ambulance calls and the number of cases of sunstroke and heat stroke (SHS), hypertensive diseases (HD), acute cardiovascular diseases (ACD) have not only direct interrelations; they also correlate with the meteorological parameters (Figure 12). Evidently, the number of sunstroke and heat stroke cases can be directly related to the air temperature (and also to the intensity of sunshine hours). However, the number of calls due to hypertensive diseases during the heat wave period decreased. Other relatively evident relations are those between the atmospheric pressure and its change rate and the number of cases of bronchial asthma (Figure 13). As can be seen from Figure 13, during the heat wave, the atmospheric pressure increased, while the number of emergency calls due to bronchial asthma cases decreased.

Analyzing such complex relations as those between meteorological parameters and human health indicators during heat wave periods, straight correlations do not represent all relations between the studied parameters; therefore, we have used the Principal Component Analysis (PCA) to study these relationships (Table 3).

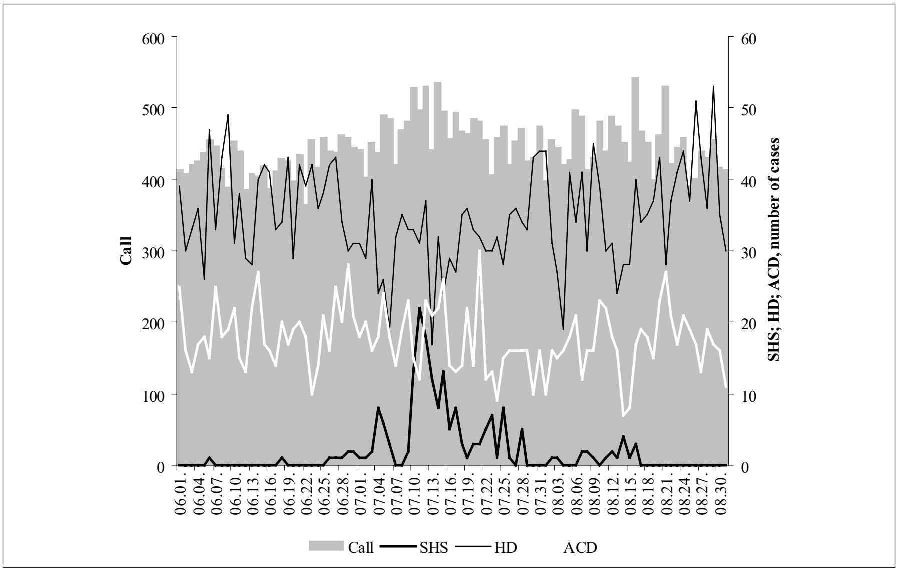

Figure 12. **Changes in the number of emergency ambulance calls (Call) and the number of cases of sunstroke and heat stroke (SHS), hypertensive diseases (HD), acute cardiovascular diseases (ACD) in Rīga in June-August 2010**

PCA allows studying the relations between selected meteorological parameters and human health indicators according to the number of emergency calls. Using PCA as the component extraction method and the Varimax with Kaiser normalization (rotation converged in 3 iterations) as the rotation method, statistically significant relations between the studied parameters were found (Table 3). Cumulative variability can be explained by 66 % with variability within 2 components. The first component can be described as heat wave impacts, and it demonstrates statistically significant positive relations between the indicators of temperature (T_{min}, T_{max}, T_{mean}), the number of emergency calls and the number of cases of sunstroke and heat stroke. The positive correlation between the indicators of temperature, the emergency calls related to intestinal infections and the concentration of NO_2 in the air is also noteworthy, indicating problems with air quality during heat waves in Rīga. The first PCA component illustrates statistically significant negative relations between the indicators of temperature (T_{min}, T_{max}, T_{mean}) and the number of emergency calls due to bronchial asthma cases and hypertensive diseases, as well as acute cardiovascular diseases (the latter was not statistically significant).

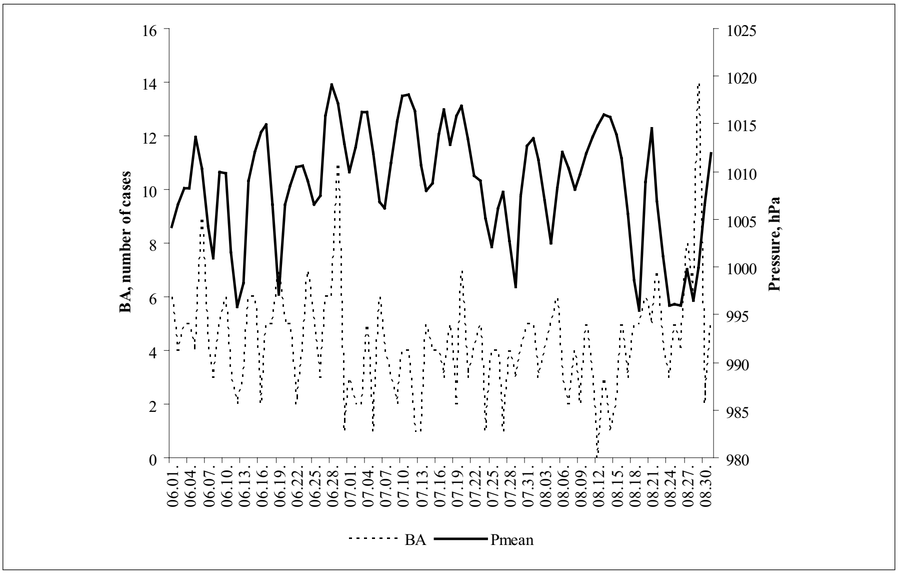

Figure 13. **Changes in the number of emergency ambulance calls due to bronchial asthma cases (BA) and 24 hrs average atmospheric pressure (P_{mean}) in Rīga in June–August 2010**

The second component of PCA analysis characterizes the parameters related to humidity – the relative air humidity during nighttime, the relative air humidity during daytime (maximal and minimal values correspondingly) and the speed of atmospheric pressure changes (maximal changes of atmospheric pressure within 3 hrs and 6 hrs). Notably, these parameters have a statistically significant positive correlation with the 24 hrs average atmospheric pressure and negative correlations with the maximal and mean daily temperatures, as well as the number of emergency calls, sunstroke and heat stroke, acute cardiovascular diseases, pneumonia and also with the concentration of ozone in the air.

Table 3. **Principal component analysis explaining the variability of meteorological factors and indications of human health according to medical emergency calls (Rotated Component Matrix – Rotation converged in 3 iterations)**

Factors*	Component	
	1	2
T_{min}	**0.927**	0.020
T_{max}	**0.907**	–0.288
T_{mean}	**0.949**	–0.196
Call	**0.539**	–0.374
SHS	**0.595**	–0.468
HD	**–0.488**	0.199
ACD	–0.220	–0.242
Pn	–0.045	–0.204
BA	**–0.515**	–0.090
II	0.228	0.108
P_{mean}	0.187	**–0.678**
P3	0.061	**0.530**
P6	–0.018	**0.498**
HN_{max}	–0.136	**0.544**
HN_{min}	–0.125	**0.655**
HA_{max}	–0.187	**0.788**
HA_{min}	–0.318	**0.682**
Oz	0.100	–0.418
NO_2	0.408	–0.119

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

* Studied factors

Sunstroke and heat stroke	SHS
Hypertensive diseases	HD
Acute cardiovascular diseases	ACD
Pneumonia	Pn
Bronchial asthma	BA
Intestinal infections	II
Number of emergency calls	Call
24 hrs average atmospheric pressure	P_{mean}
Maximum changes of atmospheric pressure within 3 hrs	P3
Maximum changes of atmospheric pressure within 6 hrs.	P6
Relative air humidity during nighttime	HN
Relative air humidity during daytime	HA
Maximum concentration of ozone	Oz
Maximum concentration of NO_2	NO_2

CONCLUSIONS

Climatic factors can significantly influence human health conditions and, consequently, human mortality. During the last decades, a significant increase in extreme climatic events associated with positive temperatures has been observed, such as increase in the mean daily mean temperature, mean daily maximum temperature, occurrence of summer days (TX > +25°C), tropical nights (TN > +20°C) as well as the maximum number of consecutive summer days (TX > +25°C). During the last decades, well expressed heat waves have been observed, although these events have occurred with expressed spatial heterogeneity in the territory of Latvia, possibly due to impacts of physical-geographical factors and large scale atmospheric circulation processes. The increased temperature events during summertime can be associated with increased mortality, while in Latvia more significant are the impacts on human health during the cold season of the year. The analysis of emergency calls indicates significant impacts on human health indicators, requiring taking adaptation actions.

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Climate Change Indicators for Large Temperate River: Case Study of the River Salaca

Spriņģe, G., Birzaks, J.*, Briede, A., Druvietis, I., Grīnberga, L., Konošonoka, I., Parele, E., Rodinov, V., Skuja, A.
Institute of Biology, University of Latvia, 3 Miera Str., Salaspils LV-2169;
***Institute of Food Safety, Animal Health and Environment, 3 Lejupes Str., Riga, LV-1076**

Nowadays due to ongoing climate change the selection of most suited climate change indicators has become necessary at global and regional scale. Long-term data of large temperate river Salaca from Baltic Province ecoregion reveal that climate change concerns physico-chemical parameters (increase of temperature, oxygen depletion) and hydrological regime (increase of discharge during winter and decrease in summer). These changes have caused enlarged phytoplankton biomasse, changes of structure of cyanobacteria communities, increased overgrowth by macrophytes as well as changes of fish communities' structure. These parameters are proposed to use as indicators for climate change affecting large temperate rivers at regional level.

Key words: climate change, temperature, oxygen depletion, discharge, biological communities, Baltic Province

INTRODUCTION

Climate change has become evident all around the world and is one of the greatest environmental and socio-economic threats. Especially sensitive to climate variations are freshwater resources. Climate change is expected to affect directly both the quantity of water resources and their quality, creating competing demands for water from multiple economic sectors. Thus climate change impact has become an actual research subject at global as well as regional scales, including Europe.

Prediction of climate change impacts to water environment is an actual exercise and a lot of studies concern it. One of the EU funded Framework 6 projects "Adaptive Strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems" (Euro-Limpacs) has made a large effort to clarify what are the main climate change impacts and which simple parameters are suited to detect them but Baltic region is not included in this project. Besides, discussions about the best suited indicators are still opened.

Our research concerns the River Salaca that is a large temperate river in Baltic Province. Salaca is anthropogenically little affected long-term ecological research site situated in the North Vidzeme Biosphere Reserve, Latvia. In the River Salaca chemical and biological investigations of water and sediment have been provided since 1982. Salmon smolts are studies since 1964, but electrofishing since 1992.

Our hypothesis is that the ongoing changes in the river ecosystem taking place after 2000 are caused mainly by climate change, and the aim of the present study is to assess climate change impact to chemical and biological quality elements of the river and to propose the best suited climate change indicators concerning river ecosystems for Baltic region.

MATERIALS AND METHODS

The River Salaca (length 95 km, river basin 3570 km^2) is situated in the North Vidzeme Biosphere Reserve (area 400 km^2), Latvia, 15 Ecoregion (Baltic Province) according to J. Illies (1978). It takes its origin from the eutrophic Lake Burtnieku (area 40 km^2) and flows into the Gulf of Riga (Fig. 1).

The data of the river discharge at gauge station Lagaste (1926–2008) were extracted from the Bulletins of hydrological observations at the **Latvian Environment, Geology and Meteorology Centre**. Also monthly records of air temperature and dissolved oxygen at the gauge station Lagaste for the period 1980 to 2008 were obtained at the centre and extracted from monthly bulletins. Trends were analyzed by using non-parametrical Mann-Kendall test (Libiseller and Grimvall 2002). The Mann-Kendall test was applied separately to each variable. Trend was considered as statistically significant at the $p \leq 0.01$ if the test statistic was greater than 2 or less than –2. Data for long-term analyses of water chemical composition (1980–2008) and river discharge (1926–2010) were obtained from the Latvian Environmental, Geological and Hydrometeorological Centre.

Surveys of the River Salaca water chemical composition, plankton and benthos have been carried out by Institute of Biology since 1982 mainly in the vegetation period and are in progress until now. Sampling of benthic invertebrates and algae is realized in three sampling stations (Fig. 1).

Water samples for chemical and phytoplankton analyses were collected at 0.5 m depth by Ruttner type sampler. The basic chemical data – COD, BOD_5, the level of nutrients and ionic composition in water were analysed by standard methods (Standard Methods 1992; HACH 1992).

Phytoplankton samples till 2004 were fixed by formaldehyde solution and examined by light microscope. After that samples were generally fixed by Lugol's solution. For counting and measurement of the phytoplankton the Utermöhl method was used (Karlson *et al.* 2010). In the time period from January 2007 till March 2009 phytoplankton samples were collected monthly.

Samples of benthic macroinvertebrates were collected by Ekman and Petersen grabs, in riffles – by Surber-type sampler and stovepipe sampler, and processed and analysed according to standard methods (Standard Methods 1992). Saprobic valences of taxa were determined (Zelinka and Marvan 1961).

Electrofishing in Salaca are carried out since 1992 till now. Sampling sites for electrofishing were selected by expert opinion, ie. in the most productive salmon reproduction areas in rapids and river littoral areas with submerged vegetation in pools (Fig.1). The electrofishing surveys were carried out in according with Standard LVS EN 14011. Density (ind/ha) and biomass (kg/ha) of fish were calculated using Zippin method modified by Bohlin *et al.* (1989). Species classification for ecological guilds is done regarding FAME (http://fame.boku.ac.at/). The scientific names used in this article are in accordance with the Handbook of European Freshwater Fishes (Kottelat and Freyhof 2007).

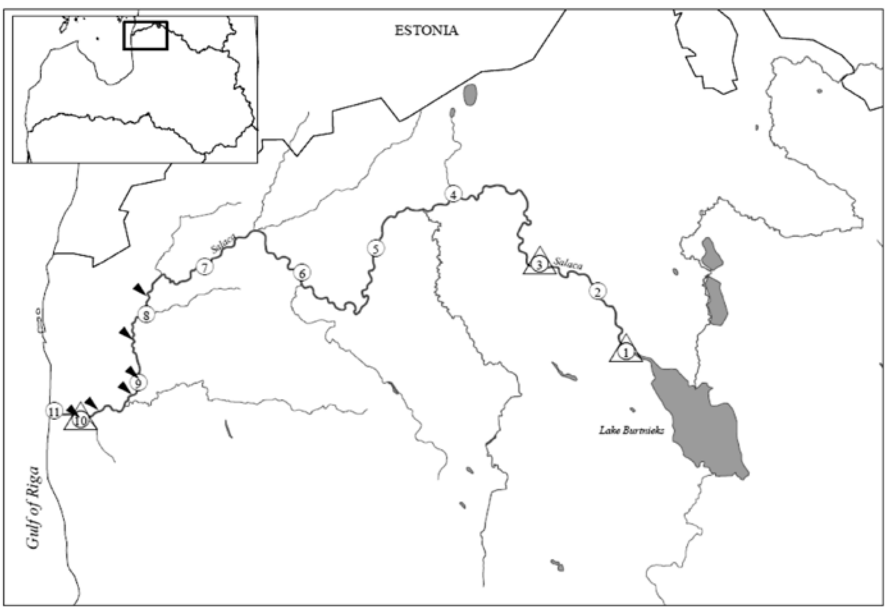

Fig. 1. **Sampling sites at the River Salaca: o, macrophytes, ▼, fish, Δ, water chemistry, phytoplankton, zoobenthos**

The survey of aquatic vegetation in the River Salaca has been performed in the beginning of August in 2007, 2008 and 2009 from boat. The submerged, emergent and floating-leaved macrophytes were mapped in percent in 11 stretches of Salaca (Fig.1). For comparing changes in the macrophyte coverage of Salaca during the last 20 years, the results of surveys carried out by A. Urtans in 1986 (Уртанс 1989) were used. Plant abundance was estimated according to a six-point scale established by Drude: 1 – very rare, 2 – rare, 3 – moderately abundant, 4 – common, 5 – frequent, 6 – abundant, predominant (Anonymous 1975).

RESULTS

Previous investigations have confirmed that mean air temperature in the Salaca River basin has an upward trend especially concerning air temperatures in the spring period (Druvietis *et al.* 2007). Also increase of water temperature is observed (Jakovļeva and Birzaks 2011). A change of water temperature will have secondary effects on various water quality parameters, including dissolved oxygen (e.g. Meyer et al. 1999). The content of dissolved oxygen in Salaca is quite high, but still there is decrease ($R^2 = 0.0247$, $p < 0.05$, $n = 348$) in the mean annual concentrations of oxygen versus evidently increasing ($R^2 = 0.2032$, $p < 0.0001$, $n = 348$) temperature (Fig. 2).

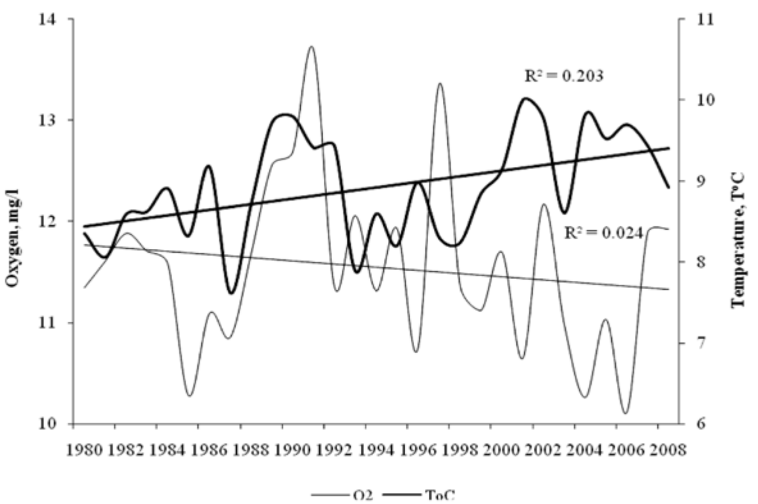

Fig. 2. **Changes of dissolved oxygen (mg/l) in the River Salaca and air temperature (annual mean 1980-2008)**

For the last decades the most significant increase in temperature is observed in April and May, but decrease in dissolved oxygen – in July that is confirmed by the results of Mann-Kendall test statistics (Fig.3).

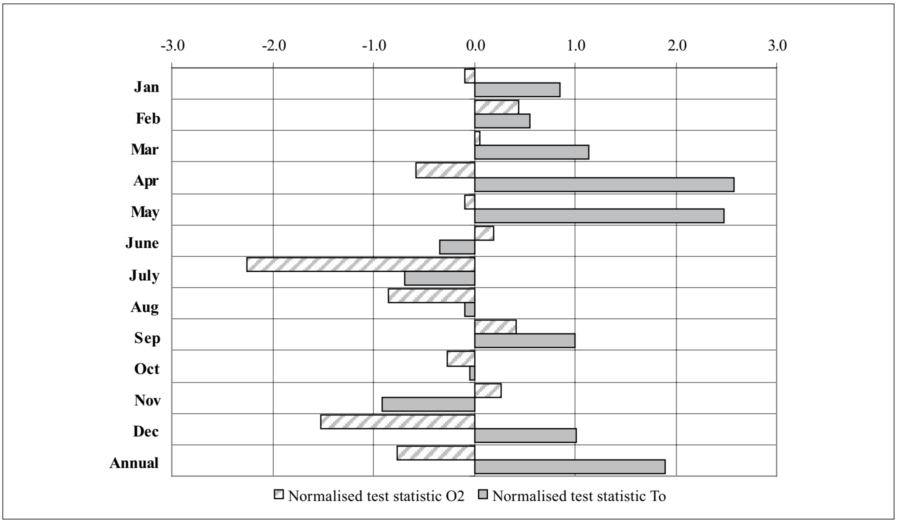

Fig. 3. **Mann-Kendall test statistics of the time series for annual and seasonal temperature at Lagaste gauge station, 1980-2008.**

Besides, in Salaca clearly pronounced changes of hydrological regime are revealed. The river's discharge has statistically significant increasing trend during winter ($R^2 = 0.2056$, $p < 0.001$, $n = 85$) and less evident decreasing trend ($R^2 = 0.0325$, $p < 0.1$, $n = 85$) during summer season (Fig. 4).

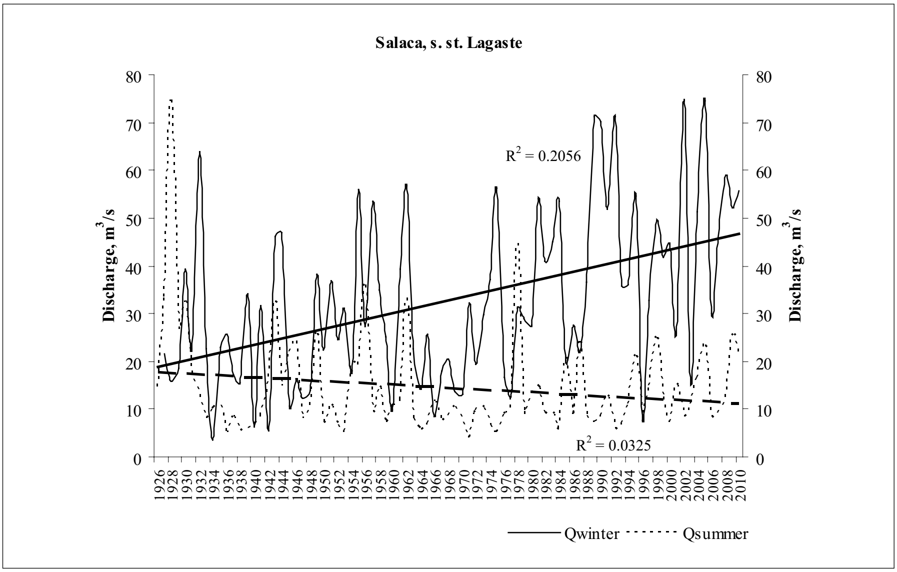

Fig. 4. **Changes of the River Salaca discharge Q (m^3/s) during winter and summer seasons (mean monthly data from gauge station Lagaste, 1926–2010).**

Interactions between climate change, other stressors and the biota are complex and it is always hard to say what the main reasons for restructuring of biota are. In any case, changes of the Salaca biota concerns both primary and secondary producers.

Since 1982 there is an increase in phytoplankton biomass. The highest biomasses all the time are usual for the river outflow from the eutrophic Lake Burtnieku but the most apparent increase is obvious in the lower part of Salaca where about thirty years ago very low biomasses were typical (Fig. 5). Monthly investigations for time period 2007–2009 confirm the impact of temperature to phytoplankton biomass (Fig. 6).

In the outflow from the Lake Burtnieku Cyanobacteria, mainly *Microcystis* spp., *Anabaena* spp. and *Oscillatoria* sp. was building up the main phytoplankton biomass which decreased in the entire length of the river (Druvietis *et al.* 2007).

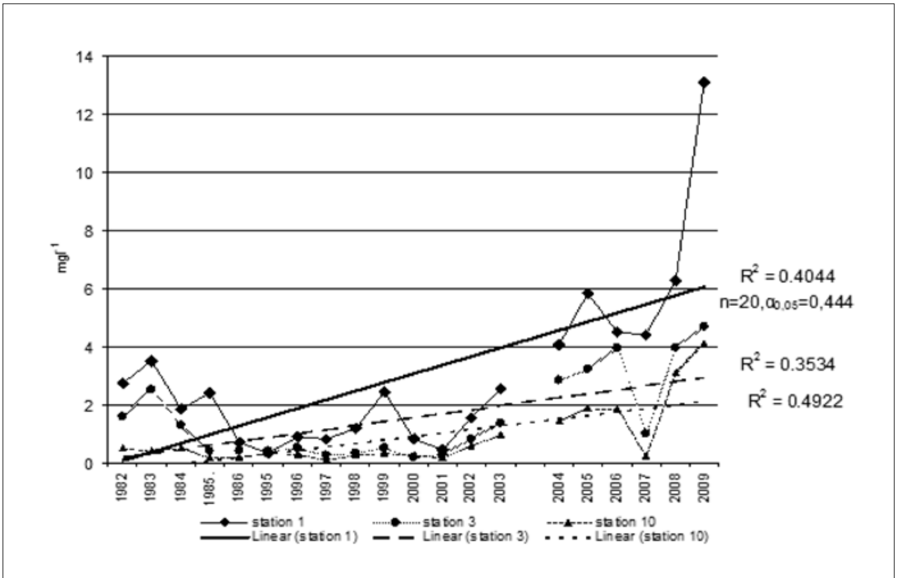

Fig. 5. **Long term changes of phytoplankton (biomass mgl^{-1}) in the Salaca River outflow (point 1), upper part (point 3) and lower part (point 10).**

Latest examinations (2007–2009) show that cyanobacterial bloom during late July-August is formed by filamentous blue-green algae, where dominant species are *Aphanizomenon flos-aquae*, *Anabaena planktonica*, *A. spiroides* and *Planktolyngbia limnetica*.

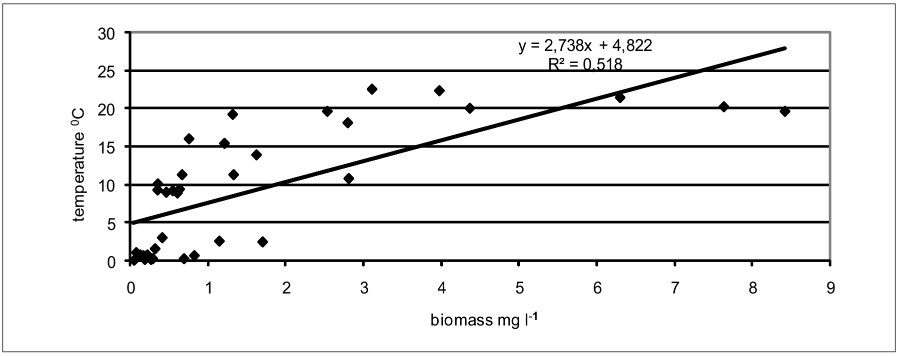

Fig.6. **Monthly data (2007–2009) of water temperature and phytoplankton biomass in Salaca.**

Regarding macrophytes no significant changes are established in species composition since 1986, and it is indicative for moderate to good water quality. At the same time, total cover of macrophytes in the river was obviously increased. Some stretches of the river were 80-90% occupied by vegetation (Fig.7).

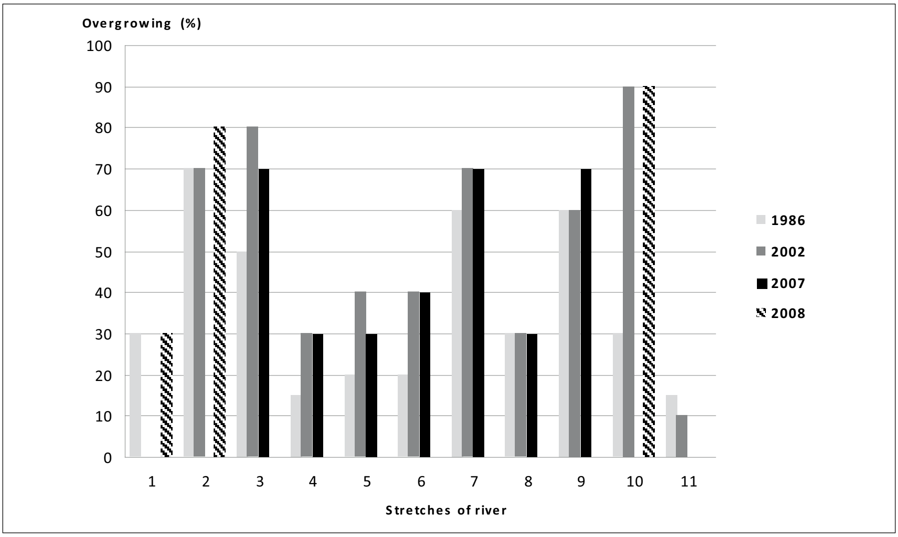

Fig. 7. **Overgrowth (%) of the River Salaca by macrophytes.**

Comparatively changeless are data concerning macroinvertebrate taxa composition and abundance. The quantitative and qualitative changes in zoobenthos community since 1982 are unimportant (Druvietis *et al.* 2007). Further details confirm that the ratio of taxa with different saprobic valences did not show certain trend in the River Salaca (Fig. 8).

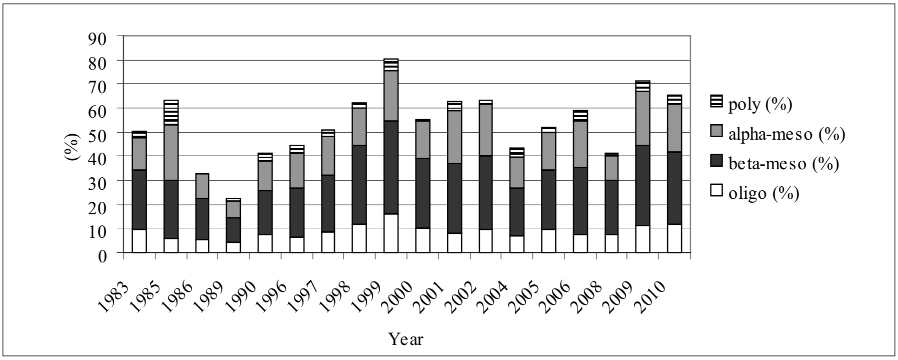

Fig. 8. **Ratio of benthic invertebrates taxa with different saprobic valences (polysaprobic, alpha-mesosaprobic, beta-mesosaprobic, oligosaprobic) in the River Salaca (1983–2010).**

Besides, freshwater bivalves *Unio crassus*, which are sensitive to the organic pollution and changes in the environmental conditions are regularly found in the lower reaches of the River Salaca.

Study methods, frequency of sampling, fishery etc. have large importance in the research of fish communities. In this study the time period of investigations with comparable results is too short for assessment of changes of number of fish species and number of individuals per square meter as indicators. However changes of fish communities' structure are stated. In ratio of fish ecological guilds the fraction of tolerant fish species has increased ($R^2 = 0.5582$, $p < 0.001$, $n = 19$) (Fig. 9A) and among them phytophilic ($R^2 = 0.6709$, $p < 0.001$, $n = 19$) (Fig. 9B) and omnivore ($R^2 = 0.6571$, $p < 0.001$, $n = 19$) fish species show the evident growth trend (Fig. 9). Roach *Rutilus rutilus* dominates these guilds and the proportion of spined loach *Cobbitis taenia* increases. Comparison of the cold-water species occurrence (*Salmo salar, S. trutta*) with that of the warm-water species (*Alburnoides bipunctatus*) shows that these changes are not unequivocal: there is an increase of riffle minnow *Alburnoides bipunctatus* but salmonid parr don't have a certain trend (Fig. 10).

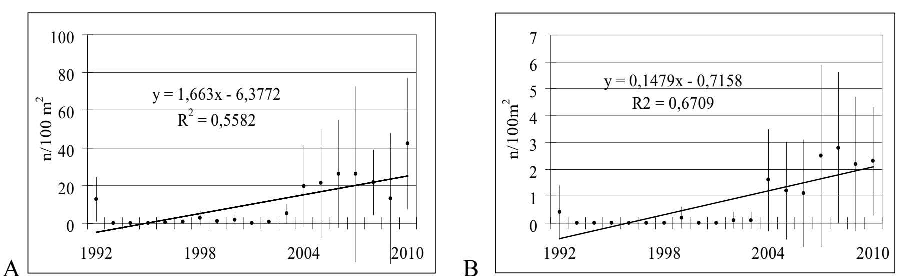

Fig. 9. **Increase of abundance of tolerant (A) and phytophilic fishes (B) in the River Salaca (1992 –2010).**

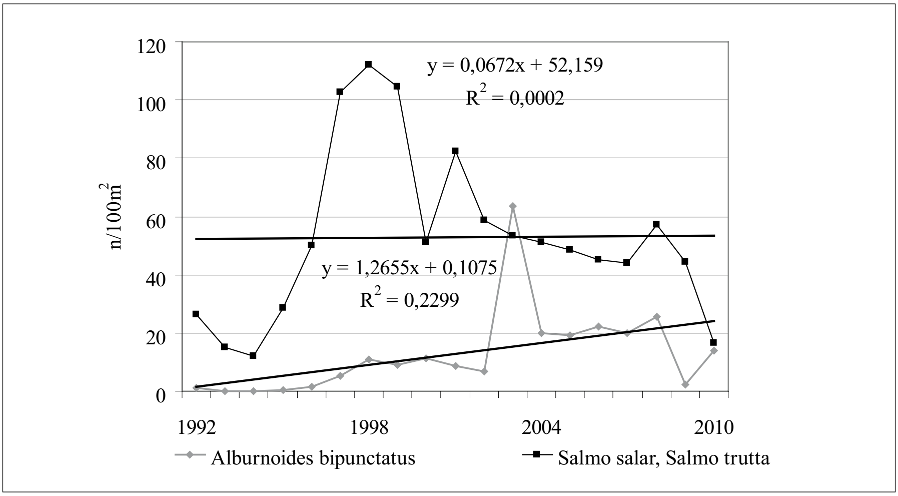

Fig. 10. **Time series trends for salmonid Salmo salar and S.trutta parr and warm-water fish species riffle minnow Alburnoides bipunctatus in the River Salaca (1992–2010).**

DISCUSSION

There are a lot of indicators proposed as climate change indicators for large rivers within Euro-Limpacs. Parameters reflecting impact of climate change are subdivided in three groups: biological, hydromorphological and physico-chemical parameters. Of course, our data material doesn't allow us to get answers to all questions in regard with proposed European-scale results but some of our findings agree with them.

Advantage of our research is the fact that the River Salaca is situated in North Vidzeme Biosphere Reserve and the natural land use patterns dominate in the river basin (Kokorīte *et al.* 2008). The studies on climate change impact on hydroecosystems have verified complexity of the problem and indications of multi causal stress to the system but in our case we assume that climate change impact to the river ecosystem is more pronounced in comparison with other factors such as land-use impact etc. In the case of intensive human activities in the river catchment it is hard mark off climate impact to biota, e.g. freshwater bivalves (Dunca *et al.* 2005). Our previous investigations (Druvietis *et al.* 2007) reveal that principal difference in biogenic element concentrations, BOD_5, COD, has not been stated from 1982 until 2002, but in the outflow of the River Salaca due to changes in land use patterns in the catchment area of the Lake Burtnieku even decrease in biogenic elements N and P was detected. The chemical composition of the upper part of Salaca is predicted by the eutrophic Lake Burtnieku, the tributaries basins of which are bogging-up (Briede *et al.*

1995), and the river water is characterized by a comparatively high level of organic substances. Long term observations show some minor decrease of COD in the lower Salaca till 2002 (Druvietis *et al.* 2007). At the same time significant increasing trends of total organic carbon and water colour are characteristic for Salaca like as for a lot of Latvian rivers during the last decade and the role of river discharge is important even it could be masked by other factors, such as changes in precipitation, biological processes, soil types or land use (Kokorite *et al.* 2011).

A lot of investigations are devoted to changes in hydrological regime as early warning indicators. One of the aspects concern changes of runoff volume and dynamics emphasizing its increase in winter and decrease in summer (e.g. Middelkoop et al. 2001, Andréasson et al. 2004, Bergström 2001). Such changes are typical for rivers of Latvia (Kļaviņs and Rodinovs 2007). Also the River Salaca discharge corresponds with these findings and increasing trend during winter and decreasing trend in summer is obvious. Significant global temperature increase in the future will change precipitation pattern in Latvia (Briede and Lizuma 2007) and for the river system these changes may lead to very low flow conditions during summer months in rivers feed by groundwater as we can see in the case of Salaca. Among factors influencing river ecosystems in Latvia decreasing ice regime has to been mention, too (Kļaviņš et al. 2007).

Regarding physico-chemical factors oxygen depletion is found as relevant indicator in Central and Western Lowlands, for example, due to increasing biological oxygen demand (Mimikou et al. 2000). We come to conclusion that this indicator fit also to rivers of Baltic Province too as the decrease of oxygen in river water is observed also in Salaca. In our case this phenomenon is connected with the increase of temperature.

It is generally known that temperature is the main climate change indicator that is fundamental reason for other ecosystem changes. Temperature is predicted to rise by 3 to 5 °C in the parts of Europe in the next half of century (IPCC 2001). In general, long-term air temperature trends in Latvia are rather similar to the trends in the other regions around the Baltic Sea. The annual mean air temperature for the last 80 years has increased about 0.5–1.0 °C (Briede and Lizuma 2002). An increase in air temperature due to global warming will transform into warmer water temperatures and could alter fundamental ecological processes. For development of Salaca crucial importance has increased spring temperature (April, May) leading to prolonged vegetation season. Higher temperatures correspondingly lead to the changed structure of aquatic organism communities and their life cycles (Schindler 2001).

At first it concerns the changes of primary producers. Phytoplankton depends upon sunlight, water and nutrients to survive. Physical or chemical variance in any of these ingredients over time affects the phytoplankton concentrations. For example, studies of phyto and zooplankton from the

Lake Peipsi, Baltic region (Laugaste and Haberman 2005) showed that the years of low temperatures coincide with the low biomass of cyanobacteria and cladocerans; the years of high temperatures coincide with their high biomass. Since 1982 there is an increase in phytoplankton biomass in the River Salaca. Our findings confirm that at least during last years the link between phytoplankton biomass and temperature exists.

Concerning cyanobacteria or blue-green algae it is established that their development can take advantage of anthropogenically induced nutrient over-enrichment (eutrophication) and hydrologic modifications (water withdrawal, reservoir construction), as well as regional and global climatic change (Paerl and Huisman 2009). On the other hand on the basis of lake studies opinion exists (Moss et al. 2003) that warming had considerably smaller effects on the phytoplankton community than did fish and nutrients. Contrary to expectation, warming did not increase the abundance of blue-green algae. Our previous investigations of phytoplankton community structure have shown some decrease of the percentage of cyanobacteria at the outflow of Salaca from the Lake Burtnieku and increase in the lower part of the river. However substantial changes concern species composition of cyanobacterial blooms in summer. Before 2007 mainly Microcystis spp., Anabaena spp. and Oscillatoria sp. composed cyanobacterial community. Latest examinations (2007-2009) show that cyanobacterial bloom during late July-August is formed by filamentous blue-green algae and dominant species are Aphanizomenon flos-aquae, Anabaena planktonica, A. spiroides and Planktolyngbia limnetica. It is hard to say what is the reason for such restructuring but one of them could be connected with changed hydrological regime ie. decreased summer discharge. Long-term investigations of water level as the mediator between climate change and phytoplankton composition in a shallow temperate Lake Võrtsjärv (Estonia) showed that phytoplankton biomass was significantly lower in years of high water level and the changes were unrelated to nutrient loading. The share of filamentous blue-greens among phytoplankton followed the changes in the water level while there was a succession of dominants (Nõges et al. 2004). Water level has the most important role according nutrients in the river but in the case of phytoplankton biomasses (particularly cyanobacteria) also the water temperature parameters had a significant effect (Milius et al. 2005).

In the fact, in rivers phytobenthos and higher aquatic vegetation or macrophytes play larger role if compare with phytoplankton. In our case we don't have reliable data on phytobenthos but enhanced overgrowth of the river by macrophytes is obvious. At the same time no significant changes are established in the macrophyte species composition. In our study we didn't find climate change consequences in the species distribution and community structure like as in some other studies (Kankaala et al. 2000, McKee et al. 2002). Like as in other ecoregions in Europe (Central Lowlands, Western

Lowlands, Western Mountains and, Central Mountains) increased macrophyte growth is a relevant biological parameter of climate change for the River Salaca representing Baltic Province. We assume that macrophyte growth rates increase due to higher temperatures and prolonged vegetation period (Grīnberga and Spriņģe 2008). In a simulation experiment on climate warming in the boreal zone of Finland it has been found that emergent macrophytes benefit from higher temperatures and the prolonged growing season, therefore in the future climate some macrophyte species will grow faster and the littoral stands will produce more shoot biomass (Kankaala et al. 2000).

In general, climate change impact to fish communities' diversity, distribution, abundance and life history is completely approved by a large number of studies (e.g. Daufresne et al. 2004, Eaton and Scheller 1996, Salinger and Anderson 2006). Characteristic feature in natural ecosystems is the decrease of cold water species (mainly salmonids) and increase of warm water species (mainly cyprinids) (Daufresne et al. 2004). Cold-water fish are projected to disappear from large portions of their current geographic range (Allan and Flecker 1993). The role of flow regime changes is expressed by the phenomena that lower summer base flows translate into less in-stream habitat for invertebrates and fish. This is expected even if winter precipitation increases in northern latitudes as projected, because excess precipitation will not be stored as snow (Frederick and Gleick 1999). On the whole hydrological factors significantly influence fish assemblage structure, and that hydrological alterations induced by climate change (or other anthropogenic disturbances) could modify stream fish assemblage structure (Poff and Allan 1995). Data available for Salaca confirm findings of other scientists according climate change impact to tolerant fish guild. Increased proportion of tolerant fish and among them phytophilic and omnivores with the dominance of roach Rutilus rutilus is typical for Salaca in the last two decades. There are no obvious changes in the occurrence of cold/cool water salmonids even if clearly pronounced increase of annual mean temperature as well as spring (April, May) temperature and changes of hydrological regime are evident. However values of temperature and oxygen still are not critical. For example, Bley (1987) has mentioned that normal growth and production occur at 15–19 °C and fish may tolerate up to 27 °C before they seek cooler water. We suppose that for the present situation concerning temperature is quite favourable for salmon parr due to prolonged growth season. Besides, there are temperate lowland rivers in Latvia and salmon populations are adapted to local conditions (Birzaks et al. in press). Nevertheless according to above mentioned findings of other scientists in the future changes of cold/cool water species are possible.

Even if it is found that warmer water can affect also benthic invertebrates due to impact to their life cycle and development (e.g. Arnell et al. 1995, Dunca et al. 2005, Harper and Peckarsky 2006), no evident shifts in the structure of benthic invertebrates communities in Salaca have been observed. At the same time analysed time series of entire communities of macrozoobenthos in lakes and streams in Northern Europe did not show direct linear effects of temperature and climate indices (North Atlantic Oscillation index) on species composition and diversity; however, future climate shifts may induce strong variance in community composition (Burgmer et al. 2007) .

CONCLUSIONS

Long-term studies of abiotic and biotic components of the River Salaca, North-Vidzeme Biosphere reserve, Latvia, allow suggest indicators, which reflect the main effects of climate change on large temperate river in Baltic Province ecoregion. Among physico-chemical parameters the increase of annual air and spring temperature is obvious. Changes of river discharge show runoff increase during winter and decrease in summer confirming principal shifts in hydrological regime of the river.

Temperature increase influence depletion of dissolved oxygen in Salaca.

As a result of these changes some biological parameters have changed. Enlarged phytoplankton biomasses and the dominance of filamentous cyanobacteria in phytoplankton during blooming are typical during last years in Salaca. Higher temperatures and prolonged vegetation period lead to increased growth of macrophytes.

Changes of fish communities in Salaca are pronounced by increased phytophilic species and tolerant fish guilds versus intolerant in general.

Our findings allow expand the use of indicators chosen by Euro-Limpacs project and find as relevant for the River Salaca to Baltic Province region that was not included in project's study area.

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Impacts of Climate Change and Adaptation to it

Facilitating Stakeholder Involvement in Adaptation to Floods in Riga: from Research and Planning to Actions

Agrita Briede, Laila Kūle, Māris Kļaviņš, Laura Kļaviņa
University of Latvia, Faculty of Geography and Earth Sciences,
Raiņa blvd. 19, LV 1586, Rīga, Latvia

Flood prevention and adaptation is one of the key priorities in adaptation approaches, especially in urban territories as it is a case of Rīga. The EU Directive EC 2007/60 specifies the structure and objectives of the flood risk management plan and the favourable mitigation measures, however, in each case specific local aspects should be considered. The aim of this study is to look at approaches used in Rīga, the strategy to develop and implement this management plan on a local level and contribution of international cooperation activities within frame of the BatltCICA project. As an important tool is multi-stakeholder participation in the decision-making process to achieve cost-effective results in a timely manner so that the results are not only optimised but also socially acceptable. Within the project in cooperation with BaltCICA have developed and implemented a governance approach, which tries to meet these requirements of good governance through stakeholder involvement in the planning process.

Key words: planning, flood risk management plan, stakeholders

INTRODUCTION

Floods are amongst the major natural hazards every year causing immense losses. Flood risk is especially high for urban territories as it is a case for Rīga, the capital city of Latvia as far as Rīga is situated on the sea coast at the mouths of three large rivers Daugava, Lielupe and Gauja. All three rivers are treated separated in terms of the EU water basin directive that makes Rīga case particular challenging from both policy making and geographical characteristics. Rīga City's 15 km of the seacoast and about 60 % waterline are vulnerable to sea level rise. Other risks concerning to the climate change adaptation are related to sea storm surges, flash floods due to intensive precipitation and outdated technical infrastructure of the urban water system.

Adaptation actions to reduce flood risks largely is regulated by the EU Flood Directive EC 2007/60 which specifies the structure and objectives of the flood risk management plans and the favourable mitigation measures to be taken for reducing the risk (Fig.1). However little information is given about the strategy to develop and implement this management plan on a local level. Obvious is the need for finding a good governance concept supporting the implementation process leading to acceptance and proper application of the flood risk management. Of importance is to ensure the necessary multi-stakeholder participation in the decision-making process, consideration of international known success stories and solutions proved to be efficient at local level.

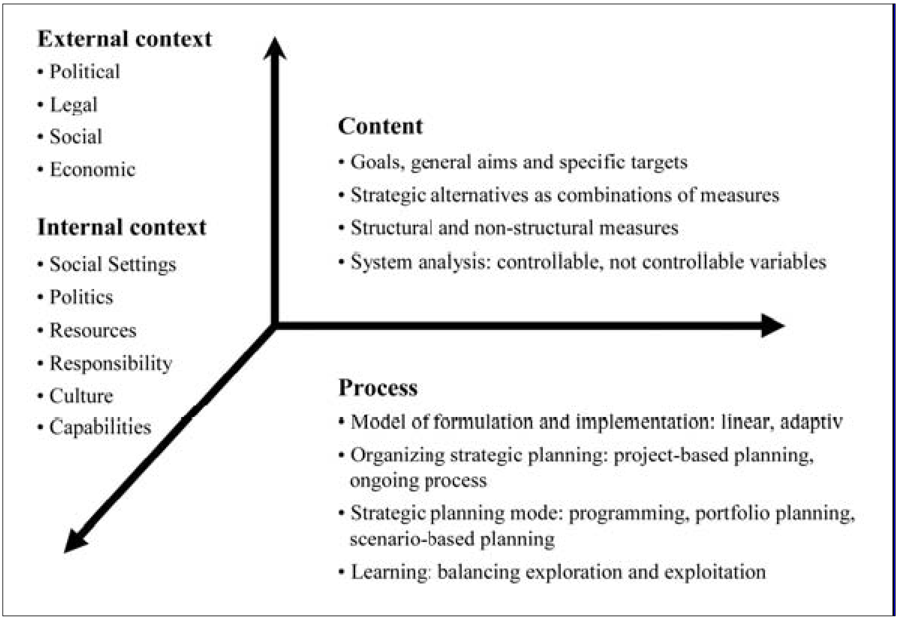

Fig. 1 **Three dimensions of strategies for Flood Risk Management (Hutter & Schanze, 2008)**

Adaptation to flood risks should be a combination of top-down process (represented by the EU Flood Directive EC 2007/60) and bottom-up process initiated by interest groups or municipalities threatened by flood. This concept is stated in the Flood Directive as (Article 10 (2) "Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans referred to in Chapter IV."

Another key problem in flood risk management is that Flood Directive replaces traditional flood defence strategies through a risk based management concept (Samuel et al., 1999). Professional and public stakeholders need to build up their capacity in the application and understanding of flood risk management (WMO, 2006). They are not a fixed set of tangible measures but an evolving process of transfer to a more adaptive flood risk management in order to cope with the emerging uncertainty due to climate change/climate variability (Tippett and Griffiths, 2007).

There are studies to how to apply interdisciplinary scientific evidence and to downscale projections to local level; including in the area of flood prevention and climate adaptation (Aall et al., 2007; Aalsta et al., 2008). There are still many open questions in relation how the results of studies are transferred into legitimized and operational activities of local governments. The understanding and responding flood prevention covers complex issues, different spatial and time scales and thus need different academic disciplines and policy fields to be involved in coordinated manner. Due to uncertainty in flood prevention, often action is needed before a complete understanding of the problem. Flood prevention includes information production, knowledge creation and transfer as well as social learning processes. Interdisciplinary and stakeholders involvement approaches are seen as solutions to complexity, uncertainty and contextualization of regional knowledge to be applied in localities. As knowledge constitutes a capacity for action and provides tools to comprehend reality by structurizing it and controlling contingent circumstances (Stehr and Ufer, 2009), it is important to be aware and use all types of knowledge - tacit knowledge and explicit or codified knowledge. There is an argument that tacit knowledge as the most strategic resource of institutions and places (Eisenhardt and Santos, 2001). According the use of knowledge for the policy production the knowledge is divided as traditional 'academic' research that is rooted in past research, based on peer review and independent, the other types are 'fiducial' and 'bureaucratic' knowledge (Hunt and Shackley, 1999). Fiducial knowledge is the basis for policymaking. Bureaucratic knowledge is produced jointly by users and it is a synthesis for a specific context and the use, often political situations and thus filtered and judged for particular needs. Both fiducial and bureaucratic knowledge produced on basis of contract and it often validated based on the status of authors. Thus stakeholder involvement and the way how stakeholders are identified are particularly important in the field of knowledge. All types of knowledge are interlinked and the distribution channels have particular importance how different knowledge types are interchanged and integrated. Usable knowledge is accurate information that is of use to politicians and policy-makers (Haas, 2004). Haas has been analysing why science is seldom directly converted to policy and how scientific consensus can be communicated to power institutions and thus such aspects of knowledge he points as relevant s credibility, legitimate and saliency. „In practice credibility and legitimacy are mutually reinforcing, as a procedural approach to developing consensual knowledge is likely to generate both accurate and acceptable knowledge (Haas, 2004). There are identified four criteria of usable knowledges: its adequacy, value, legitimacy, and effectiveness (Clark and Majone 1985). The bridging of knowledge and knowing involves organizational learning and dynamic capabilities of involved institutions and focus have to be not only on internal and external knowledge transfer but also knowledge integration processes, in which the development of meaning and the creation of new knowledge occurs through individual interactions and is affected by social contexts (Eisenhardt and Santos, 2001). Beside knowledge integration processes, interpretation and institutionalization of knowledge are equally important. Institutionalization is a process by which ideas and practices become durable reference points for social action and institution building that requires both a design of arenas with certain consensus about underlying values and a the commitment to administrative and financial agreements between different levels of government, sectors and private institutions (Albrecths, 2001: 738).

The term stakeholder from business management (Freeman, 1984) has been spread to different aspects of governance and is used in all policy fields, including environment and resource management (Grimble & Chan, 1995; Grimble & Wellard, 1997). Stakeholder participation is widely used in coastal management (Fletcher, 2003; Rockloff & Lockie, 2004). There are examples on studies how stakeholder involvement have been used in flood prevention (Janssen, 2008; Heitza et al, 2009; Adams *et al.*, 2005) that is related with a paradigm change in flood risk management (Werritty, 2006; Tippett & Griffiths 2007; Dworak & Görlach, 2005).

Stakeholder, or all persons, institutions or organisations with interest in the issue involvement, either because they will be affected (positively and negatively), have an interest or because they can influence (positively and negatively) on its outcome, involvement is closely linked with social learning (Ridder et al., 2005; Pomeroy & Rivera-Guieb, 2006). At various stages of the decision making process different stakeholders might be involved in participation events and other activities with direct involvement, however all stakeholders need to be informed on the process and outcomes of dialog at each stage. There is often a possibility to identify many individuals and groups with interest in the issue, and thus large number of involved might encumber ability to take a decision that will solve a problem (Harrison & Qureshi, 2000). Thus stakeholder mapping, focus group, and other approaches are suggested to use in order to identify stakeholders. Studies suggest using mapping stakeholder dispositions in such dimension as interest to the issue or ability to change situation (power, finances or knowledge-related aspects). Various thematic areas, categories, typologies can used in order to structure a vast and diverse pattern of stakeholders and their discourses in relation to the issue.

Stakeholder mapping is linked with "the notion of 'interactional field', a social situation/space defined by its contextualities, a cluster of actors and processes with geographically, socially, economic, and politically defined boundaries", and "that implies a look at social spaces in time/dynamics" (Aligica, 2006: 85).

Harrison and Qureshi (2000) highlight that stakeholder identification is a process that needs to be repeated as discussions will reveal groups and individuals that are not identified before. Stakeholders can provide information and knowledge not only about the issue but also on other stakeholders involved. Stakeholder participation process are greatly dependent from the responsible institutions in the issue concerned, it is greatly important to provide a policy framework, capacity in terms of human, financial, knowledge resources and time and place-related aspects for stakeholder involvement process and its management. Stakeholders have to have ability and capacity to participate (Weber & Christopherson, 2002). Early involvement of stakeholders is important for decision-making process with qualitative outcome (Blahna & Yonts- Shepard, 1989; Chess & Purcell, 1999; Reed, 2008).

Social learning is based on a dialog where stakeholder independence, the need for interaction, openness, mutual trust and cultural tolerance, common vision, critical self-reflection, and strong leadership are recognized. Stakeholder participation ensures that different perspectives of the problem will be taken account. Stakeholders can provide additional details and correction to existing codified knowledge and thus provide contribution to science. Stakeholder participation adjusts planned decisions to real situation and the will of society and its groups and thus provides contribution to justice. Early stakeholder involvement will contribute to the support of implementation of planned actions, and thus is a crucial element of governance aspects. Political commitment, expected and planned organizational changes and the increase of institutional capacity are aspects that also need to be considered in building stakeholder participation process.

The objective of this paper is to evaluate approaches elaborated within Latvian National research program "Climate change and waters (KALME)", INTERREG project "Towards climate change adaptation in the Baltic Sea region (ASTRA)", used to develop flood management practices supported by the Baltic Sea Region project BaltCICA on example of Rīga flood management solutions developed within a Life+ project "Integrated Strategy for Riga City to Adapt to the Hydrological Processes Intensified by Climate Change Phenomena".

RESULTS AND DISCUSSION

There are estimations by Rīga city planners that the current 1% probability urban flooded area of 31.1 km^2 will increase in year 2100 by 28 percent. The projection was made based on IPCC A1B scenario that indicates water level raise by 4.8 mm per year (Riga against flood, 2011).

There is both natural and man-made coastal protection in Riga. Traditionally in Latvian human settlements did not have situated in dune and flood-prone areas. There is evidence that Rīga City has had the protection system on the Daugava River since the end of the 13th century (Biedriņš and Ļakmunds, 1990).

Two types of constructions has been used – (1) coastal wooden propping to protect city fortification wall from ice and foundations from washing-out; and (2) compacted gates for flood protection. However the latter did not function sufficiently to the needs. In the middle of the 17th century the city fortification system was improved and erected earth walls were also used for flood protection. However the mentioned flood protection systems couldn't completely protect water inflow to the city. The dangerous problem rose also due to ice and spring floods. The main causes were yearly transformation of water flow that changed river bed and therefore shipping route has been adapted frequently.

One of results of the BaltCICA project was a review of historical extreme weather events in Rīga area. There are various types of challenges facing Rīga planners today as urban area is characterized by the large diversity of residential and economical activities' densities, patterns and land use types.

Rīga City municipality' planners and multi-disciplinary researchers from the University of Latvia by the support of the BaltiCICA project closely cooperate and thus provide the transfer and the integration of specialized climate change knowledge into legitimized and operational activities of local government, particularly in the field of spatial planning regulations. Both foreign climate change adaptation experiences from local municipalities around the Baltic Sea as well as methods of multi-criteria decision-making analysis have been learned and will be explored for application in the Rīga City.

The epistemic community of planners and particularly these with nature, environment or geography sciences background plays an import role to the transfer of scientific knowledge to the management of policy documents of the Riga municipality. In 2010 the Development Department of the City Council had eighty employees from them twelve has nature science background. The area various sources how experts of Riga municipalities gain new knowledge produced by the scientists. Science and applied projects are one of such source, for instance the Baltic sea region INTERREG III B project "Developing Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region ASTRA 2005–2007" that indicated affected areas in Riga city if sea water will raise, and the Latvian National Research Program "Climate change and Waters", that provided wide range of scientific evidences as well as public awareness activities. Other information source is the specific flooding events. They provide information on the extent of the current problems in relation to municipality capacity in the field of human, technical and financial resources.

Prior to the envisioning of the objectives and strategy to manage the flood risk in the planning area, the capacity of the participants is to be raised towards the understanding of the "Concept of Risk Management" in flood risk mitigation. This phase is the key to opening towards flood risk management planning, as stakeholders have to give up their traditional ways in dealing with flood issues and to develop new skills and understanding. This process of transfer to new knowledge and practices need time and continuous support by the stakeholder group of researchers and just from this perspective active cooperation between academics, and practitioners considering international experience is of utmost importance. At the end of this process the stakeholders need to proof their new knowledge by developing their vision on how to deal with flood, considering both current situation and drivers of future development such as climate change and urbanisation. After the consensus reaching on the objectives of the flood risk management Riga City municipality' planners begin with the "concrete planning phase". They have made use of the new knowledge by selecting the appropriate flood mitigation and adaptation measures. At the end of this planning phase a set of various options on flood risk management are prepared which marks milestone in the governance process.

Table 1. **Parameter characterizing the conflict potential and shared interests**

Parameter	Description
Level of impact	Shows in which way and to which extent the stakeholders are affected by implementation of flood risk management plan. It can be differentiated as *direct* or *indirect*. This parameter characterizes the motivation of the stakeholders to participate in the flood risk management.
Level of understanding	Assessment of the present knowledge and background of the stakeholder groups, including flood risk awareness and understanding of the flood situation in the area and understanding of the EU Flood Directive- risk assessment, flood risk mapping etc.
Overlapping responsibilities	conflicting interests or ambitions among institutions (for example, Ministry of Environment and regional development).
Diverging interests – conflicts	Description and assessment of the conflicts due to the implementation of the flood risk management plan

The final phase of flood risk adaptation planning is the process of consensus building by agreeing on one set of mitigation and adaptation measures. In this phase the members must agree on the relevant criteria in assessing the various options of flood risk management. Again experts have to coach this process by introducing into the theory of Multi-Criteria-Analysis, developing an assessment matrix of relevant criteria and providing a decision support tool which all stakeholders can use to select and modify options of flood risk management and to determine their efficiency, benefits and conflicts. Good guidance is necessary to explore possibilities to minimize remaining conflicts of interest between the different stakeholder groups. Probably not all conflicts can be avoided that in the end the stakeholders have to agree on an "acceptable level of conflict" by defining priorities. In urban area as it is in Rīga many stakeholder groups will be affected by the actions to be taken in flood risk management plan. The stakeholder analysis should provide the existing political, social and institutional structure with special reference to the organizational structure of the flood management within the area of interest (EC, 2003).

Stakeholder workshops and meetings have been organised by the University of Latvia to widen the spread of information and consultations outside the Rīga City's municipal institutions (Table 2). Latvia University involved and transfer the climate change adaptation knowledge of other BaltCICA project partners. In close cooperation between the experts of Rīga municipality and the Latvia University possible adaptation options for urban spatial development will be prepared (Figure 2).

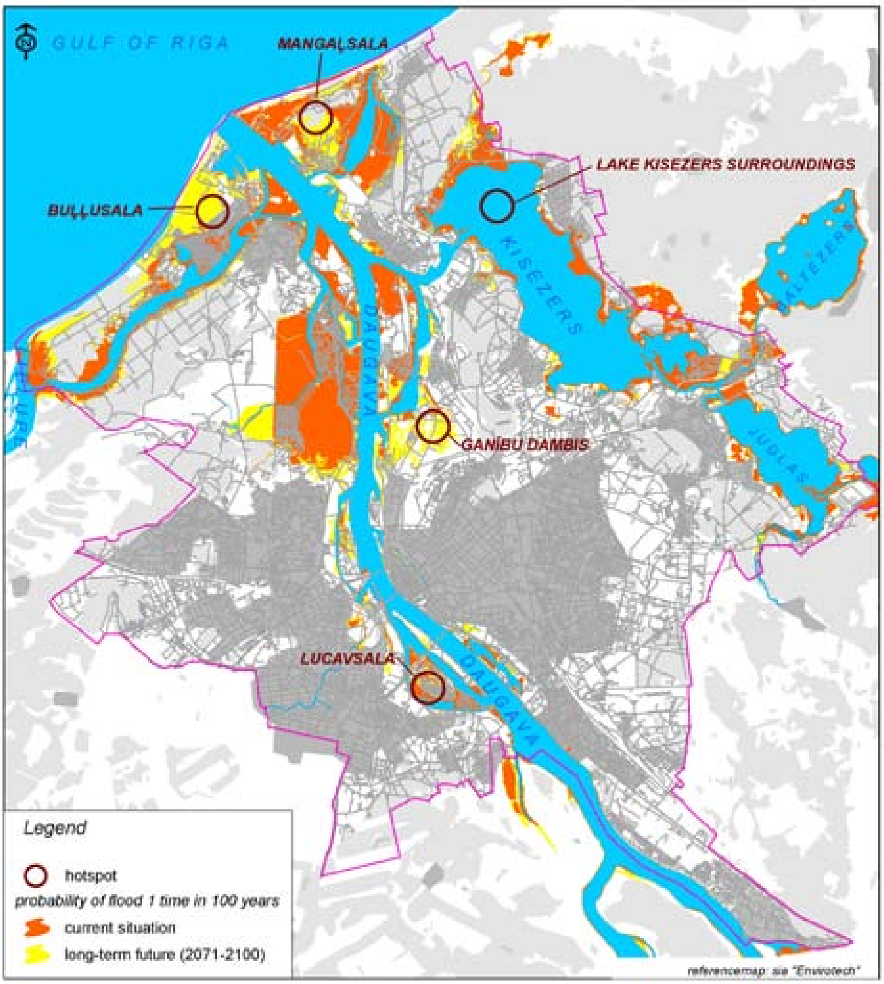

Figure 2. **Hot spots under discussion that are identified as places or technical structures for climate change adaptation measures (prepared by Andris Locmanis, Rīga City Council)**

Rīga city case proves that in spite of public finances cuts at national level, the local level and the expert community is capable to attract the EU funding (BaltCICA and Life+ project) and continues to work towards safer places and thus climate change adaptation measures as that fits to their everyday tasks and strategic aims.

The results of modelling revealed that Riga City has rather high number of flood prone areas that are relatively unconnected with relation of water management options. Therefore for developing flood prevention and climate change adaptation measures there is a need to define comprehensive and acceptable criteria for planning purposes including prioritization of measures.

CONCLUSIONS

New concepts are required to support the active participation of stakeholders in development of flood risk management plans in the sense of the EC Flood Directive (2007). Bottom up approaches are likely to fulfil this requirement. Development of mutual trusts and open atmosphere turned out to be a crucial factor for proceeding with planning. Analysis the city's sensitivity to floods and economic analysis is a necessary extension of the obligatory flood maps in order to understand the system's limits, enabling stakeholders to assess risk more realistically. Harmonisation with the other directives and planning procedures (e.g. WFD) has to be made at an early stage, introducing already planned synergetic measures as an element of the flood risk management planning. As this is a knowledge and resources intensive process, the expertise of different groups and international experience is required.

ACKNOWLEDGEMENTS

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Changes of the Phenological Seasons in Latvia

Fenoloģiskās sezonas un to izmaiņas Latvijā

Gunta Kalvāne
Faculty of Geography and Earth Sciences, University of Latvia,
Raiņa Blvd. 19, LV1586, Rīga, Latvia,
e-mail: *Gunta.kalvane@lu.lv*

Abstract
Phenological indication is one of the most frequently used methods for identifying the phenological seasons. The aim of the study is to define indicators of phenological season in case of Latvia and characterize the variability and changes of the phenological seasons for the 1971–2000 period. Particular study is based on voluntary collected phenological data from 15 observation point in Latvia.
Based on scientific literature as well as on the data analysis, it is suggested that in case of Latvia the following phases for plant species can be used as phenological season indicators: the beginning of flowering of the hazel *Corylus avellana* for the phenological spring, the beginning of flowering of the wild raspberry *Rubus idaeus* as the indicator for the commencement of summer and to accept the beginning of leaf colouring of the birch *Betula pendula* as the commencement of the phenological autumn. Current study confirms that the beginning of season as well the length of phenological seasons significantly changed during reference period: phenological spring and summer started earlier, but the trend of phenological autumn is neutral with large local differences. The length of phenological spring, summer and autumn is increasing.

Keywords: phenology, phenological indication.

INTRODUCTION

Phenological indication is one of the most frequently used methods for identifying the phenological seasons: a specific, easily observable plant or animal development phase (key phase) is adopted as the indicators of the beginning or end of the phenological season. Phenological seasons can be used to help describe seasonality of environmental conditions, ecosystems, and individual species (Ahas and Aasa, 2003).

The beginning and the end of season are important parameters in phenology, which qualitatively describe year to year phenological variability and phenological changes. Phenological changes show trends in climate change and can be used as biological indicators of changes in the environment

(Badec et al., 2005; Gordo and Sanz, 2005; Menzel, 2003; Schwartz, 2003; D`Odorico *et al*., 2002; Menzel and Fabian, 1999).

Indicators of phenological seasons as well as the number of seasons and name of season vary from region to region. Developing and naming phenological seasons is usually based on local traditions and depending of native species (Ahas and Aasa, 2003). Usually each of the four traditional seasons can be divided in a more detailed way into 9 – 13 sub-seasons (Krauklis and Draveniece, 2004; Ahas and Aasa, 2003; Ģērmanis, 2003; Kulienė and Tomkus, 1990; Šulcs (Шульц), 1981; Sproģe, 1979; Deutcher Wetterdienst, undated). For example, in Estonia the indicative phase for the beginning of early spring is birch *Betula pendula* sap rising, full bloom of apple tree *Malus domestica* for spring, and pollination of rye for summer (Ahas and Aasa, 2003). In Germany, phenologists to deal out 10 phenological seasons: the beginning of flowering of the hazel *Corylus avellana* is the indicator of pre-spring or very early spring; flowering of apple tree *Malus domestica* is the phase for the beginning of summer; flowering of linden *Tilia platyphyllos* is indicator of the mid-summer, and the beginning of ripening of black elder *Sambucus nigra* is the first autumn phase. The beginning of leaf fall for Pedunculate or English oak *Quercus robur* is indicator of phenological winter (Deutscher Wetterdienst, undated).

Unfortunately there is little scientific research in Latvia on phenological seasons, and there are no widely accepted unified methods and indicators for dividing the seasons in Latvia (Table 1).

The authors have used the commencement of the snow melt (Sproģe, 1979), the flowering of the coltsfoot *Tussilago farfara* (Ģērmanis, 2003), the beginning of flowering of hazel *Corylus avellana* (Krauklis and Draveniece, 2004), or the beginning of the circulation of birch *Betula pendula* sap (Šulcs, (Шульц), 1981) as indicators for the beginning of the phenological spring in Latvia.

The beginning of the flowering of wild raspberries *Rubus idaeus* has been used in this research as the value for the commencement indicator for the phenological summer. Other authors define the commencement of flowering of lilacs *Syringa vulgaris* or jasmine *Philadelphus coronaries* or the flowering of rye *Secale* (Kulienė and Tomkus, 1990), or even the beginning of flowering of potato *Solanum tuberosum* (Ģērmanis, 2003) as the commencement of summer. However, these indicators have not been used in this research, because the development phases of cultivated plants are significantly influenced by the great diversity of varieties as well as local, human influenced growing conditions.

Of the autumn phases analyzed in the research, an earlier yellowing of leaves has on average been observed for the linden *Tilia cordata*, but the yellowing of birch leaves has been accepted in the research as the commencement indicator for the phenological autumn, which is the most commonly used and observed autumn indicator (Kuliene and Tomkus, 1990; ulcs (Шульц), 1981). In addition, the yellowing of lindens is often linked with dryness (Ģērmanis, 2003) rather than with the commencement of autumn.

Table.1. **Indicators of the phenological seasons in Latvia after Krauklis un Draveniece, 2004, Ģērmanis, 2003, Sproģe, 1979.**

Season	Sproģe, 1979		Ģērmanis, 2003		Krauklis and Draveniece, 2004	
	Sub-season	**Indicators**	**Sub-season**	**Indicators**	**Sub-season**	**Indicators**
Spring	Period of snow melting	Snow melting	Pre-spring	*Galantis nivalis* BBCH61	Pre-spring	*Alnus incana, Corylus avellana* BBCH61
	Awakening of spring	*Alnus incana, Corylus avellana* BBCH61	Beginning of spring	*Tussilago farfara* BBCH61	Early spring	End of sap rising for *Betula pendula / Tussilago farfara* BBCH61
	Greening	*Betula pendula* BBCH11	Mid-spring	Meadow greening / *Syringa vulgaris* BBCH11	Full spring	*Betula pendula* BBCH11
	N	N	End of spring	*Cerasus, Fragaria vesca* BBCH61	N	N
	N	N	N	N	Pre-summer	BBCH61
Summer	Beginning of summer	*Rosa moyesii* BBCH61 / *Ulmus laevis* seed spreading	Beginning of summer	*Solanum tuberosum* BBCH61	Early summer	Maximum of flowering
	Mid-summer	*Fragaria vesca, Vaccinium myrtillus* BBCH 85	N	N	High summer	*Tilia cordata* BBCH61
	End of summer	*Calluna vulgaris* BBCH61	N	N	Late summer	Fruits` ripening, *Calluna vulgaris* BBCH61
Autumn	Start of autumn	*Betula pendula* BBCH92	Start of autumn	First colouring leaf/ *Sorbus aucuparia* BBCH85/ *Solanum tuberosum* BBCH99	Early autumn	BBCH92/ first frost
	Golden autumn	*Acer platanoides* BBCH92 / first frost	Mid-autumn	BBCH92	Full autumn	BBCH92 / first frost
	End of autumn	Leaf fall 100%	End of autumn	BBCH93	N	N
Winter	N	N	Winter	First snow	Pre-winter	*
	N	N	N	N	Midwinter	*

BBCH11 – leafing; BBCH61 – beginning of flowering, BBCH85 – ripening; BBCH92 – beginning of leaf colouring; BBCH93 – beginning of leaf fall.

The beginning and end, as well as the length of phenological seasons in the 20th century have changed substantially. As indicated by research conducted around the world (IPCC, 2007, Ho *et al*., 2006; Linderhom, 2006; Chen *et al*., 2005; Chmielewski, *et al*., 2004, Aasa *et al*., 2004; Menzel, 2003a; Root *et al*., 2003; Ahas *et al*., 2002; D`Odorico *et al*., 2002; Walther *et al*., 2002; Defila and Clot, 2001; Menzel *et al*., 2001; Beaubien and Freeland, 2000; Menzel, 2000; Roetzer *et al*., 2000; Schwartz and Reiter, 2000; Ahas, 1999, Post and Stenseth, 1999) an earlier commencement time for spring phenological phases can be observed in all of the world's regions. The spring phases, like the beginning of leafing and beginning of flowering in the last 3–5 decades in Europe, have commenced on average 0.12–0.31 days/year earlier, whereas in North America 0.08–0.38 days/year earlier. The autumn phases in Europe, in turn, have commenced later, 0.03–0.26 days/year on the average (Menzel, 2003).

The aim of the study is to define indicators of phenological season in case of Latvia and characterize the variability and changes of the phenological seasons for the 1971–2000 period.

MATERIALS AND METHODS

Particular study is based on voluntary collected phenological data. Phenological data has been digitized from *Dabas un vēstures kalendārs* [Nature and History Calendar] (from 2005's *Daba un vēsture* [Nature and History]).

The number of observation points varies from year to year and there are gaps in the data series as well. Based on the data quality and quantity, data from 15 observation points were selected for this study. Phenological data of the reference period from 1971 till 2000 were analysed.

The phenological dates given refer to day of the year, but phenological phases are in BBCH codes in accordance with the unified European phenological observation guidelines (Koch et al., 2006). The extended BBCH-scale is a system for a uniform coding of phenologically similar growth stages of all mono- and dicotyledonous plant species. The entire developmental cycle of the plants is subdivided into ten clearly recognizable and distinguishable longer-lasting developmental phases (Meier, 1997).

Statistical data processing methods (correlation analysis, single factor linear regression) in the SPSS 19 programme have been used in the data analysis. The non-parametric *Mann-Kendall* test was used for determining long term changes (Libiseller, 2002). The result was considered to be statistically significant if the value of the normalised test statistic was ± 1.96, with $p < 0.05$.

RESULTS AND DISCUSSION

Phenological spring. In the research on the commencement indicators for phenological spring, the beginning of flowering of the hazel *Corylus avellana* is used, because contrary to the circulation of birch *Betula pendula* sap this is a visually observable phase, and data analysis also shows that in the reference period (data from 15 observation points) the beginning of flowering of hazel tree commences before the beginning of the circulation of birch sap. In turn, the commencement of the melting of snow is a debatable indicator in dividing seasons, as often, in the case of Latvia, snow cover develops in a fragmentary way, melts a number of times or doesn't even develop (for example, 1989/1990). The time-series on the beginning of flowering of the coltsfoot *Tussilago farfara* are incomplete, which abnegates the use of this data in the characterization of the phenological seasons in Latvia.

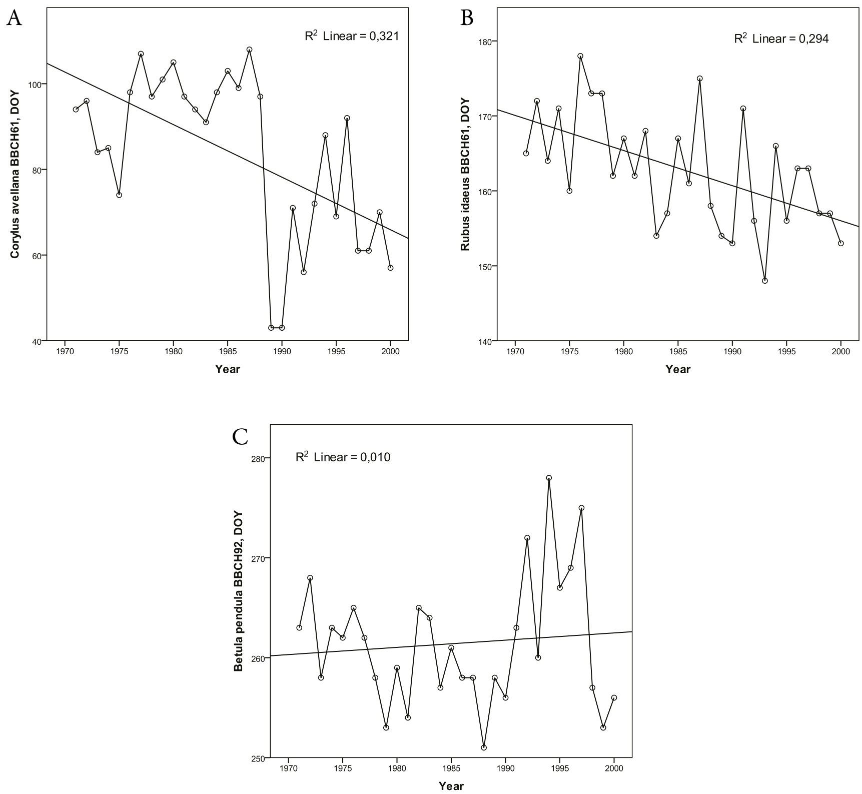

Fig. 1. **Trends of phenological seasons: A, beginning of phenological spring, *Corylus avellana* BBCH61; B, beginning of the phenological summer, *Rubus idaeus* BBCH61; C, beginning of autumn, *Betula pendula* BBCH92.** DOY, day of year; BBCH61, flowering; BBCH92, leaf colouring.

The phenological spring starts in Latvia with the flowering of the hazel (the 24th March on the average) and ends with the beginning of the intensive flowering phase. The beginning of phenological spring has been observed earlier in coastal areas, at Rucava and Nīca, whereas the latest flowering has been observed in northern Latvia (Alūksne) and at Vidzeme highland (Jumurda).

Research data provides evidence that a commencement trend for spring phase is negative, i.e., the flowering of hazel begins earlier (Fig. 1, A.), and the beginning of spring indicator on the average (data from 15 observation points) has changed by 12 days per decade (Table 2.).

Phenological spring commenced at its earliest in 1990 and 1989 when the beginning for hazel was observed 42-45 days earlier then in the period average, i.e. at the beginning of February, in some places even at the end of January. It is important to mention, that the early or first spring phase commencement period varies in much wider amplitude than the spring end or summer phase, and in addition the spring phases have much more characteristic extreme early deviations from the periods' average values, being distinctly early phases (more than 10 days earlier) observed mainly after 1990.

Table. 2. **Statistical description for the phenological seasons (beginning and length of season).**

Season	**Phenological spring**		**Phenological summer**		**Phenological autumn**	
Indicator	**B**	**L**	**B**	**L**	**B**	**L**
Average value	24.03.	78 days	11.06.	99 days	18.09.	43 days
Earliest value (date/ length; year)	12.02. (1989;1990)	59 (1984)	28.05. (1993)	83 (1987)	07.09. (1988)	15 (1992)
Latest value (date/length; year)	18.04. (1987)	112 (1989)	26.06. (1976)	116 (1992)	05.10. (1994)	70 (2000)
Amplitude, in days	67	53	19	33	28	55
SD	19.3	15.5	7.6	8.8	6.4	14.9
r	**-0.57****	**0.38***	**-0.54****	**0.54****	0.09	0.236
MK-t * $p<0.05$, ** $p<0.01$	**-2.50****	1.55	**-2.97****	**2.82****	-0.38	1.44
Slope, days/decade	-12.4	6.7	-4.8	5.4	0.6	4.3

B, beginning of seasons; L, length of season; r, coefficient of correlation; MK-t, *Mann-Kendell* test, in bold – significant values.

It is possible to divide up to three clearly visible sub-seasons in the spring phenological calendar: the beginning of spring (flowering of hazel and grey alder *Alnus incana*, beginning of the circulation of birch sap), middle spring, which is defined by the wide scale appearance of leaves, and the end of spring, characterized by the flowering of lilacs *Syringa vulgaris* and rowan trees *Sorbus aucuparia*. The suggestion of A. Ģērmanis (2003) for designations of sub-seasons like "beginning", "end" and "middle" is followed in the study. The often used terms for sub-seasons like „early" and „late" can cause confusion, e.g. calling the beginning of spring "early spring", it is unclear, if this means that spring is early (the phase has commenced early) or whether it is the beginning of spring.

Phenological summer. The commencement of the flowering of the wild raspberry has been accepted as the indicator of the phenological summer, which is observed in Latvia (data from 14 places) on the 11th June on the average.

As in case of the spring phase, flowering of raspberry begins earlier and phenological trend is significantly negative (Fig. 1. B). Beginning of flowering of wild raspberry has changed by 4.8 days per decade.

Some authors are dividing sub-seasons for phenological summer, but in the opinion of the author, a more detailed subdivision of the phenological summer season is not required, because as opposed to the spring phenological calendar, clear sub-seasons do not appear during summer and relatively few phenological phases are recorded.

Phenological autumn. Of the autumn phases analyzed in the research, an earlier yellowing of leaves has on the average been observed for the linden, but the yellowing of birch leaves has been accepted in the research as the commencement indicator for the phenological autumn, which is the most commonly used and observed autumn indicator (Kuliene and Tomkus, 1990; ulcs (Шульц), 1981). The beginning of leaf colouring of birch most common fixed on 18th of September in Latvia (Table 2.). Opposite to summer and spring phases, trend of autumn phase is neutral: colouring of leaves didn't change in the observed period (Fig. 1 C). It is important to mention, that there are significant local differences in timing of phenological phase, for example, at Barkava colouring of birch leaves started earlier, but at Dagda – later (r values are statistically significant). As noted by A. Menzel (2003) the autumn phenological phases had a heterogeneous character and data from nearby stations/observation points often showed an opposite trend. K. Ramans too (1958) indicated that in Latvia, in the Vidzeme highland, the autumn phenological phases differed markedly between observation points, which was explained by micro-climatic differences.

Length of the seasons. The length of the phenological spring (from the beginning of hazelnut flowering until the commencement of the phenological summer, which is signified by the flowering of the wild raspberry) in Latvia in the 30 year reference period is 78 days, while the phenological summer lasts 99 days and is the second longest season after winter (Fig. 2 A).

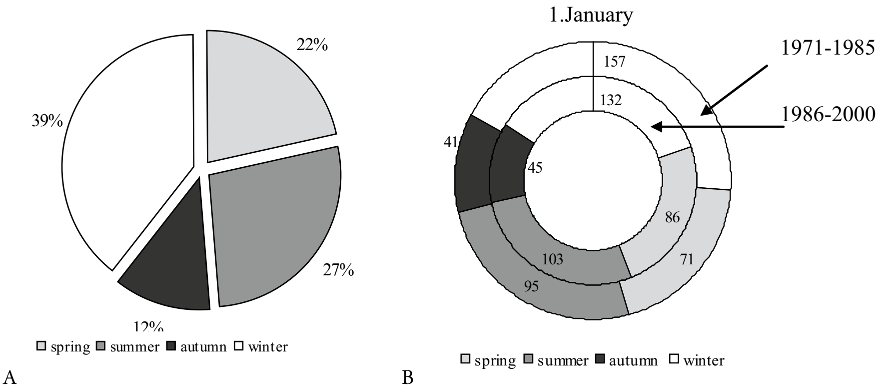

Fig. 2. **A, percentage of the length (in days) of phenological seasons. B, changes in the length of the phenological seasons (in days), 1971-1985 and 1986-2000.**

The length of the phenological autumn (the period from the commencement of birch leaf colouring until the first snow) in the territory of Latvia is on average 43 days with large regional differences.

The length of the phenological season, as well as the commencement time in the analyzed period has changed significantly (Fig. 2 B). The average length of the phenological spring in the period 1971–1985 was 71 days, while in the period from 1986–2000 the length of the phenological spring was 86 days. The length of the phenological spring in the reference period has changed significantly, i.e., increased in length, on the average by 6.2 days/decade, mainly due to the earlier commencement of spring (the trend for the commencement of the flowering of hazel tree is negative and the phase commences –1.2 days earlier each year, on the average). If the phenological spring commences early, then the phenological summer also commences earlier (Fig. 3 A), plus, when there's an early spring, the season is relatively long. Late springs are shorter than the early ones, which indicates that the development of plants takes place faster, as described by A. Aasa (2005), F.E. Šulcs (Шульц, 1981) and K. Ramans (1958).

Overall, the length of the phenological summer in the territory of Latvia is 99 days, and the length of summer trend is positive, which means that the length of the phenological summer is increasing. The length of the phenological summer has changed by 8 days.

The length of the phenological autumn in Latvia is 43 days, from 18th September (data from 14 observation points), when the colouring of birch leaves has been recorded until 31st October, when, on the average, the first snow cover is observed, which is considered to be the indicator of the phenological winter. Taking into account the large spatial and annual changeability of the appearance of the first snow, the first snow does not qualitatively characterize the season's end, and consequently the length of the phenological autumn season. For example, one could consider that in 1989 the phenological autumn did not end, as in places the first snow cover did not developed. It is more useful to use the leaf fall as the indicator for the end of the phenological autumn, as indicated by L. Kuliene and J. Tomkus (1990), F. E. Šulcs (Шульц,1981), R. Ahas and A. Aasa (2006). Unfortunately the end of the leaf fall does not get recorded in traditional observations in Latvia, and consequently it's not possible to use this indicator. However, it would be useful to include this in a phenological observation plan.

The length of the autumn season has increased by 4 days. The most significant changes have been established in the length of the phenological winter. In the first sub-period, the length of the phenological winter was 157 days, whereas in the second period 132 days, i.e., a decrease of 25 days, which is connected with the earlier commencement of spring and the later appearance of the first snow.

The length of the season (in days) interconnection analysis shows that the length and the commencement time of the phenological spring and summer seasons are well correlated: when the spring commences early, then the phenological summer also commences earlier on the average (Fig. 3 B).

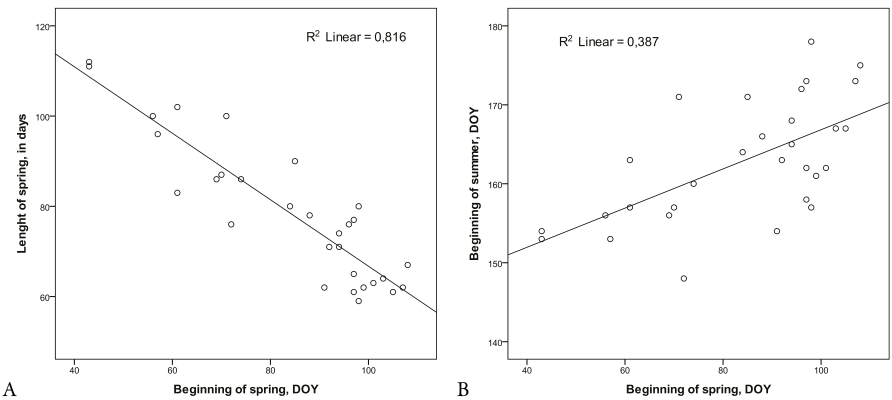

Fig. 3. **A, interconnection between the beginning of spring (DOY) and the length of phenological spring (in days); B, interconnection between the beginning of phenological spring and phenological summer.**
DOY, day of year.

If the spring is long, then the length of the summer season also tends to be extended. The research undertaken confirms that the beginning of the autumn and its length are not dependent on the length and commencement time of previous phenological season.

CONCLUSIONS

Latvia's location in a humid continental climate zone determines the phenological seasonality which can be seen here. Indicators of phenological seasons as well as the number of seasons and name of season vary from region to region; there aren't unified methods and indicators for dividing the seasons. It is suggested that the following phases for plant species be used as phenological season indicators in case of Latvia: the beginning of flowering of the hazel *Corylus avellana* for the phenological spring, the beginning of flowering of the wild raspberry *Rubus idaeus* as the indicator for the commencement of summer and to accept the commencement of leaf colouring of the birch *Betula pendula* as the commencement of the phenological autumn. Up till now the first snow cover was used as the indicator for the commencement of the phenological winter, but it would be more useful to replace this with the end of the leaf fall.

Studies over the world suggested, that the beginning and end, as well as the length of phenological seasons have changed substantially in the 20th century. The length of phenological spring, summer and autumn in Latvia in the reference period is increasing, but winter – decreasing. Length of spring has changed on the average by 6.7 days/decade, mainly due to the earlier commencement of spring, the length of phenological summer changed by 5.4 days, autumn by 4.3 days. The most significant changes have been established in the length of the phenological winter due to earlier commencement of spring and the later appearance of the first snow.

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Changes in Climate and Discharge Regime in Latvia at the End of the 21st Century

Inese Latkovska[1], Elga Apsīte[1], Līga Kurpniece[1] and Didzis Elferts[2]
[1] University of Latvia, Faculty of Geography and Earth Sciences,
Raiņa bulv. 19, Rīga LV-1586, Latvia, E-mail: inesepallo@inbox.lv
[2] University of Latvia, Faculty of Biology,
Kronvalda bulv. 4, Rīga, LV-1586, Latvia

Abstract
The hydrological model HBV was applied to 10 river basins and sub-basins in Latvia to assess climate change impacts on river discharge regime at the end of the 21st century. Climate change was predicted by the regional climate model RCAO with driving boundary conditions from the global general circulation model HadAM3H applied for the IPCC scenarios A2 and B2 and time periods: 1961–1990 (control) and 2071–2100 (scenario). Major changes in hydro-climate data in the future were predicted according to A2 scenario, where trends of increase are identified for the annual mean air temperature by 4 °C, precipitation by 12% and evapotranspiration by 21%, while river discharge will decrease by 15%. Both scenarios predict changes in the seasonal discharge regime where the major part will be generated in winter, followed by spring, autumn and summer. Maximum river discharge will occur in winter instead of spring. Two discharge periods instead of 4 will be distinguished in the Latvian river hydrograph.

Key words: hydrological model, climate change, river discharge, scenario.

INTRODUCTION

During recent decades, considerable attention has been paid to the studies of global climate change impact on the hydrological cycle, to evaluate and predict the changes in water resources at various spatial and temporal scales, including the Baltic region. In the study by Bolle *et al.* (2008) it was forecasted that at the end of the 21st century in the Baltic Sea basin the southern areas will get drier and the northern parts will become wetter which will determine river runoff patterns: decrease in annual river runoff in the South and increase in the North. The Baltic countries, including Latvia, are situated in the middle of both regions and no significant changes in the river runoff should be expected. Besides, in the Graham (2004) study a borderline was distinguished in the territory of Latvia, where increase of the annual mean discharge was forecasted in the north, east and partly central and western river basins of Latvia and decrease of the annual mean discharge was forecasted in the rest of river basins. Dankers *et al.* (2007) have found stronger increase in annual river runoff of the western part of Latvia than in others. However, on the basis of the latest studies in Latvia by Rogozova (2006), Bethers and Seņņikovs (2009) and Apsite *et al.* (2011) the main tendency in the future climate and river runoff change is shifted rather towards the southern region forecast of the Baltic Sea basin. This leads to intensification of the hydrological cycle with more precipitation and evapotranspiration under warmer and wetter climate and decrease in annual river runoff during this century.

The aim of this study is to analyse and discuss the following: the calibration results of the hydrological model; changes in the mean annual, seasonal, monthly and extreme river discharge and climate data; and compare results to other studies in Latvia.

MATERIALS AND METHODS

Studied river basins

The study focuses on 6 river basins and 4 sub-basins of the Salaca basin. Locations and characteristics are presented in Fig. 1 and Table 1.

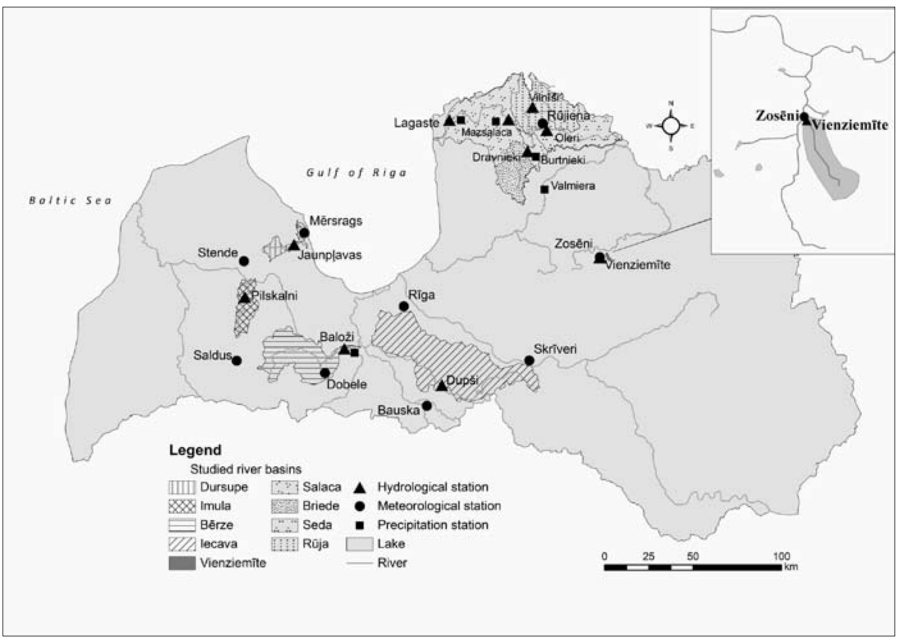

Fig. 1. **Location of river basins and hydrological, meteorological and precipitation stations used in the study**

Table 1 . **Characteristics of studied river basins**

River basins	Imula-Pilskalni	Dursupe-Jaunpļavas	Bērze-Baloži	Iecava-Dupši	Vienziemīte-Vienziemīte	Salaca-Lagaste	Salaca-Mazsalaca	Rūja-Vilnīši	Seda-Oleri	Briede-Dravnieki
Total drainage area, km²	263	138	904	1166	5.92	3420	3420	962	542	449
Studied drainage area, km²	207	138	904	519	5.92	3220	2260	729	431	369
Forests, %	47	59	31	63	14	46	37	40	36	53
Lakes, %	0.20	0	0.9	5.6	0	9	10	5	1	1.2
Agricultural lands, %	53	41	68	31	86	46	53	55	63	46

The river basins differ in size and natural conditions. According to the classification by Glazacheva (Глазачева 1980), the river basins Dursupe and Imula are located in Western hydrological district; the Bērze and Iecava in the Central; the Vienziemīte and Salaca with sub-basins the Mazsalaca, Briede, Seda and Rūja – in the Northern district. The Salaca River basin is the largest studied basin with the total drainage area 3220 km^2, of which 62% are occupied by the catchment of the lake Burtnieks. Forests cover 46% and lakes account for up to 9% of the territory. The Vienziemīte Brook is the smallest studied catchment. It is located in the Vidzeme Upland, 180 m above the sea level. The streams Vienziemīte, Imula and partly Bērze can be characterised as upland and the others as lowland rivers.

The hydrological model HBV

The HBV is a semi-distributed conceptual rainfall-runoff hydrological model by S. Bergström (1976), developed in Swedish Meteorological Institute. The model is a widely used tool in Europe and other countries, including also Latvia, for simulation of hydrological processes in water catchments with a daily step. The model usually is simple and relatively easy to use. The required input meteorological and hydrological data are readily available for most applications. The model consists of subroutines for snow accumulation and melt, soil moisture accounting procedure, routines for runoff generation and finally, a simple routing procedure (IHMS 2008).

A statistical criterion R^2 (Nash and Sutcliffe 1970), mean values and a graphical representation were used in the analysis of the model calibration results. The efficiency criterion R^2 measures the proportion of the total variance of the observed data explained by the predicted data. Nash–Sutcliffe efficiencies can range from −∞ to 1. A perfect model would result in R^2 equal to 1. However, normally R^2 ends up somewhere between 0.8 and 0.95. Naturally, this is only the case when there are good quality input data. A more detailed description of the model HBV is presented in other sources (Bergström 1992; IHMS 2008).

Input data used for the hydrological model and statistical methods

The input data for the HBV model calibration and validation, daily measurements of air temperature (°C) and precipitation (mm) at 9 meteorological stations and precipitation (mm) at 5 stations, and long-term monthly average values of evaporation (mm) at 2 stations (Ķemeri and Zosēni) as well as daily river discharge (m^3/s) at 10 hydrological stations were used. The location of the utilised meteorological and hydrological stations is shown in Figure 1. All data were obtained from the Latvian Environment, Geology and Meteorology Centre and VSIA „Meliorprojekts". In this study, the selected calibration period was from 1961 to 1990, and the proceeding ten years from 1991 to 2000 was the validation period. The period of 1961-1990 was chosen because it could be conditionally described as a period with no considerable changes in hydro-meteorological data series observed. This fact was confirmed by the World Meteorological organization (http://www.wmo.int/pages/prog/wcp/wcdmp/GCDS_1.php). Besides, the calibration period covers five wettest (1962, 1978, 1980, 1981 and 1990) and three driest (1964, 1969 and 1976) years in Latvia over last hundred years. This is a good opportunity to perform the hydrological simulation as it allows model parameters to respond to extreme values in the process of simulation of future climate scenarios.

We used climate data series (daily temperature and precipitation) as the input data for the hydrological model developed by a separate study (Seņņikovs and Bethers, 2009) of the national research program Climate Change Impact on Water Environment in Latvia. Therefore, climate changes are predicted by the regional climate model (RCM) Rossby Centre Atmosphere Ocean (RCAO) with driving boundary conditions from the global general circulation model (GCM) HadAM3H applied for the two IPCC scenarios A2 and B2. The climate scenario A2 is a high emission scenario compared to B2, and it was chosen for this study to illustrate the worst case scenarios (Nakicenovic *et al.* 2000). Full description of the applied downscaling methodology can be found in Seņņikovs and Bethers (2009). The calculated data series indicated the following: CTL represents the control period 1961–1990 and characterises contemporary climate conditions, while A2 and B2 represent the period of future scenarios 2071–2100 and forecast future climate conditions. All data series were interpolated from the grid cross points to the meteorological stations involved in our study.

The T-test at the significance level $p < 0.05$ (Sokal and Rohlf 1995) was used to compare mean annual, seasonal and monthly values of the mean and maximum discharge, the mean temperature, evapotranspiration and amount of precipitation between the control and scenario run of the 30 years period. The confidence intervals of 95% were calculated for the hydro-climate data values using the Student's t-distribution.

RESULTS AND DISCUSSION

Calibration and validation of the hydrological model

The conceptual hydrological model HBV was calibrated (1961–1990) and validated (1991–2000) for 10 studied river basins and sub-basins (Fig. 1). The calibration results present a good fit between the observed and simulated daily discharges where statistical criterion R^2 values vary from 0.69 to 0.82 (Table 2).

Table 2 **The obtained statistical criteria for studied river basins**

Station	Calibration period (1961-1990)	Validation period (1991 – 2000)
	R^2	R^2
Imula-Pilskalni[4)]	0.78	0.75
Bērze-Baloži	0.82	0.80
Iecava-Dupši[4)]	0.72	0.72
Dursupe – Jaunpļavas[3)]	0.74	0.69
Vienziemīte-Vienziemīte	0.77	0.70
Salaca – Lagaste	0.80	0.71
Salaca - Mazsalaca	0.78	0.72
Rūja – Vilnīši [1)]	0.74	0.79
Briede – Dravnieki	0.69	0.60
Seda – Oleri [2)]	0.70	0.76

Operating since: [1)]1978; [2)]1979; [3)] 1980; [4)] Closed since 1995

The best coincidence was obtained for the river basins Bērze at Baloži and Salaca at Lagaste (Fig. 2).

The lowest statistical criteria values were found for the river Briede at Dravnieki and Seda at Oleri. The validation results (the values of R^2 vary from 0.60 to 0.80) show that the model HBV responds well in simulation of hydrological process using meteorological observation data.

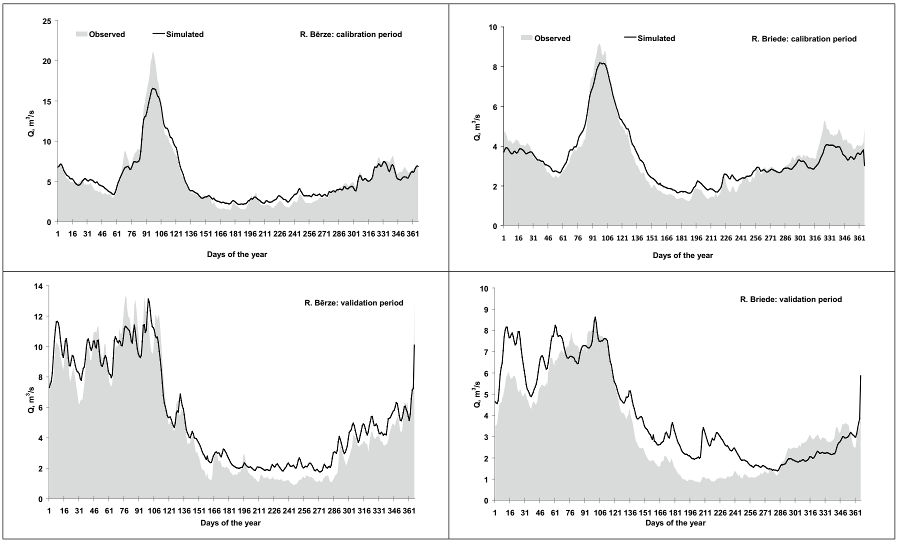

Fig. 2. **Observed and simulated long-term mean daily discharge of the rivers Bērze and Briede for the calibration (1961–1990) and the validation (1991-2000) periods**

One of the main reasons for the difference between the observed and simulated discharge values is the number and location of the used meteorological stations characterising the spatial and temporal distribution of precipitation and air temperature in the studied river catchments. In a case of the rivers Bērze and Salaca at Lagaste, where more meteorological stations were involved, we have obtained better results of the model calibration and validation. Therefore, the parameter values of model can better fit to climatic conditions and simulate hydro-climatic processes of catchment. The data quality is another important reason. Generally, the results of homogeneity analysis for input precipitation data were good. However, we suppose in some cases the quality of precipitation data could be better.

Having analysed the calibration results of the HBV model of this study and the METQ2007BDOPT model by Apsite *et al.* (2011) to the same river basins, generally, we have obtained a little better calibration results with the HBV for the rivers Imula, Bērze, Iecava, Rūja and Seda; the results are the same for the Briede and Salaca; and the result is lower for the Vienziemīte. However, for both hydrological models one of the drawbacks of calibrating a daily model based upon observations is that the resulting hydrographs tend to be somewhat smoothed, as runoff peaks are dampened in the model, while low flows tend to be overestimated.

Changes in climate data

Results of changes in climate data as differences between the scenario and CTL periods are summarised in Tables 3, 4 and 5.

In the studied river basins the major significant changes in meteorological parameters are forecasted according to A2 scenario, where the annual mean air temperature will increase by 3.9–4.1 °C, precipitation by 9–12% and evapotranspiration by 22–28%. Less pronounced changes in climate parameters are identified according to B2 scenario. The increase trend is predicted for all meteorological parameters, but statistically significant trend is validated for temperature (by 2.5–2.7 °C) and evapotranspiration (by 15–21%), and in only two river basins (Dursupe and Salaca) for precipitation (by 10%).

The seasonal analysis of mean air temperature show statistically significant increase in all seasons, but the most significant increase is forecasted for winter (December, January and February) and autumn (September, October and November) seasons, by 4.5–4.9 °C and 4.0–4.1 °C according to A2, and by 2.9–3.4 °C and 2.9–3.3 °C according to B2, respectively. At the same time the smallest change in temperature is predicted for summer (June, July and August) by 3.0–3.6 °C according to A2 and by 1.3–1.9 °C according to B2, respectively.

For both scenarios A2 and B2 the following trends have been identified in the precipitation and evapotranspiration data series: increase in the first half of the year, and decrease in the second half of the year. A statistically significant increase in precipitation is predicted during the winter season for all studied river basins by 49–71% according to A2 and by 29–39% according to B2, while in other seasons the forecasted increase/decrease trends are not significant. The changes of evapotranspiration in annual cycle and seasonality are more linked to the air temperature. Therefore, the statistically significant increase in evapotranspiration for both scenarios is observed for winter, followed by spring and autumn as well, and no considerable change is forecasted for summer.

For both scenarios, no considerable changes in variation of climate time series among the studied Salaca river sub-basins were identified. Therefore, climate data are presented for the entire river basin. In other cases, the changes in climate data vary among studied river basins, but the differences are comparatively small. However, higher changes in temperature and evaporation values are identified for the rivers Vienziemīte and Salaca located in the Northern hydrological district and higher change in amount of precipitation is predicted for the Imula, Dursupe and Bērze rivers located in the Western and Central districts.

Changes in river discharge

It is a generally known fact that the changes of river discharge regime are determined mainly by climate changes. Therefore, simulation results of the hydrological model HBV showed that the river discharge regime will change according to both scenarios (Fig. 3).

Table 3 **Annual and monthly mean values for temperature. CTL (in °C); all changes of A2 and B2 (in °C) are calculated as differences between the scenario and control periods and statistically significant at $p < 0.05$, except 2 cases with ***

River basin	Bērze			Iecava			Imula			Dursupe			Vienziemīte			Salaca		
Control /Scenario	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**
Annual	5.6	3.9	2.5	5.7	4.0	2.6	5.8	4.1	2.7	5.7	3.9	2.6	4.7	4.1	2.7	5.2	4.0	2.7
Jan	-5.2	5.2	3.6	-5.8	5.6	3.6	-4.6	5.1	3.4	-4.4	5	3.3	-6.8	5.6	3.7	-6.3	5.6	3.8
Feb	-5	3.6	2.7	-5.2	3.8	3	-4.5	3.5	2.6	-4.5	3.4	2.6	-6.4	3.8	3.1	-5.8	3.7	3.1
Mar	-1.4	3.6	2.6	-1.2	3.9	3.2	-1	3.6	2.6	-1.3	3.6	2.8	-2.4	4	3.4	-1.8	4	3.3
Apr	4.6	3.9	2.6	5.3	3.9	3	4.7	4.3	3	4	3.8	2.8	4.1	4.2	3.2	4.4	4.1	3.2
May	11.1	4.1	2.1	11.9	4.2	2.5	11.1	4.7	2.7	10.2	4.2	2.6	10.9	4.3	2.5	11.2	4.3	2.5
Jun	14.8	2.3	1*	15.5	2.3	1.1	14.8	2.8	1.5	14.5	2.8	1.4	14.5	2.4	1.1	15	2.5	1.2
Jul	16.3	3.2	0.8	16.8	3.3	1	16.3	3.7	1.3	16.2	3.4	1.2	16	3.2	0.8	16.5	3.1	0.7*
Aug	15.5	3.7	2.5	15.8	3.8	2.5	15.5	4.3	3	15.6	3.7	2.4	14.8	3.8	2.4	15.3	3.5	2.2
Sep	11.1	4.3	3.3	11.3	4.3	3	11.4	4.5	3.5	11.5	4.2	3	10.3	4.3	3	10.7	4.1	2.9
Oct	6.5	4.1	3.2	6.5	4.3	3	6.9	4.2	3.2	7	4.1	2.9	5.6	4.4	3.1	6	4.1	2.9
Nov	1.4	3.7	3.1	1.3	3.6	2.8	1.8	3.7	3.2	2.1	3.6	2.8	0.3	3.7	2.9	0.8	3.9	2.9
Dec	-2.7	4.9	2.9	-3.3	5.2	3	-2.3	5	2.9	-2	4.8	2.9	-4.3	5.2	3.1	-3.8	5.3	3.2

Table 4 **Annual and monthly mean values for amount of precipitation. CTL (in mm); changes of A2 and B2 (in %) are calculated as differences between the scenario control periods scenarios, statistically significant * $p < 0.05$**

River basin	Bērze			Iecava			Imula			Dursupe			Vienziemīte			Salaca		
Control /Scenario	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**
Annual	561	12*	8	589	9*	6	621	11*	8	568	12*	10*	751	10*	6	671	12*	10*
Jan	31	96*	31*	37	72*	17	37	90*	32*	30	99*	33*	50	67*	18	38	85*	28
Feb	24	68*	56*	27	55*	46*	27	64*	54*	22	68*	56*	36	51*	46*	27	50*	46*
Mar	28	21	14	32	6	3	33	22	12	27	18	11	39	8	4	30	13	4
Apr	37	-9	8	37	-2	4	37	-11	9	33	-7	10	46	3	8	34	0	6

May	39	30	4	44	29	12	38	33*	3	38	14	-2	54	33	9	46	21	16
Jun	48	24	30	56	22	23	52	22	28	47	24	33	64	33*	34*	61	33*	37*
Jul	75	-13	-8	69	-8	-2	81	-17	-13	75	-7	0	88	-11	-6	85	-10	-1
Aug	71	-19	-11	66	-14	-13	74	-23	-10	68	-10	-3	92	-14	-13	84	-5	-2
Sep	58	-24	-10	62	-23	-12	64	-23	-9	67	-22	-8	78	-20	-12	78	-21	-6
Oct	52	6	-6	54	-4	-12	61	7	-4	57	8	-1	69	-1	-10	67	5	-8
Nov	56	8	15	56	2	8	65	9	16	59	10	14	72	2	6	67	11	9
Dec	45	50*	31*	51	33*	23*	54	44*	29*	47	43*	29*	65	28*	23*	53	35*	27*

Table 5 **Annual and monthly mean values for evapotranspiration. CTL (in mm); changes of A2 and B2 (in %) are calculated as differences between the scenario control periods scenarios, statistically not significant * $p < 0.05$**

River basin	**Bērze**			**Iecava**			**Imula**			**Dursupe**			**Vienziemīte**			**Salaca**		
Control /Scenario	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**	**CTL**	**A2**	**B2**
Annual	12.3	22	16	11.9	22	14	11.9	25	17	11.9	25	17	14.3	28	21	13.9	26	16
Jan	0.04	396	148	0.03	661	281	0.04	420	160	0.04	354	127	0.01	957	957	0.03	677	288
Feb	0.13	297	138	0.10	397	198	0.12	318	151	0.13	283	130	0.04	741	460	0.03	245	245
Mar	0.47	195	132	0.45	252	164	0.46	223	137	0.44	198	130	0.24	440	316	0.10	309	207
Apr	1.64	52	40	1.88	33	33	1.56	60	47	1.42	62	48	1.47	104	84	0.81	98	73
May	2.51	4*	4*	2.44	-10*	-10	2.36	6*	2*	2.36	10	6*	3.10	16	10	2.55	18	10
Jun	2.44	-6*	-6*	2.10	0*	-5*	2.28	-4*	-4*	2.46	-2*	-6*	3.27	-5*	-5*	2.64	6	2*
Jul	1.95	-3*	-3*	1.81	-1*	-1*	1.92	-1*	-1*	1.97	-3*	2*	2.53	-1*	-1*	2.54	6	2*
Aug	1.57	2*	8*	1.47	2*	2*	1.57	-5*	8*	1.56	3*	9*	1.92	4*	4*	2.26	6*	6*
Sep	0.96	4*	14	0.97	14*	14*	0.99	11*	11	0.97	14	14	1.12	16	16	1.59	19	13
Oct	0.44	36	36	0.48	24	24	0.47	28	28	0.46	31	31	0.48	47	26	0.97	35	14
Nov	0.10	108	108	0.11	85	85	0.1	98	98	0.10	95	95	0.08	154	154	0.34	107	77
Dec	0.04	370	135	0.04	412	156	0.04	353	127	0.05	318	109	0.02	404	404	0.07	446	173

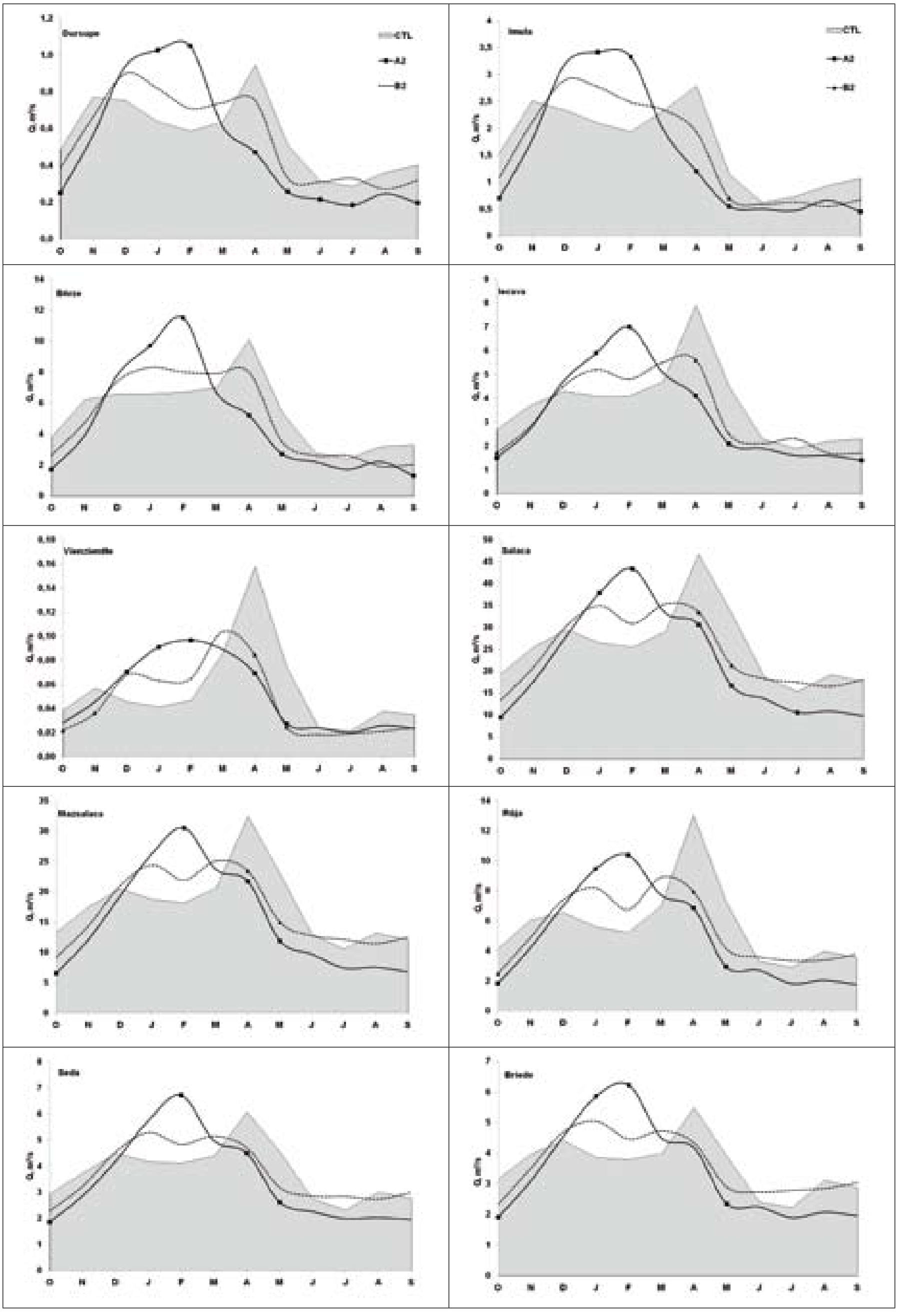

Fig. 3. **River hydrograph of a hydrological year from October to September for the control (CTL) and 2 scenario (A2 and B2) periods in studied river basins and sub-basins. The black triangles and squares for the respective scenarios indicate statistically significant changes in the monthly mean value of the parameter**

The major changes are predicted according to A2 scenario in both annual and seasonal analyses. The mean annual discharge is predicted to decrease by 8–15% according to A2 and by 4–10% according to B2 scenario. However, statistically significant decrease (by 8% according to B2) is maintained only for the Vienziemīte River.

As it can be seen in Fig. 3, the major changes in seasonal river discharge were identified between winter and spring streamflows scenarios. In winter, due to warmer and wetter climate, the river discharge is predicted to increase by 30–93% according to A2 (applicable to all river basins) and by 15–46% according to B2 (applicable only to the rivers Vienziemīte and Imula), followed by a decrease in spring streamflow by 18–42% according to A2 (applicable to all river basins, except the Briede) and by 11–33% according to B2 (applicable only to the rivers Vienziemīte, Rūja and Iecava). The highest increase in discharge is forecasted for January and February, and the highest decrease is predicted for April and May. According to the forecasts of climate changes in the second part of the year, in most cases the river discharge is predicted to decrease according to both scenarios. However, more considerable changes in streamflow are predicted for the autumn season (especially for September and October) and according to A2 scenario (by 26–48%).

Similar changes in seasonal mean maximum discharge are forecasted (Fig. 4).

Also, the major considerable changes are predicted according to A2 scenario where the maximum discharge will increase by 24–45% in winter, and decrease by 14–44% in spring and by 16–39% in autumn.

Figures 3 and 4 show the predicted changes in river hydrograph of the monthly mean and mean maximum discharges. It is likely that in future two main periods instead of four will be distinguished in the river hydrograph, a high flow from November to April and low flow from May to October. In such cases the typical autumn discharge peaks will disappear, but the spring discharge peaks will shift to an earlier time, i.e. to February according to A2 and mostly to December or March according to B2 scenario. This means that the winter low flow period will disappear, and the summer flow period will be longer depending on the scenario.

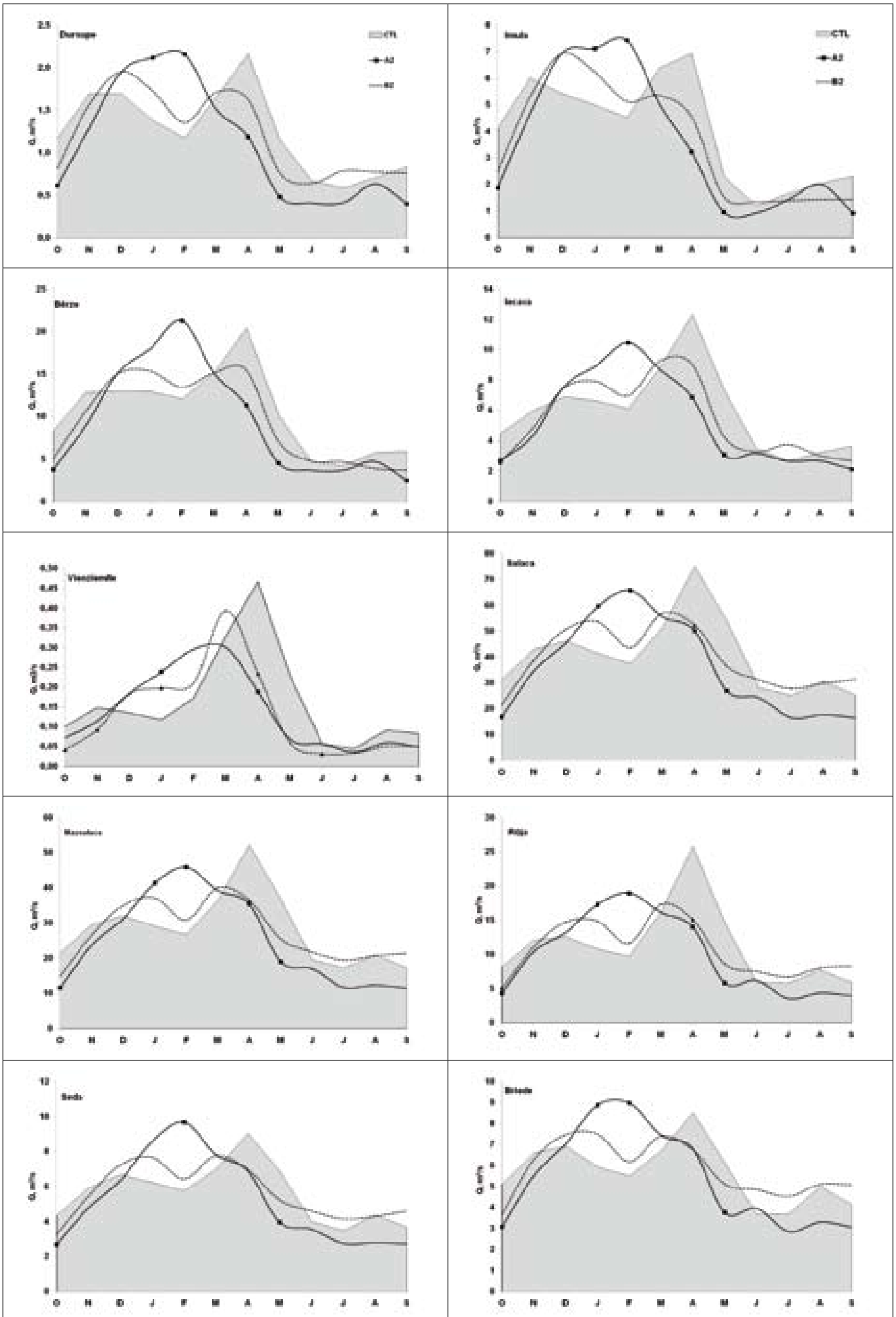

Fig. 4. **Changes in the mean maximum discharge of a hydrological year for the control (CTL) and 2 scenario (A2 and B2) periods in studied river basins and sub-basins. The black triangles and squares for the respective scenarios indicate statistically significant changes in the monthly mean value of the parameter**

Comparison to other studies in Latvia

To compare the results of our studies to other studies in Latvia we have been searching for similar studies dealing with predicted changes in river discharge regime which were based on the climate data series taken from the used RCM RCAO. In the study by Rogozova (2006) for two river basins, the Irbe and the Gauja, the climate data series were based on the RCM RCAO using two different GCMs and emission scenarios (A2, B2) and the hydrological model HBV. She has identified both increase (ranging from +15% to +17% in case of using GCM ECHAM4/OPYC3) and decrease (ranging from –7% to –2% in case of using GCM HadAM3H) trends in annual river runoff. It was concluded that prediction of runoff changes may depend on the chosen GCM and emission scenario in RCM RCAO.

In both studies by Bethers and Seņņikovs (2009) and Apsite *et al.* (2011) the prediction of streamflow changes and the used climate data series were based on the RCM RCAO deriving from GCM HadAM3H and different emission scenarios (A2, B2). In the study by Bethers and Seņņikovs (2009) changes in river discharge regime were predicted with the hydrological model "MIKE Basin" for 4 river basins (Abava, Bērze, Salaca and Dubna) and using only one emission scenario A2. They have concluded that there will be decrease in both the annual river runoff (but not more than by 25%) and maximum monthly discharge (but not more than by 20%), and the regional differences in streamflow will disappear or become smoother.

More detailed analyses of changes in hydro-climate parameters are provided by Apsite *et al.* (2011) for the same river basins as were used in this study, except the river Dursupe, and climate data series involved in our study. The hydrological modelling was performed with the model METQ2007BDOPT which, like the model HBV, belongs to the group of conceptual rainfall-runoff models. Generally, we have detected the same trends in hydro-climate data in both annual and seasonal analysis, and regional peculiarities as well. However, there are scattered instances which do not agree with our study results. In study by Apsite *et al.* (2011) higher values of increasing annual evapotranspiration (in particular, by 37–41– % according to A2 and 20–24% according to B2, respectively) and the most considerable changes in the second half of a year – in summer and autumn – were predicted. It could be explained by the fact that in the studies there were different approaches to the calculation of evapotranspiration data series and the structure of used hydrological models, i.e. the HBV and the METQ2007BDOPT, themselves were performed. Also this fact could explain a little higher percentage in predicted reduction of annual (some seasonality as well) river discharge by Apsite *et al.* (2011), i.e. 13 to 24% according to A2 and by 2 to 11% according to B2 scenario. Contrary to our study results, no change according to A2 and insignificant increase by 10% according to B2 in mean annual runoff for the Bērze River was identified.

In all studies mentioned above it was predicted that the increase of river runoff will be remarkable during winter seasons due to the shortening of the period with snow and ice cover, while the spring runoff maximum will mostly decrease and shift to earlier periods. However, there are different predictions concerning the total annual river runoff, where the decrease of runoff is predicted in all studies, except by Rogozova (2006) in case of using GCM ECHAM4/OPYC3 in the RCM RCAO and Apsite *et al.* (2011) for the Bērze river basin, and these results comply with the results of our study.

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Response of Scots Pine Radial Growth to Past and Future Climate Change in Latvia

Didzis Elferts[1], Āris Jansons[2]
[1]University of Latvia, Faculty of Biology,
Kronvalda bulv. 4, Riga, Latvia, LV-1586,
e-mail: didzis.elferts@lu.lv
[2]Latvian State Forest Research Institute "Silava",
Rigas str. 111, Salaspils, Latvia, LV-2169,
e-mail: aris.jansons@silava.lv

Abstract
Climatic conditions in the world are changing and these changes will affect growth of trees. The study was carried out in ten sampling sites across Latvia to determine the relationships between climatic variables (mean monthly air temperature and precipitation amount) and radial growth of Scots pine. Response of radial growth to the precipitation amount is very low and determined by local factors, but the mean air temperatures in winter months have a significant positive relation that is regional in character. The predicted increase of winter temperatures will probably cause loss of sensitivity of pine to winter temperatures, but an increasing effect of precipitation amount may occur. In the future in Latvia, Scots pine may switch from a temperature-limited to precipitation-limited species.

Keywords: *Pinus sylvestris*, dendroclimatology, tree rings

INTRODUCTION

During the last fifty years a rapid increase of air temperatures and also precipitation amount has been observed in Europe (IPCC 2007) and on a regional level also in Latvia (Briede and Lizuma 2007; Lizuma et al. 2007). The scientific forecasts suggest that mean air temperatures in Europe will continue to increase and these changes are expected to have an effect on ecosystems and organisms and their possibilities to adapt to a changing environment (IPCC 2007). Changes in response of trees to climatic factors have already been observed (Linderholm et al. 2002; Linderholm et al. 2003) and large-scale dieback of trees has become a significant problem in many regions. For example, temperature increase induced droughts in south-western North America and die-off of piñon pine (*Pinus edulis*) have been observed (Breshears et al. 2005).

Climate changes also can have indirect effect on trees, for example, by creating more suitable conditions for fungi development (Thor et al. 2005), insect outbreaks (Theurillat and Guisan 2001), or spread of pests to new territories (Jepsen et al. 2008).

One of the unique sources of proxy data for information about changes in the environment are tree rings. Changes in environmental conditions cause a change in tree ring width, creating a "picture" of tree-ring width series for the time period when the tree-rings were formed (Schweingruber 1996; Vaganov et al. 2006). The growth of trees is influenced by both internal and external factors. A relatively large part of variability in tree-ring width can be explained by climate (Fritts 2001). Tree growth response to environmental conditions can be at a local and a regional scale (Desplanque et al. 1999).

Scots pine (*Pinus sylvestris* L.) tree-rings have been successfully used in dendroclimatological studies for many years throughout the Europe: in Latvia (palte 1975; Elferts 2007), Lithuania (Vitas 2004), Estonia (Läänelaid and Eckstein, 2003), Poland (Cedro 2001), Scandinavia (Linderholm 2001; Linderholm et al. 2002) and other countries. Pine has wide ecological amplitude and it can occur in different habitats: in dune forests, in dry forests with moss dominated vegetation, in wet forests and in bogs. The ecology of Scots pine is largely characterized by stress tolerance (Zackrisson 1977; Kelly and Connolly 2000).

The aim of the study is to determine relationships between the climatic variables (mean monthly temperature and precipitation amount) and Scots pine radial growth and to forecast future growth of Scots pines in the context of climate change in Latvia.

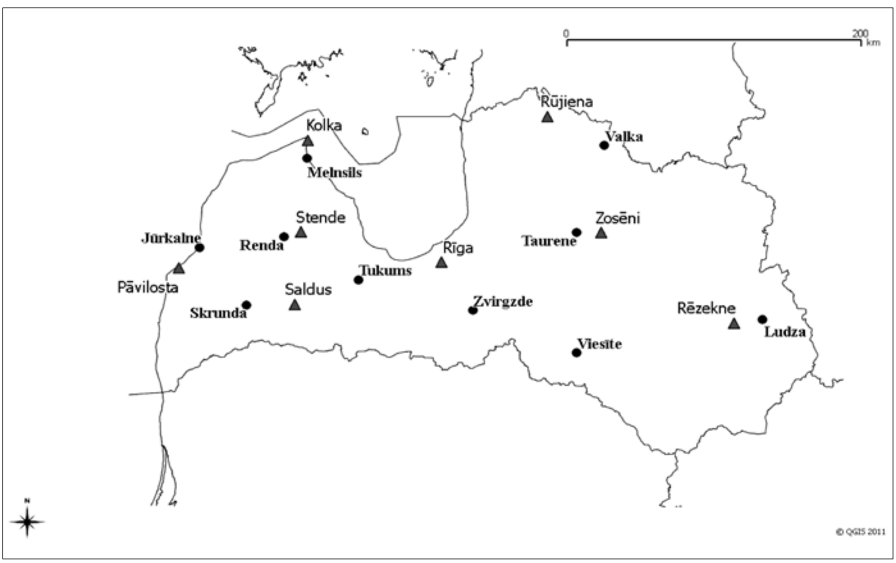

Figure 1. **Location of sampling sites (circles) and meteorological stations (triangles).**

MATERIAL AND METHODS

Study sites

Ten sampling sites were established in the territory of Latvia (Fig. 1). The sampling sites were evenly distributed across Latvia. Of these, seven sites were in dry forest growth types and three sites (Ludza, Tukums and Zvirgzde) were in wet types (Table 1).

Table 1. **Coordinates and forest growth types of sampling sites.**

Sampling site	Coordinates (LKS92)	Forest growth type
Jūrkalne	342873 6321935	Hylocomiosa
Ludza	721509 6267408	Caricoso-phragmitosa
Melnsils	415326 6387920	Myrtillosa
Renda	399238 6330548	Hylocomiosa
Skrunda	374428 6281471	Myrtillosa
Taurene	597213 6334011	Hylocomiosa
Tukums	450644 6300125	Vaccinioso-sphagnosa
Valka	616785 6396927	Vacciniosa mel.
Viesīte	598034 6246609	Hylocomiosa
Zvirgzde	527731 6280281	Myrtillosa

Climatological data

For each sampling site, the closest meteorological station with a sufficiently long time series of data was chosen for the analysis of growth-climate relationships. Meteorological data from eight meteorological stations (Table 2) were obtained from the Latvian Environment, Geology and Meteorology Centre. Data on monthly and ten-day period mean temperature and precipitation amounts were used.

Sample collection, measurement and chronology development

Wood samples were collected from Scots pine trees in 2010. Tree ring width samples (cores) were taken from the oldest trees, based on visual appearance (tree height, stem diameter). Two tree-ring width samples from each tree were taken with an increment borer; in total 20 to 25 trees were sampled in each site. In the laboratory the cores were dried and gradually sandpapered. WinDendro 2008 software was used for tree-ring width measurements. Tree ring width was measured from scanned cores images (scanned with 2400 dpi resolution with an EPSON Expression 10000XL scanner) (Regent Instruments Canada INC 2007). Cross-dating and quality control of tree-ring measurements were performed using the program COFECHA (Holmes 1983). After tree-ring width measurements and quality control, a mean tree-ring width series was calculated for each tree. To analyse the relationships between climatic variables and radial growth, long-term growth trends (Cook and Kairiukstis 1992) were removed by detrending with a 30-year cubic spline using the ARSTAN program (Holmes 1999). After detrending all tree-ring series were summarized to one site chronology (using ARSTAN). The residual chronology was used for climatic analysis. The residual was obtained by detrending and autoregressive modelling (Holmes 1999). EPS (expression population signal) values for all sites were calculated using package dplR (Bunn 2008) in program R 2.12.0 (R Development Core Team 2010) to determine whether the chronology shows a common signal for the site (EPS value higher than 0.85) or if signals of individual trees dominate in the chronology (EPS value lower than 0.85) (Speer 2010).

Table 2. **Meteorological station, time period of available data and closest sampling site(s) for which those data used.**

Meteorological station	Precipitation data	Temperature data	Sampling site
Kolka	1891-2009	1925-2009	Melnsils
Pāvilosta	1945-2009	1945-2009	Jūrkalne
Rēzekne	1947-2009	1947-2009	Ludza
Rīga	1851-2009	1851-2009	Tukums, Viesīte, Zvirgzde
Rūjiena	1926-2009	1926-2009	Valka
Saldus	1933-2009	1948-2009	Skrunda
Stende	1923-2009	1923-2009	Renda
Zosēni	1945-2009	1945-2009	Taurene

Statistical analysis

Pearson correlation coefficients between chronologies and meteorological data of the closest meteorological station were determined (at $\alpha = 0.05$) using the time period for which both climatic and chronological data were available. Multiple regression analysis was performed to determine the proportion of variation explained by climatic variables. All climatic variables (predictors) that showed significant correlation with chronology were initially included in the regression equation and then non-significant predictors were excluded (one predictor in each step).

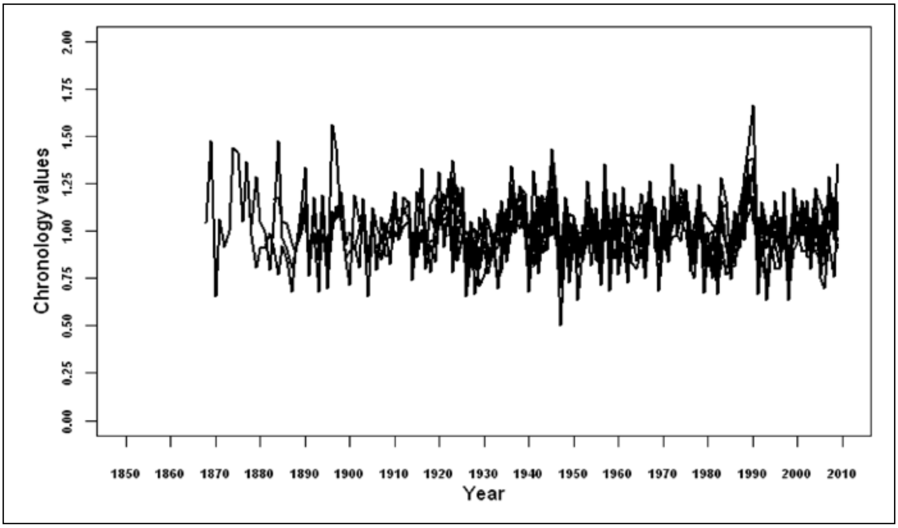

Figure 2. **Sampling site chronologies.**

RESULTS

The number of successfully cross-dated samples ranged from 17 to 22 trees per sampling site (Table 3). The main reason for discarding samples was poorly visible tree-rings or too many cracks. Even when samples were discarded, all sampling site chronologies had EPS values higher than 0.85. The oldest trees were in the Skrunda sampling site, where the maximal number of tree-rings has been found. In the youngest stand in the Melnsils sampling site, the maximal number of tree-rings was 70 (Fig. 2). All chronologies had rather low mean sensitivity values, ranging from 0.144 to 0.184.

Table 3. **Characteristics of sampling site chronologies: number of trees, number of tree-rings in samples, EPS and mean sensitivity.**

Sampling site	Time span	Number of trees	Number of tree-rings	EPS	Mean sensitivity
Jūrkalne	1932-2009	22	62-80	0.963	0.162
Ludza	1916-2009	17	64-95	0.902	0.172
Melnsils	1941-2009	22	57-70	0.925	0.163
Renda	1913-2009	21	85-98	0.958	0.164
Skrunda	1868-2009	20	84-145	0.950	0.184
Taurene	1920-2009	21	64-91	0.936	0.157
Tukums	1922-2009	18	73-89	0.931	0.144
Valka	1883-2009	19	108-128	0.949	0.168
Viesīte	1906-2009	17	86-106	0.942	0.168
Zvirgzde	1878-2009	19	74-133	0.915	0.157

Table 4. **Statistically significant correlation coefficients between sampling site chronologies and climatic variables – mean air temperature and precipitation amount (only those months or ten-day periods which had correlation with at least two sampling site chronologies are shown). The total number of climatic factors that had statistically significant correlation with each chronology is shown.**

	Jūrkalne	**Ludza**	**Melnsils**	**Renda**	**Skrunda**	**Taurene**	**Tukums**	**Valka**	**Viesīte**	**Zvirgzde**
Temperature										
Monthly										
October		0.25					0.22			
January				0.22				0.30		0.22
February	0.39	0.27	0.38	0.46	0.36		0.22	0.45	0.31	0.44
March	0.49	0.36	0.36	0.47	0.44	0.31	0.25	0.40	0.44	0.50
April	0.28		0.25	0.24						0.38
July		0.31				0.30		0.30		0.21
August				0.21		0.26		0.24	0.20	0.31
Ten-day periods										
December_II		0.28	0.25	0.24	0.34	0.35			0.23	
January_I		0.29	0.25			0.38		0.34	0.26	0.26
January_III	0.35			0.31						
February_I	0.40	0.28	0.38	0.45	0.35		0.24	0.45	0.30	0.44
February_II	0.35		0.38	0.32	0.33			0.37	0.20	0.29
February_III				0.34	0.29			0.28	0.31	0.36
March_I	0.42	0.34	0.27	0.41	0.36	0.36	0.22	0.33	0.37	0.45
March_II	0.34	0.26		0.42	0.35			0.36	0.42	0.40
March_III	0.47	0.29	0.41	0.34	0.38			0.29	0.34	0.36
April_I	0.26		0.38	0.23		0.33		0.24		0.32
June_I								0.27		0.21
June_III		0.29				0.26				
July_I		0.43				0.42				
August_II	0.28		0.28				0.22		0.21	0.26
Precipitation										
Monthly										
July	0.37		0.29							
Ten-day periods										
October_III									-0.24	-0.22
December_II			0.26							0.23
February_III		0.25		0.24						
July_II	0.37								0.23	
September_III	0.29	0.30		0.32	0.34					
Total number of significant climatic factors	**22**	**18**	**18**	**19**	**11**	**10**	**8**	**17**	**16**	**21**

Of the 96 climatic variables included in the analysis, 59 of them showed significant correlation with at least one sampling site chronology, and 27 variables showed significant correlation with at least two sampling site chronologies (Table 4). Of the 48 precipitation variables, only 27 variables had significant correlation and only six variables had significant correlation with at least two chronologies. Precipitation amount in the 3rd ten-day period of September had significant positive correlation with four of ten sampling site chronologies, which was the highest number of significant chronologies for precipitation amount. Of the 48 temperature variables, 32 had significant correlation with at least one sampling site chronology and 21 variables with at least two sampling site chronologies. Winter monthly and ten-day period temperatures generally showed a higher number of significant correlations with the site chronologies. March monthly and March 1st ten-day period mean temperature had positive significant correlation with all sampling site chronologies and February monthly and 1st ten-day period mean temperature had positive significant correlation with nine of the ten sampling site chronologies. The Tukums sampling site chronology had significant correlation with only eight of 96 climatic variables (one precipitation variable and seven mean temperature variables) and the Jūrkalne sampling site chronology had significant correlation with 22 climatic variables.

Climatic variables explained only 18.21% of chronology value variation for the Tukums sampling site and 24.54% for the Viesīte sampling site (Table 5). For the other sampling sites climatic variables explained more than 30% of chronology value variation and for the Jūrkalne sampling site even 62.99% of variation.

Table 5. **Part of chronology value variation explained by climatic factors.**

Sampling site	Explained variation	Sampling site	Explained variation
Jūrkalne	62.99	Taurene	41.16
Ludza	43.07	Tukums	18.21
Melnsils	31.04	Valka	31.75
Renda	39.84	Viesīte	24.54
Skrunda	33.83	Zvirgzde	40.92

DISCUSSION

Previous studies in Poland (Cedro 2001) and Latvia (Elferts 2007; Elferts 2008; Zunde et al. 2008) have shown that in most months, precipitation in this region has minor correlation with the Scots pine growth on mineral soils. This was confirmed also in this study, where Scots pine growth showed relation to precipitation only locally. The lack of an effect of precipitation can be explained by optimal moisture conditions for the pine growth (Linderholm

2001) in the region. In several sites (Jūrkalne, Melnsils) summer month (July) precipitation amount had significant positive correlation with radial growth, as observed for pine growing in southern regions (Lindholm et al. 2000; Cedro 2001). This suggests that during summer when the temperatures are the highest, the moisture level might be insufficient in these sites. Both the Jūrkalne and Melnsils sites are located on coastal dunes where the soils are sandier and moisture level is likely lower.

Air temperatures in February and March (monthly and also separate ten-day periods) have been demonstrated to be the most limiting climatic variables for radial growth of Scots pine in Latvia (Elferts 2007, Zunde et al. 2008), Estonia (Läänelaid and Eckstein 2003; Hordo et al. 2009; Pärn 2009), Lithuania (Vitas 2004), Poland (Cedro 2001) and Sweden (Linderholm 2001). Low air temperatures in February and beginning of March can cause a deeper frozen soil layer. If the frozen soil layer is deeper it takes more time for the soil to thaw in spring, which delays initiation of growth in spring (Dau kane and Elferts 2011). There is a positive correlation of July mean air temperature with radial growth of Scots pine in four sites, which is characteristic of pines growing in the northern part of their distribution range where a warmer summer can compensate for the shorter growing season (Lindholm et al. 2000). However, an alternative explanation might be that a warmer summer is needed to decrease the soil moisture level, particularly since two of these four sites (Ludza and Valka) were located in wet forest types.

Previous studies (Elferts 2008) showed that climatic factors in Latvia explain only small part of Scots pine chronology value variation. Also, in the present study the mean sensitivity of pines chronologies for ten sampling sites was low. Nevertheless, for at least half of the sampling sites, the high proportions of variation explained indicate that climate can be considered as one of the most important factors influencing the pine growth. This is surprising, since climatic variables usually explain the highest amount of variation in residual chronologies close to the distribution limits of tree species (Schweingruber et al. 1990), whereas Latvia is in the central part of the distribution range of pine. This discrepancy may be explained by the use of climatic variables for ten-day periods, which may more precisely describe relationship between climate and growth. Also, the time period of analysis should be considered. The highest proportion of explained variation was for the Jūrkalne sampling site, where only 65 years were included in the analysis.

The main climatic variables that had significant effect on residual chronologies for Scots pine in Latvia were January, February and March monthly and ten-day period mean temperatures. All of these variables had positive effect on the ring width. According to climate change scenarios it is forecasted that the mean temperatures in these winter months will increase (Bethers and Seņņikovs 2007; IPCC 2007; Sennikovs and Bethers 2009; Jansons 2010), and that there will be less years with very low winter temperatures. We can expect that the negative impact of low winter temperatures on the growth of Scots pine will decrease but we can not expect that with increase of temperatures also radial growth will increase. It may take several generations to adapt to new climatic conditions. It is quite possible that the relationship between winter month temperatures and radial growth will become insignificant in the future, as was observed for Scots pine at the end of the 20th century in Latvia (Elferts 2008) and for other species in Northern Europe (D'Arrigo et al. 2008). It might imply that air temperatures have not yet reached a level where growing conditions have become optimal for Scots pine, and that only extreme changes in temperatures have significant influence.

The relationship between residual chronologies of pine and precipitation is unclear, as the effect appears to be low and local. According to climate change scenarios (Bethers and Seņņikovs 2007; IPCC 2007; Sennikovs and Bethers 2009; Jansons 2010) the precipitation amount in Latvia will change minimally – for some time periods it will slightly increase or will stay the same, in same cases it may even decrease. We can expect that there will be obvious changes in the influence of precipitation amount on radial growth of Scots pine. In a scenario that temperatures increase and precipitation amount changes minimally, evapotranspiration will increase. This will decrease the amount of moisture available for pines, especially in summer months. Longer drought periods for the summer also are forecast. Although longer drought periods are not observed yet, local populations of Scots pine may switch from temperature limited to precipitation amount limited, as it is characteristic to pines growing in Southern regions (Lindholm et al. 1997; Bogino et al. 2009). The first signs of this type of switching in limiting factors already can be seen in Lithuania (Vitas and Erlickyté 2008) and Poland (Cedro 2001) where pine growth has significant relation to the summer precipitation amount.

CONCLUSIONS

1. The most important climatic variables positively influencing the radial growth of Scots pine are mean air temperatures in January, February and March. The effect of precipitation amount is insignificant and local.
2. Due to climate change, the influence of winter months mean air temperatures will decrease, but the influence of precipitation amount can increase and Scots pine may become precipitation-amount limited in Latvia.

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The Phenology of Spring Arrival of Birds in Latvia in Response to Climate Change

Mārcis Tīrums
University of Latvia, Faculty of Geography and Earth Sciences,
19 Raiņa Blvd., Riga, LV 1586, Latvia
E-mail:marcis@lob.lv

Annotation
The study is based on phenology of the first arrival dates of 40 bird species that have been observed during the period between 1950 and 2010 in the area of Snēpele, on the western Latvia. Trend towards earlier arrival was statistically significant for 10 out of 18 bird species (56%) of short distance migrants, and for 13 out of 22 bird species (59 %) of long distance migrants. In 95 per cent cases of studied short and medium distance migrant's arrival date significantly negatively correlated with NAO*DJFM* seasonal index. Significantly negative correlation coefficients between arrival dates of the long distance migrants and NAO*DJFM* has been found only for 7 species (32%). Spring arrival of birds occurred significantly earlier in years with warmer and wetter milder than normal in winter and spring seasons that has been caused by activity of North Atlantic Oscillation.

Keywords: Climate variables, migratory birds, North Atlantic Oscillation, phenological trends.

INTRODUCTION

Phenological phases, like spring arrival of birds, can be used as indicators for detecting the climate change. Phenological time-series of bird migration have been observed since 18th century, but only in recent decades are used as indicator for climate change studies.

In recent decades in Central and Eastern part of Europe evidence of a trend towards earlier spring arrival of passerine and non-passerine migrant birds has been found (e.g. Sokolov et al. 1998, Ahas 1999, Tryjanowski et al. 2002, Sparks et al. 2005, Gordo 2007, Askeyev et al. 2008, Zalakevicius 2009).

Under the conditions of climate change the dates of spring arrival of birds became noticeably earlier for short- and also for long-distance migrants (Zalakevicius 2001). The difference between these arrival dates for short-distance migrants was much higher, but more constant for long-distance migrants (Zalakevicius 2001, Palm et al. 2009).

Many factors play an important role in predictions of spring phenological responses to climate change (Dolenec 2010). According to Ahas and Assa (2006), the onset of migration may be determined endogenously; the timing of migration is flexible and can be adjusted in response to variation in weather and/or phenology along migration routes. The authors noted that the early migratory period for earliest arriving species (i.e., short-distance migrants) and earliest arriving individuals of a species (i.e., males) most frequently correlate with climate variables.

The climate in Europe is influenced by the large scale atmospheric circulation types – North Atlantic Oscillation (NAO), East Atlantic pattern, and Scandinavian pattern. The NAO index is characterized by decadal oscillations and periodically reverses from positive to negative phases, and describes the fluctuation of the pressure difference at the sea level (Hurrell 1995).

The increase of NAO index in winter explains the earlier spring arrival times of migratory birds in the northern part of Europe, for example, in Scandinavia and Baltic states (Forchhammer et al. 2002; Jonzén et al. 2002; Hüppop and Hüppop 2003; Stervander et al. 2005; Zalakevicius 2006; Ahas 2006; Zalakevicius 2009; Palm et al. 2009).

In Latvia the phenological studies of arrival of migratory birds were performed episodically. E.Ķemlers published the results of spring arrival phenology of birds in Snēpele accordingly to data for period from 1947 till 1986. A. Aunins has been analyzed spring arrival of 17 bird species in Latvia during 1993–1998. Ķemlers according spring arrivl of birds divided time period in late (cold) years (1955, 1960, 1963, 1970, 1980 and 1986) and in early (warm) years (1950, 1959, 1966, 1967, and 1974). Also Ķemlers (1990) emphasized that late years have been very quickly, but early years were slowly and quietly Results by Aunins (1999) suggest that 10 earliest species (9 of them are short distance migrants) are dependent on weather conditions while the arrival dates of the seven long distance migratory species are more or less stabile. The most widespread territorial pattern of the bird arrival is from southwest while two species (Thrush nightingale *Luscinia luscinia* and Cuckoo *Cuculus canorus*) usually arrived from southeast.

The objective of current study was to evaluate the phenology of spring arrival of 40 migratory bird species in relation to climate change variables in Snēpele during period from1950 till 2010.

MATERIAL AND METHODS

The observation was carried out in Snēpele (56°84'05"N, 21°94'46"E), that is situated in the western part of Latvia – in Kurzeme region (Curland). Snēpele lies approximately 40 km from the Baltic seacoast and 10 km from the River Venta. The study is based on the first arrival dates of 40 bird species, monitored during the period from 1950 to 2010 in Snēpele area, on the western

Latvia. The data of spring arrival of birds were obtained from the phenological database of the Latvian Ornithological Society. 95 per cent of dataset were collected by two observers – E. Ķemlers and A. Ķemlers, during 1950–2007. In total the data of spring arrival of birds in Snēpele were available for 132 species. The main criterion for 40 species selection in particular study was the length of the time series (40 or more observation during 60 years). Data were critically checked to eliminate incorrectly recorded single values.

In this study the short and medium distance migrants are defined as species that breeding in Latvia and wintering in western and eastern part of Europe. Also bird species wintering in northern part of Africa is related to the same group. In the group of long distance migrants' there are species that are wintering in central and southern part of Africa.

Dates were converted into numerical values, where 1 represented 1st January, 90 represented 31st March. To test the relationship between the arrival trends of birds in the last six decades, Pearson's correlation and regression analysis were applied. For each species the mean arrival date, correlation coefficient, determination coefficient, slope and standard deviation were calculated.

To detect possible long-term trends in the timing of arrival of bird species and climatic variables the MULTMK/PARTMK program with non-parametric univariate Mann-Kendall test (MK_test) were used (Libiseller and Grimvall 2002).

North Atlantic Oscillation indexes (NAO) used for the study were obtained from the Climate Prediction Center's home page (http://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml) and have been calculated as the difference of pressure in the sea level between Azores high and Icelandic low (Hurrel 1995). The monthly NAO indexes from 1950 to 2010 are standardized by the time period from 1981 to 2010.

The first arrival of birds in spring was analyzed separately with the NAO from December to May, as well as with seasonal NAO_{DJFM} (December-March) and NAO_{JFMA} (January-April) index.

RESULTS

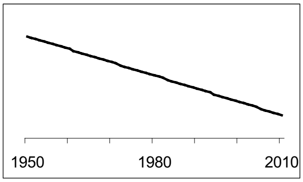
From analyzed 40 bird species 18 species are the short/medium distance migrants and 22 are the long distance migrants (Table 1). The results of the Mann-Kendall test analysis revealed that negative trend of arrival time was statistically significant ($p< 0.05$, MK_test – 1.99 to – 6.11) for 23 species of 40 analyzed. The data of spring arrival during the last 61 years for each analyzed species are presented in Table 1 and Figure 1.

Earlier arrival was statistically significant for 10 (56%) of 18 bird species of short distance migrants and for 13 (59%) of 22 bird species of long distance migrants. Detailed values for all species are shown in Table 1. Tendency of later arrival was found only for one migrant species – Tree pipit *Anthus trivalis*.

Table 1. **Changes in the average dates of the first arrival of birds in Snēpele from 1950 to 2010 (*p<0.05, **p<0.01)**

Species	*Dist.*	*n*	*mean arrival date*	*slope*	*r*	R^2	*SD*	*Correlation coefficient* NAO_{DJFM}	NAO_{JFMA}
Common buzzard *Buteo buteo*	S	53	09.Mar	-0.33	**-0.45****	0.21	12.8	**-0.62****	**-0.56****
European robin *Erithacus rubecula*	S	58	10.Mar	-0.33	**-0.40****	0.16	14.8	**-0.57****	**-0.56****
Skylark *Alauda arvensis*	S	59	11.Mar	-0.11	-0.16	0.03	11.8	**-0.58****	**-0.54****
Starling *Sturnus vulgaris*	S	55	14.Mar	-0.06	-0.12	0.02	7.9	**-0.35***	**-0.30***
Whooper swan *Cygnus cygnus*	S	48	16.Mar	-0.63	**-0.56****	0.43	16.6	**-0.56****	**-0.60****
Lapwing *Vanellus vanellus*	S	60	16.Mar	-0.20	**-0.35****	0.12	10.3	**-0.39****	**-0.34****
Blackbird *Turdus merula*	S	51	19.Mar	-0.38	**-0.52****	0.27	11.8	**-0.38****	**-0.32***
Woodlark *Lullua arborea*	S	60	21.Mar	-0.13	-0.23	0.05	10.0	**-0.52****	**-0.46****
Chaffinch *Fringilla coelebs*	S	60	23.Mar	-0.13	**-0.28***	0.08	8.4	**-0.28***	**-0.33***
Song thrush *Turdus philomelos*	S	57	27.Mar	-0.09	-0.19	0.04	8.4	**-0.42****	**-0.37****
Fieldfare *Turdus pilaris*	S	53	27.Mar	-0.16	**-0.27***	0.07	10.7	**-0.39****	**-0.38****
Meadow pipit *Anthus pratensis*	S	53	28.Mar	-0.25	**-0.52****	0.27	8.4	**-0.49****	**-0.51****
Wood pigeon *Columba palumbus*	S	40	29.Mar	-0.31	**-0.29***	0.22	11.3	**-0.52****	**-0.38****
Reed Bunting *Emberiza schoeiclus*	S	50	29.Mar	-0.06	-0.10	0.01	10.9	**-0.34***	-0.17
Rook *Corvus frugilegus*	S	59	29.Mar	-0.13	**-0.47***	0.08	7.9	**-0.30***	-0.24
Redwing *Turdus iliacus*	S	58	30.Mar	-0.06	-0.12	0.02	8.9	**-0.39****	**-0.45****
Woodcock *Scolopax rusticola*	S	48	31.Mar	-0.30	**-0.55****	0.31	10.0	**-0.51****	**-0.47****
Green sandpiper *Tringa ochropus*	S	54	09.Apr	-0.04	-0.13	0.02	5.5	-0.12	-0.10
Common crane *Grus grus*	L	54	24.Mar	-0.58	**-0.75****	0.56	13.9	**-0.54****	**-0.47****
White wagtail *Motacilla alba*	L	60	30.Mar	-0.06	**-0.25***	0.06	4.5	**-0.28***	-0.20
White stork *Ciconia ciconia*	L	57	30.Mar	-0.21	**-0.63****	0.39	6.1	**-0.39****	**-0.35****
Wheatear *Oenanthe oenanthe*	L	45	15.Apr	-0.07	-0.20	0.05	6.2	-0.09	-0.07
Chiffchaff *Phylloscopus collybita*	L	58	16.Apr	-0.15	**-0.46****	0.21	5.8	-0.10	-0.15
Tree pipit *Anthus trivalis*	L	57	20.Apr	0.04	0.15	0.02	5.2	0.04	0.08
Barn swallow *Hirundo rustica*	L	60	26.Apr	-0.09	-0.25*	0.06	6.2	0.02	-0.03
Willow warbler *Phylloscopus trochilus*	L	59	27.Apr	-0.09	**-0.31***	0.10	5.2	**-0.27***	-0.26
Wryneck *Jynx torquilla*	L	49	28.Apr	-0.05	-0.15	0.02	5.6	-0.02	0.03
Cuckoo *Cuculus canorus*	L	60	29.Apr	-0.06	**-0.29***	0.08	3.7	-0.08	-0.09
Pied flycatcher *Ficedula hypoleuca*	L	55	30.Apr	-0.02	-0.05	0.00	5.9	-0.14	-0.11
Whinchat *Saxicola rubetra*	L	54	30.Apr	-0.07	-0.24	0.06	5.3	-0.10	-0.01
Whitethroat *Sylvia curruca*	L	51	02.Mai	-0.22	**-0.61****	0.37	6.7	**-0.34***	**-0.32***
House martin *Delichon urbica*	L	52	03.Mai	-0.11	-0.26	0.07	8.0	-0.04	-0.04
Blackcap *Sylvia atricapilla*	L	51	06.Mai	-0.19	**-0.51****	0.03	6.7	**-0.40****	**-0.42****
Thrush Nightingale *Luscinia luscinia*	L	54	07.Mai	-0.15	**-0.49****	0.24	5.2	**-0.29***	**-0.31***
Lesser whitethroat *Sylvia communis*	L	48	09.Mai	-0.05	-0.13	0.02	5.9	0.01	0.08
Golden oriole *Oriolus oriolus*	L	52	13.Mai	0.00	-0.01	0.00	5.4	0.08	0.07
Garden warbler *Sylvia borin*	L	51	14.Mai	-0.05	-0.22	0.05	3.7	0.15	0.15
Icterine warbler *Hippolais icterina*	L	44	16.Mai	-0.01	-0.05	0.00	4.8	-0.12	-0.14
Swift *Apus apus*	L	54	16.Mai	-0.10	**-0.27***	0.07	6.7	0.16	0.17
Corncrake *Crex crex*	L	44	18.Mai	-0.31	**-0.52****	0.27	9.2	-0.04	-012

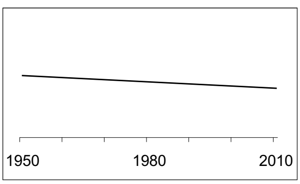
Dist., migration distance, where S, short/medium distance migrants, L, long distance migrants, n, number of observations, r, correlation coefficient of year, R^2*, determination coefficient, slope, trend changes in days per year, SD, standard deviation, NAODJFM, correlation coefficient of seasonal index (December to March) and birds, NAOJFMA, correlation coefficient of seasonal index (January to April) and birds.*



A – *trend toward earlier, statistically significant changes*

Short/medium distance	*Slope in days*	*MK-test*
Whooper swan *Cygnus cygnus*	-28.8	-4.56**
European robin *Erithacus rubecula*	-19.1	-3.05**
Blackbird *Turdus merula*	-18.4	-3.69**
Common buzzard *Buteo buteo*	-17.5	-3.03**
Rook *Corvus frugilegus*	-17.1	-2.85**
Woodcock *Scolopax rusticola*	-14.4	-3.98**
Meadow pipit *Anthus pratensis*	-13.3	-3.65**
Lapwing *Vanellus vanellus*	-12.0	-2.69**
Fieldfare *Turdus pilaris*	-8.5	-1.98*

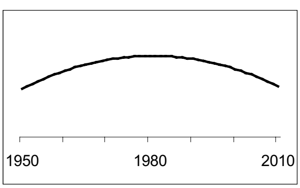
Long distance	*Slope in days*	*MK-test*
Common crane *Grus grus*	-31.3	-6.11**
White stork *Ciconia ciconia*	-12.0	-4.75**
Corncrake *Crex crex*	-11.4	-3.79**
Chiffchaff *Phylloscopus collybita*	-8.7	-3.18**
Thrush Nightingale *Luscinia luscinia*	-8.1	-3.93**



B – *insignificant changes*

Short/medium distance	*Slope in days*	*MK-test*
Woodlark *Lullua arborea*	-7.8	-1.78
Chaffinch *Fringilla coelebs*	-7.8	-1.9
Skylark *Alauda arvensis*	-6.5	-1.06
Song thrush *Turdus philomelos*	-5.1	-1.46
Redwing *Turdus iliacus*	-3.5	-0.71
Starling *Sturnus vulgaris*	-3.3	-1.24
Reed Bunting *Emberiza schoeiclus*	-3.0	-0.81
Green sandpiper *Tringa ochropus*	-2.2	-1.03

Long distance	*Slope in days*	*MK-test*
Swift *Apus apus*	-5.4	-1.5
Cuckoo *Cuculus canorus*	-3.6	-2.27*
White wagtail *Motacilla alba*	-3.6	-1.99*
Garden warbler *Sylvia borin*	-2.6	-1.82
Icterine warbler *Hippolais icterina*	-0.4	-0.43



C - *bow-shaped trend* (3-D polynomial trend)

Short/medium distance	*Slope in days*	*MK-test*
Wood pigeon *Columba palumbus*	-5.2	-1.98*

Long distance	*Slope in days*	*MK-test*
Whitethroat *Sylvia curruca*	-11.2	-4.50**
Blackcap *Sylvia atricapilla*	-9.7	-3.48**
House martin *Delichon urbica*	-5.7	-2.00*
Barn swallow *Hirundo rustica*	-5.4	-2.15*
Willow warbler *Phylloscopus trochilus*	-5.3	-2.41*
Whinchat *Saxicola rubetra*	-3.8	-2.12*
Wheatear *Oenanthe oenanthe*	-3.2	-1.11
Wryneck *Jynx torquilla*	-2.5	-1.17
Lesser whitethroat *Sylvia communis*	-2.4	-1.18
Pied flycatcher *Ficedula hypoleuca*	-1.1	-0.6
Golden oriole *Oriolus oriolus*	0.0	-0.35
Tree pipit *Anthus trivalis*	2.3	0.92

Figure 1. **Grouping of migratory bird species accordingly to the long-term trend analysis and to the MK_test results.** *MK_test, 1-sided normalized Mann Kendall test, DJFM*

The most significant changes were founded in the arrival of the 5 short distance migrants including Common buzzard *Buteo buteo,* Whooper swan *Cygnus cygnus*, Meadow pipit *Anthus pratensis*, Blackbird *Turdus merula*, Woodcock *Scolopax rusticola* and European robin *Erithacus rubecula*, as well as for 7 long distance migrants such as Common crane *Grus grus*, White stork *Ciconia ciconia*, Chiffchaff *Phylloscopus collybita* Whitethroat *Sylvia curruca*, Blackcap *Sylvia atricapilla,* Thrush nightingale *Luscinia luscinia* and Corncrake *Crex crex* (Table 1). The first arrival date of *Grus grus* during the last 61 years is getting earlier on the average at a rate of 5.8 days per decade (r – 0.73, MK_ test – 6.11, $p < 0.01$).

Depending on variance of long term trends migratory bird species were sorted in three groups: the first group contained bird species ($n = 14$) with trend toward significantly earlier (Figure 1. A) and results of Mann-Kendall test for these species were statistically significant. The long term changes of spring arrival trends varying from species to species between 8 and 32 days. In second group (Figure 1. B) were merged species ($n = 13$) that have advanced their migration time up to 8 days, but these changes are statistically insignificant. Only for two species arrival date of 3.6 days earlier during 61 year period were statistically significant – for Cuckoo *Cuculus canorus* and for White wagtail *Motacilla alba*. Third group ($n = 13$) (Figure 1. C) demonstrate bow-shaped trend where the 3-D polynomial trend were used. In the period between 1970s and 1980s, (depending from species) migratory bird species of this group revealed trend towards later, but in the last 30 years the migratory birds of this group are showing trend towards significantly earlier. In this group were merged 13 bird species, and only one (Wood pigeon) is short distance migrant. For seven species arrival time was advanced from 2 to 11 days and these changes were statistically significant. Only one species (Tree pipit *Anthus trivialis*) has demonstrates trend towards arrival later for 2 days in the whole studied period.

The variability of average arrival date of short/medium distance migrants nearly twice exceeds variability on average date for long distance migrants (Figure 2). Largest standard deviation has been found for Whooper swan *Cygnus cygnus* (SD = 16.6) and Common crane *Grus grus* (SD = 13.9). For the group of the long distance migrants average standard deviation varies in range of 3.7–8.0., except Common crane *Grus grus* and Corn crake *Crex crex*. The smallest fluctuations (SD = 3.7) have been found for Cuckoo and Garden Warbler *Sylvia borin* (Table 1).

The local precipitation and temperatures have been studied in relation to migration time. Trend analysis of winter and spring (December–May) temperature changes in Snēpele during period from 1950 to 2010 according to the MK-test demonstrated statistically significant increases. The mean temperature of first three months of the year (January–March) has increased for about 0.5 degrees per decade. The average depth of snow cover in February and March has decreased, while the amount of precipitation has increased on average 3.5 mm per decade (Tīrums, unpublished data).

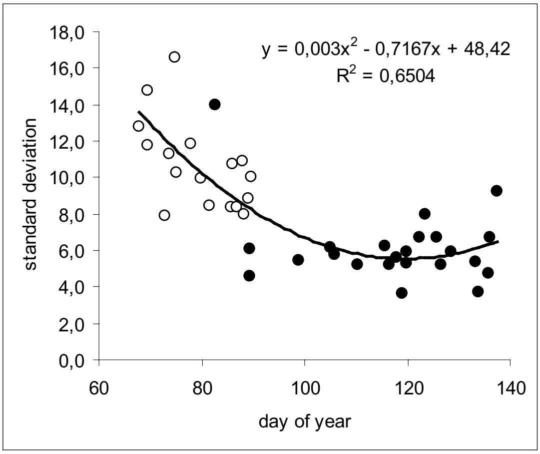


Figure 2. **Relationship between standard deviation (SD) and the timing of spring arrival.**

White circles - short/medium distance migrants, black circles – long distance migrants

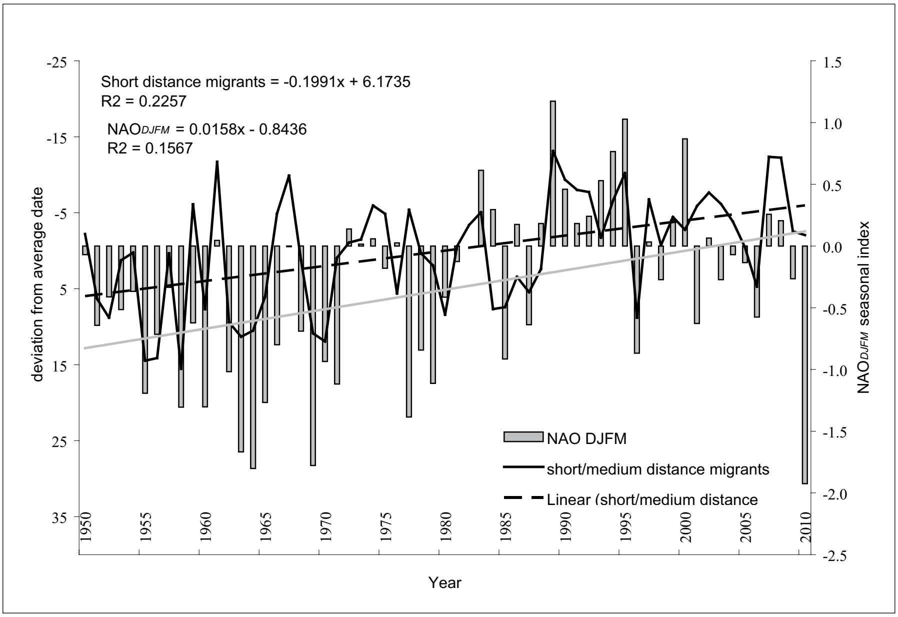


Figure 3. **The relationship between the long-term trends of North Atlantic Oscillation index and the deviation of average arrival day of 18 short distance migrants from 1950 to 2010.**

The North Atlantic Oscillation seasonal index NAO_{DJFM} and NAO_{JFMA} was used in order to investigate the link to large-scale climatic forcing and phenology of spring arrival of 40 bird species. The correlation between the arrival dates of bird species and the results of seasonal NAO index are summarized in the Table 1. For the short distance migrants statistically significant correlation between the arrival dates and NAO in Snēpele has been found for 14 (78%) species with NAO in March, for 11 with NAO in February for 7 species with NAO in January and only 3 species and NAO in December. The NAO index in the April and May does not show any statistically significant correlation neither for the short nor for long distance migrants during the period from 1950 to 2010. The strongest correlation was found between the arrival of birds and the NAO_{DJFM} and NAO_{JFMA} seasonal index (Table 1). For 17 (95%) of 18 short and medium distance migrants the earlier timing of spring arrival was correlated significantly with the NAO_{DJFM} index (Figure 3). During the past three decades NAO_{DJFM} index was positive with minor exception and arrival time of migratory birds has advanced equally. For seven species (32%) statistically significant negative correlation was found between the arrival of the long distance migrants and NAO_{DJFM} index. Coefficient of linear correlation between the arrival of the short distance migrants and NAO_{DJFM} index was statistically significant ($r = 0.64$, $p < 0.05$) (Figure 2), but relationship was not found for the long distance migrants ($r = 0.14$, $p > 0.05$). The NAO_{DJFM} index (DJFM) correlated significantly ($p < 0.01$) with first arrival in spring of Common Buzzard *Buteo buteo* (–0.62), European robin *Erithacus rubecula* (–0.57), Skylark *Alauda arvensis* (–0.58), Whooper swan *Cygnus cygnus* (–0.56) and Common carne *Grus grus* (–0.54) (Table 1). The seasonal NAO_{DJFM} index on the average explained 20% of cases (range 1–39%) variability in the phenological instants of the 18 short-distance migrants, whereas only 5% (range, 0–29%) variability in the 22 long-distance migrants.

DISCUSSION

The study based on observation network of bird phenology covered a relatively small site of the western part of Latvia in the long time period. The results revealed that the majority of the analyzed species nowadays are arriving earlier. The results of the first arrival date of 40 bird species in Snēpele from 1950 till 2010 suggest that the phenology of spring migration of both short/medium and long distance migrants have been changed remarkably; furthermore, larger changes occurred in the arrival of the short distance migrants than the long distance migrants. Timing of spring arrival has tended to advance since the middle of the 1970s. The accuracy of long distance migrants' notwithstanding on the migration distance and the climate variables in migration time is remarkable.

The main results of the current study of arrival trends of birds in Latvia show statistically significant changes demonstrating that 9 bird species have advanced by 15–35 days, and 16 bird species – by 5–15 days during period from 1950 till 2010. Typical are changes in the phenology of spring arrival of birds advanced by 0–5 days, but usually these changes are statistically insignificant.

Nowadays advancement of migration times of birds in Europe has been reported due to the increasing local temperatures (Sparks 1999; Tryjanowski et al. 2002) and increasing air temperature along the migration route (Huin & Sparks 2000). These results correspond well with findings in particular study, showing the importance of increase of seasonal air temperature and earlier arrival of short/medium distance migrants.

The changes of arrival of migration species are linked with large-scale atmospheric circulation pattern (e.g. Forchhammer et al. 2002; Huppop & Huppop 2003; Ahola 2004). The circulation index, such as NAO, influenced bird phenology in spring via temperature changes caused by atmospheric circulation. The positive winter NAO index means a milder winter and spring in Europe, and specifically – a warmer than normal weather over central Europe (Hurrell 1995). Many reports demonstrate strong correlation between arrival times of short and long-distance migrants and the winter North Atlantic Oscillation. A negative correlation has been shown between the arrival dates and positive NAO index values in the northeast part of Europe, suggesting that spring migrants arrive earlier after milder and wetter winters (Jonzén et al. 2006; Forchhammer et al. 2002; Hüppop and Hüppop 2003; Vähätalo et al. 2004). The results at Snēpele area showed that strong negative relationship with NAO*DJFM* and NAO*JFMA* indexes has been found for all short/medium distance migrants. Strongest correlation was founded in NAO*DJFM* index and Common Buzzard *Buteo buteo*, European robin *Erithacus rubecula*, Skylark *Alauda arvensis*, Whooper swan *Cygnus cygnus* and Common carne *Grus grus.* However, Jonzén et al. (2006) have reported the opposite trend for southern Italy where a positive NAO appears to delay arrival times and Cotton (2003) found no effect of the NAO on arrival times in the UK (Donelly 2009). The majority of bird species analyzed here demonstrates statistically significant correlation of arrival trend with the NAO*DJFM* index.

North Atmospheric Oscillation effect on long distant migrants is not strong and this could be explained by the fact that long-distance migrants in Snēpele arriving in the last days of April till the middle of May, while the impact of NAO on the territory of Latvia is significantly reduced.

Since 1990 at Snēpele area, some of the short distances migrants demonstrate trend toward later arrival, and this is consistent with the NAO trend towards negative phase in the last decade. The arrival time in spring of European robin *Erithacus rubecula*, Common crane *Grus grus* as well as for long distance migrant – White stork *Ciconia ciconia*, has advanced remarkably, and that could be explained by wintering closer to breeding grounds.

There has been mentioned that earlier spring arrival of the short distance migrants could be achieved by wintering closer to the breeding grounds similarly as for the long distance migrants. Accordingly to Gordo (2006) dry years in Africa, in Sahel, were associated with later arrival of birds in Europe. Therefore, earlier arrival in last three decades for long distance migrants was induced by climate warming and also by the ecological condition in the Sahel region.

The food availability for migratory birds in spring is an important limiting factor, which directly depends on the temperature and amount of snow cover in spring affected by large-scale atmospheric circulation in Europe, such as the North Atlantic circulation.

The results of arrival phenology of white stork *Ciconia ciconia* in Spain analyzed by Gordo (2006) demonstrate changes with advancement by approximately 40 days during period from 1944 to 2004. Also changes occurred arrival dates of barn swallow and shift, especially from 1970s. Over the last decades during the winter season increase of numbers of White storks *Ciconia ciconia* has been observed in rubbish dumps in Mediterranean region (Gordo 2006, Archaux et al. 2004). It is important to emphasize that result of current study representing only changes in trends towards arrival of first migratory birds rather than as a whole population. Also in the warmer winters some species of short distance migrants have been regularly seen in Latvia, for example, Common buzzard *Buteo buteo*, European robin *Erithacus rubecula*, Starling *Sturnus vulgaris,* Whooper swan *Cygnus cygnus*, Rook *Corvus frugilegus.*

It could be assumed that wintering range of Common cranes *Grus grus* their has changed as a result of the NAO effect over the last 60 years. Data about wintering range of Common Cranes suggests that since 80s of the 20th century a large proportion of the population in winter season is staging in France and Germany. On the other hand, researchers from Estonia (Leito 2006) have revealed that earlier spring arrival of Common cranes *Grus grus* is associated with rapid population growth in the breeding area.

Authors of similar studies emphasize that population size and detectability of species could influence arrival date (Tryjanowski 2005, Linden 2011). They foresee if population size increases the probability of earlier detection should also increase. Second factor could be a detectability. Therefore, there is a greater chance to observe and record early dates with greater accuracy for well known species like Common Crane *Grus grus*, White stork *Ciconia ciconia*, Skylark *Alauda arvensis*, rather than less easily detected bird species like Golden Oriole *Oriolus oriolus* or Tree pipit *Anthus trivialis*.

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Latvijas industriālās telpas ilgtspējīgā piedāvājuma scenāriju analīze klimata pārmaiņu ietekmē

Analysis of Scenarios on the Industrial Premises' Sustainable Supply in Latvia under the Influence of the Climate Change

Tatjana Štaube
Rīgas Tehniskā universitāte
Inženierekonomikas un vadības fakultāte
Rīgā, Meža ielā 1/7 – 210, LV-1048
e-pasts: tatjana.staub@gmail.com

Ineta Geipele
Rīgas Tehniskā universitāte
Inženierekonomikas un vadības fakultāte
Būvuzņēmējdarbības un nekustamā īpašuma ekonomikas institūts
Rīgā, Meža ielā 1/7 – 211, LV-1048
e-pasts: ineta.geipele@rtu.lv

Analīze ir veikta, lai prognozētu Eiropā pieprasītākās industriālās telpas Latvijas Republikā. Autores piedāvā oriģinālu pieeju industriālo telpu ilgtspējīgā piedāvājuma noteikšanai, izmantojot Eiropas klimata pārmaiņu problemātiku, lietojot loģiskās pieejas un salīdzināšanas metodes analīzi, kā arī sistēmu un dinamikas rindas analīžu metodiku ekonomiskos aprēķinos. Strukturējot pētījuma rezultātus un pamatojoties uz Latvijas, Čehijas un Zviedrijas ražošanas nozares potenciālu, autores secināja, ka, pastāvot efektīvai darbībai, rūpniecības nozares ražīguma potenciāls Latvijā rūpniecības nozares apgrozījuma uz moderno industriālo telpu izteiksmē ir 3-6 reizes lielāks un palielināt moderno industriālo platību tirgus apjomu nav nepieciešamības.

Atslēgvārdi: klimata pārmaiņas, Latvijas rūpniecības attīstība, industriālā nekustamā īpašuma tirgus apjoma prognozes.

The carried research is devoted to forecast stock of the most demanded industrial premises in Europe in the territory of the Republic of Latvia. The authors proposed the original approach of including the European climate change issue as a basis to assign the sustainable supply of the industrial premises, applying complex of the methods like logical approach and comparison, the system and dynamic row's analyses. According to the research results, Latvia may process the manufacturing industry development following the Czech or Swedish scenarios, which mean the considerable increase of the manufacturing branch efficiency approximately 3 to 6 times in Latvia, the authors allow that the modern industrial real property market does not need any further growth under the chosen scenarios.

Keywords: climate change, Latvian manufacturing development, industrial real property market stock forecast.

IEVADS

Latvijas industriālo telpu nekustamā īpašuma attīstību var vērtēt dažādi. Eiropā un arī vietējā tirgū izplatītā prakse ir prognozēt nekustamā īpašuma tirgus piedāvājumu, analizējot esošo pieprasījumu. Tas neapšaubāmi atspoguļo esošo situāciju, bet prognozēm nepietiekami un ne vienmēr objektīvi statistisko informatīvo datu nepilnību dēļ. Latvijā plānojamo pieprasījumu arī eksperti precīzi neprognozē, jo pašlaikt ir nelabvēlīgi apstākļi nekustamā īpašuma tirgus attīstībai sakarā ar ekonomisko recesiju un politisko nestabilitāti.

Autores ir pārliecinātas, ka Latvijas tirgum pietiekams piedāvājuma apjoms un kvalitāte īpaši spēj ietekmēt pozitīvas izmaiņas pieprasījumā, jo vietējā tirgus attīstības raksturs ir impulsīvs, kā arī atkarīgs no politiski ekonomiskajām pārmaiņām.

Savukārt, politiski ekonomisko situāciju Latvijā ietekmē ārvalstu investoru noteikumi, kas kļuvuši vēl ietekmīgāki sakarā ar aizņēmuma saņemšanu no Eiropas Savienības globālās finansiālās krīzes seku pārvarēšanai. Pēc oficiālajiem dokumentiem var spriest, ka klimatisko apstākļu izmaiņām ir veltīta nopietna uzmanība.

Klimata mainību var izraisīt gan dabas procesi, gan arī cilvēka darbība. Mainoties klimatiskajiem apstākļiem, var mainīties valsts ekonomikas attīstības prioritātes (Štaube and Geipele, 2010).

Industriālās telpas objekti ir starp tiem nekustamā īpašuma tirgus objektiem, kuru darbība pat īsā laikā var ietekmēt atmosfēras, ūdens un zemes sastāva izmaiņas. Taču industriālo objektu izvietojums un pastāvēšana ir cieši saistīta ar valsts ekonomisko attīstību un prioritātēm. Industriālo telpu un biroju nekustamā īpašuma tirgu var attiecināt uz ekonomikas attīstību veicinošiem un noteicošiem sektoriem. Tie veicina ražošanu un uzņēmēju sadarbību, rada darba vietas, papildina valsts budžeta ienākumus. Nekustamā īpašuma objektiem, kas kalpo šādiem mērķiem, ir jāatbilst nākotnes kvalitātes standartiem.

Autores piedāvā oriģinālu pieeju industriālo telpu ilgtspējīgā piedāvājuma noteikšanai, izmantojot klimata pārmaiņu faktoru salīdzināšanas analīzi un sistēmu un dinamikas rindas analīžu metodikas ekonomiskos aprēķinos.

Tēmai ir zinātniskā un praktiskā aktualitāte un lietojums gan vietējā, gan starptautiskā tirgus līmenī. Pasaules mēroga un vietējās zinātniskajās konferencēs tādās sekcijās kā ilgtspējīga globālā attīstība, ilgtspējīgā pilsētu attīstība, jaunattīstības valstu nekustamā īpašuma tirgu perspektīvas apspriež jautājumus par teritoriju trūkumu Eiropas tirgū, ekoefektīvās ekonomikas attīstību. Tas nozīmē, ka jāizskata ražošanas jaudu pārvietošana. Starp oficiālajiem darba dokumentiem jāizceļ Eiropas Savienības „Latvijas nacionālā Lisabonas programma", „Zemes politikas pamatnostādnes 2008.–2014. gadam", „Teritorijas attīstības plānošanas likumprojekts" un „Latvijas ilgtspējīgas attīstības stratēģija 2030". Savukārt, komercorganizācijas Baltijas un starptautiska mēroga sanāksmēs jautājumiem uzsver jautājumus par industriālo telpu trūkumu un Baltijas tirgus pievilcību.

Ir pieprasījums pēc modeļiem, kurus varētu izmantot teritoriju ilgtspējīgā ekonomiskā plānošanā, ievērojot ekoloģiskās un ekonomiskās pārmaiņas, kā arī strauju globalizācijas procesu.

AGRĀKIE PĒTĪJUMI

Autores turpina uzsākto pētījumu, kā globalizācijas procesā var analizēt un prognozēt nekustamā īpašuma tirgus ilgtspējīgu attīstību, izmantojot sistēmu un dinamikas rindas analīžu metodiku. Izstrādātajā modelī galvenā uzmanība tika veltīta Latvijas klimata pārmaiņu, iekšzemes tirgus potenciāla izmantošanas un valstu ekonomiskās mijiedarbības jautājumiem. Šajā rakstā autores piedāvā rezultātus, kas iegūti un pārbaudīti, lietojot loģiskās pieejas un salīdzināšanas metodes, salīdzināšanai izmantojot 21. gadsimta sākuma datus.

MATERIĀLS UN METODES

Pētījuma objekts ir A klases telpas jeb modernās industriālās telpas Latvijas teritorijā. Piedāvātā metode ir universāla un attiecināma uz nekustamā īpašuma industriālajiem objektiem arī citās valstīs.

Atspoguļotā pētījuma mērķis ir noteikt moderno industriālo telpu tādu apjomu, kas veicinātu konkrēta nekustamā īpašuma tirgus segmenta veiksmīgu attīstību Latvijas teritorijā saskaņā ar vietējā tirgus potenciālu.

Izskatītā ekonomiskā modeļa izstrādāšanai tika izmantoti pasaules nozīmes projekta ENSEMBLES komplekso aprēķinu rezultātu dati, Eiropas Komisijas statistikas, lokālo centrālās statistikas biroju datubāzes, klimata pārmaiņu jautājuma un ekonomikas atjaunošanas jautājumu izpētes autoru publicēto darbu rezultāti un citu oficiālo informatīvo avotu dati.

Tika izvirzīti vairāki uzdevumi.

1. Atspoguļot piedāvātā industriālo telpu nekustamā īpašuma ilgtspējīgā pieprasījuma prognožu modeļa būtību.
2. Noteikt valstis, kuru pašreizējie klimatiskie apstākļi ir līdzīgi prognozētajiem Latvijā (2035. gadā).
3. Veikt analīzi par Latvijas un ārvalstu rūpniecības un lauksaimniecības nozaru attīstības dinamiku un sastādīt prognozes to īpatsvaram un apgrozījumam Latvijā 2035. gadā.
4. Veikt aprēķinus attiecībā uz moderno ražošanas telpu potenciālo piedāvājumu Latvijas nekustamā īpašuma tirgū, lietojot izstrādāto modeli.

Pētījuma ierobežojumi.

1. Analīzes gaitā ir noskaidrots, ka starp vairākiem klimata pārmaiņu novērošanas un izpētes institūtiem, kas darbojas Eiropas Savienības teritorijā, nav vienotas specializācijas un rezultātu izmantošanas mērķa. Lai objektīvi novērtētu vairāku valstu klimata pārmaiņu rādītājus, šajā analītiskajā darbā ir nolemts pamatoties uz ENSEMBLES projekta datiem. Pēc oficiālās informācijas, tie ir vairāku avotu klimatu pārmaiņas datu novērošanas materiālu apkopošanas rezultāts.
2. ENSEMBLES projekta datu analīze prasa konkrēto datorprogrammu un sistēmu iesaistīšanos, kas nav pieejamas.
3. Datu pieejamības ierobežojums un konfidencialitāte. Katrai valstij un to statistisko un citu oficiālo datu atspoguļošanā ir sava fokusēšanās un īpatnības. Šādi, piemēram, iekšzemes kopprodukta struktūras analīzē tika izmantoti vairāki informācijas avoti, bet Zviedrijas kopējā industriālo telpu apjoma statistika plašsaziņas līdzekļos nav pieejama, bet nekustamā īpašuma konsultanti par aktuālu uzskata Stokholmas tirgu, pārējo reģionu statistiku neizplata. Tāpēc Zviedrijas moderno industriālo telpu tirgus analīzē tika izmantoti Stokholmas statistikas un nekustamā īpašuma tirgus dati.

Analizējot Latvijas 2035. gada rūpniecības un lauksaimniecības nozaru prognozes, tika pētīta Čehijas un Zviedrijas rūpniecības un lauksaimniecības nozaru dinamika iekšzemes kopprodukta struktūrā pēdējo divdesmit piecu gadu griezumā.

Tika pieņemti vairāki pētījuma periodi.

1. 2009. gada dati visām valstīm.. Pasaules ekonomiskās krīzes ietekmē veidotais tirgus. Tam piemīt scenārija raksturs, kas atbilst pakāpeniskās ekonomikas atveseļošanas principam.
2. Latvijas analīzes rezultāti tika salīdzināti ar 1998. gada datiem, kad ekonomika vēl nebija nostabilizējusies pēc neatkarības atgūšanas, bet politika bija vērsta uz attīstību un pievienošanos Eiropas Kopienai (laikā no 1996. gada līdz 1998. gada vidum iekšzemes kopprodukts (turpmāk tekstā IKP) gada vidējie pieauguma tempi bija 6% (http://www.em.gov.lv/images/modules/items/tsdep/zin_2001_1.pdf)). 1998. gada rezultātus daļēji ietekmēja Krievijas ekonomiskās krīzes sākums, kas ieviesa korekcijas Latvijas ekonomikā.
3. 2020. gada prognozes ir starpposms 2035. gada prognožu sastādīšanā, jo autores analizēja oficiāli pieejamās IKP prognozes, lai noteiktu nozaru īpatsvara līmeni. Analīzē izmantotās 2020. gada IKP prognozes sagatavojusi pasaules tirgus izpētes kompānija *Euromonitor International* (http://www.euromonitor.com/World_Economic_Prospects).
4. Starpposma prognožu sastādīšanai tika izpētīti statistikas rādītāji no 1998. gada.

Analizējot 2035. gada Latvijas vasaras vidējās temperatūras prognozes (+17,2 °C) un ziemas vidējās temperatūras prognozes (–1,8 °C) tika pieņemts standartnoviržu intervāls +/– 0,5 °C. Analīzē galvaspilsētas tika asociētas ar to pārstāvētajām valstīm. Latvijas gadījumā tas arī sakrīt ar aptuveno vidējo valsts atmosfēras temperatūras rādītāju Rīgā, jo ģeogrāfiski tā atrodas valsts teritorijas vidū.

Rūpniecības nozares attīstības virziena prognožu sagatavošanai autores veica izvēlēto valstu (Latvijas, Čehijas un Zviedrijas) iekšzemes kopprodukta struktūras analīzi nozaru griezumā. Pēc NACE klasifikācijas (http://ec.europa.eu/competition/mergers/cases/index/nace_all.html) rūpniecības nozarē tika iekļautas C (Ieguves rūpniecība un karjeru izstrāde), D (Apstrādes rūpniecība) un E (Elektroenerģija, gāzes un ūdens apgāde) kategorijas. Lauksaimniecības nozare atbilst A (Lauksaimniecība, medniecība un mežsaimniecība), un B (Zvejniecība) kategorijām NACE klasifikācijā. Rakstā uzmanība tiek veltīta Latvijas teritoriju attīstības perspektīvām.

Lai paredzētu, kā mainīsies lauksaimniecības un rūpniecības īpatsvars IKP sastāvā pēc 11 gadiem, tika lietotas dinamikas rindas analīzes formulas.

REZULTĀTI UN INTERPRETĀCIJA

Latvijas moderno industriālo telpu ilgtspējīgas attīstības modeļa būtība ir šāda:

- izmantojot klimata pārmaiņu datu izpēti, kur noteicošais rādītājs ir sezonu vidējā temperatūra Celsija grādos, atrast salīdzināmās teritorijas, kur mūsdienās esošie klimatiskie apstākļi ir līdzīgi Latvijā prognozētajiem apstākļiem klimatisko pārmaiņu rezultātā pēc 25 gadiem.
- Uz šā pamata izvērtēt teritoriju rūpniecības un lauksaimniecības nozaru attīstības dinamiku, izveidojot ekonomiski pamatotas proporcijas izvēlēto nozaru attīstības tendencēm Latvijas teritorijā vidējā augšanas tempa koeficienta un rūpniecības nozares ražīguma izteiksmē (eiro uz kvadrātmetru).
- Rezultātā, zinot izvēlēto valstu – Čehijas un Zviedrijas moderno industriālo telpu apjomus, sastādīti trīs iespējamie scenāriji to attīstības potenciālam Latvijas teritorijā kvadrātmetru un rūpniecības nozares ražīguma eiro uz kvadrātmetru izteiksmē (Staube and Geipele, 2010).

Prognožu sastādīšanai autores pieņēmušas vērā esošo pieprasījumu pēc industriālajām telpām, pēc nekustamā īpašuma statistikas kvadrātmetru izteiksmē, kā arī Baltijas tirgus nepilnīgi izmantotu potenciālu un vietējā tirgus nesabalansētības faktu. Doto modeli var atspoguļot kā parādīts 1. attēlā.

Pamatojoties uz iepriekš aprakstītajām metodēm, autores ir nonākušas pie turpmāk minētajiem aprēķinu rezultātiem un secinājumiem.

Pēc statistikas, vidējās temperatūras paaugstināšanas vairāk nekā par 2 grādiem gadsimta laikā var izraisīt apmēram 40% pastāvošo sugu izzušanu, tādējādi nodarot nozīmīgu kaitējumu lauksaimniecībai. Dabas postošo procesu starpā lielākā nozīme ir atmosfēras vidējās temperatūras pieaugumam, kas var radīt paaugstinātu ugunsgrēku risku mežos, augsnes faunas izmaiņas, ietekmēt augsnes struktūru un auglību, augu slimību un kaitēkļu sugu izplatību. Novērota arī ekosistēmu pielāgošanās , kas spēj pozitīvi ietekmēt mežu produktivitātes pieaugumu un ražības pieauguma iespējas daudzām lauksaimniecības kultūrām (Kļaviņš and Āboliņa 2008, http://www.mps.gov.lv/Ecology.html, http://www.zm.gov.lv/index.php?sadala=34).

Zemes bagātības, zemes rente un valsts ģeopolitiskais stāvoklis nosaka zemes izmantošanas veidus un tautsaimniecības attīstības virzienus. Mainoties klimatiskajiem apstākļiem, valsts ekonomikas attīstības prioritātes var mainīties. Izstrādājot konkrētu ilgtspējīgas attīstības modeli, kura mērķis ir noteikt potenciālo industriālo telpu nekustamā īpašuma tirgus apjomu, nevar ignorēt klimata pārmaiņu jautājumu.

Aktuālajās zinātniskajās publikācijās tiek minētas šādas īpašas klimata mainības ietekmes uz Latvijas teritoriju:

- sausuma periodu skaita pieaugums vasarā;
- augstāka temperatūra ziemā;
- stiprākas lietusgāzes, vētru un vējuzplūdu skaita palielināšanās;
- palielināts plūdu risks – palielinās teritoriju applūšanas biežums un nodarītā kaitējuma apjoms palu laikā, jūras piekrastē vējuzplūdu laikā, kā arī piekrastes teritoriju noskalošanā vētrās (Kļaviņš and Āboliņa 2008).

Pirmie divi faktori kļuva par šī raksta svarīgajiem aspektiem dažādu valstu klimata salīdzinājumā. Pētījuma pamatā tika izmantoti ENSEMBLES starptautiskā zinātniskā projekta dati (http://ensembles-eu.metoffice.com/misc_docs.html, http://www.metoffice.gov.uk/climatechange/science/projects/ensembles_map.html), kuri atšķirībā no citiem klimata izmaiņu pētījuma datiem ir izlīdzināti pēc vienotās metodes.

Klimata izmaiņu prognozēšanas modeļos pasaulē lieto dažādas metodes (Kļaviņš and Āboliņa 2008, http://news.bbc.co.uk/2/hi/science/nature/6320515.stm http://www.metoffice.gov.uk/climatechange/science/projections/), to skaitā CO_2 emisijas pieauguma vai samazināšanas ietekmi, kā arī ekonomisko un sociālo izaugsmi. Visi modeļi norāda uz Zemes globālās sasilšanas pastāvīgu turpinājumu visos reģionos, kas galvenokārt saistīts ar jau esošo atmosfēras piesārņojumu.

Pētījuma aprēķinos 20. gadsimtā fiksētie vēsturiskie dati ietekmē datu prognozes. Tās liecina, ka Rīgas vasaras un ziemas temperatūras rādītāji 2035. gadā klimata pārmaiņu rezultātā ir salīdzināmi ar Prāgas un Stokholmas fiksētajiem atmosfēras temperatūras rādītājiem.

Pēc 2. attēlā apkopotajiem datiem redzams, ka pieļautās novirzes robežās atrodas_pārsvarā vasaras temperatūras rādītāji. Saskaņā ar analīzes rezultātiem vidējais Eiropas temperatūras pieaugums Eiropā nākamajos prognozētajos 25 gados vasarā un ziemā ir 1,52 °C un 1,64 °C gadā (attēlā nav atspoguļots).

Pilnīgas klimata sakritības dabā nevar atrast un sasniegt. Valstu teritorijas atrodas dažādās ģeogrāfiskajās dabas vidēs: Latvija – Baltijas jūras līča krastā maiga un mitra klimata zonā; Čehija ir kontinenta vidū Centrālās Eiropas kalnu rajonā tālu no piejūras zonas, kurai raksturīgs mēreni kontinentāls, maigs klimats, bet Zviedrija ir Atlantijas gaisa masu ietekmē. Zviedrijai ir raksturīgs pārejas klimats (no jūras uz kontinentālo), jo tās austrumu un dienvidu krastu pilnīgi apskalo Baltijas jūras ūdeņi, rietumos teritoriju aizsargāa kalnu zona (http://www.latvia.travel/lv/klimats-un-laika-apstakli, http://www.prahaclub.cz/clamate-czech-republic.htm, http://www.wordtravels.com/Travelguide/Countries/Sweden/Climate/).

Tā kā Latvijā, Čehijā un Zviedrijā ir kopīgas klimata iezīmes: maigs klimats un salīdzināmi temperatūras rādītāji, autores izvēlējās veikt šo valstu ekonomiski statistisko datu analīzi.

Patēriņa cenu indekss (PCI turpmāk tekstā) pēdējos 10 gados salīdzināmās cenās ir ievērojami pieaudzis. Atzīmēts krituma tendences sākums, sasniedzot 169,0% 2010. gadā. Redzams, ka pirms pasaules finansiālās krīzes tas bija nedaudz virs 2000. gada līmeņa (sk. 3.att.).

Latvijas zinātnieki ir secinājuši, ka tautsaimniecībā saražotās pievienotās vērtības dinamiskās rindas raksturs garākā periodā salīdzināmās cenās būtiski atšķiras no pievienotās vērtības dinamiskās rindas rakstura faktiskajās cenās. Bet garākā un īsākā perioda trenda funkcijās iekļauto parametru vērtības ir lielākas īsākā laika perioda trenda funkcijām, kas norāda uz pievienotās vērtības pieauguma intensitātes pakāpenisku palielināšanos, saīsinoties dinamiskās rindas garumam (Vanags and Geipele 2008).

1.–4. tabulā atspoguļoti galvenie izpētes rezultāti. Tie izskaidrojami galvenokārt ar PCI ievērojamām izmaiņām.

1. tabula. **2009. gada IKP struktūra Latvijā, Čehijā un Zviedrijā, %**

Rādītāji / valstis	Čehija	Latvija	Zviedrija
Pavisam, IKP	100	100	100
Lauksaimniecība, medniecība un zvejniecība	2	3	2
Rūpniecība, ieskaitot enerģijas apgādi	30	14	20
Būvniecība	8	7	6
Tirdzniecība, viesnīcas un restorāni, transports un sakari	24	28	21
Komercdarbība un finanšu starpniecība	18	26	25
Pārējie pakalpojumi	18	22	26

Avots: Eiropas Komisijas EUROSTAT dati (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database)

1. tabulā ir apkopota informācija par IKP struktūru 6 svarīgākajām tautsaimniecības nozarēm katrai no atlasītajām valstīm.

Table 1 contains data on Gross Domestic Product (GDP further in text) structure for 6 main economy branches for each focus country: Latvia, Czech Republic and Sweden.

2. tabula. **2009. gada rūpniecības nozares ražīguma salīdzinājums, salīdzināmās cenās (2000. gads = 100)**

Rādītāji / valstis	Čehijas	Stokholma (Zviedrija)	Latvija
Rūpniecības nozares IKP, miljardi eiro	55,3	10,2	1,3
Moderno industriālo platību tirgus, miljoni m^2	3,36	11,00	0,45
Rūpniecības IKP uz 1 m^2 moderno industriālo telpu platību, eiro/ m^2	16 500	927	2900

Avots: oficiālie statistikas dati (http://www.scb.se/default____2154.aspx, http://www.czso.cz/csu/2009edicniplan.nsf/engkapitola/0001-09-2009-0700, http://www.csb.gov.lv/), publicētie tirgus dati (http://www.xe.com/ucc/convert.cgi?Amount=1&From=USD&To=EUR&image.x=66&image.y=9&image=Submit, http://www.kingsturge.com/) un raksta autoru aprēķini

2. tabulā tiek piedāvāti komplekso aprēķinu rezultāti Latvijas rūpniecības nozares ražīguma un moderno industriālo telpu apjoma scenāriju sastādīšanai.

Table 2 presents the results from the complex calculations as a basis for the further scenarious assessment on the manufacturing branch capacity and modern industrial real property stock.

Čehijā visaugstāko pievienoto vērtību mūsdienās dod rūpniecības nozare (30%). Pēc pasaules reitingiem Čehija, neraugoties uz nelielo neatkarības pieredzi, ir ierindota progresīvās ekonomikas valstu sarakstā. Savukārt, Latvijā izplatītāka ir tirdzniecība, sabiedriskās apkalpošanas, ēdināšanas biznesa un sakaru pakalpojumi, t. i., lielāku īpatsvaru veido tieši pakalpojumu sfēra.

Zviedrijā lauksaimniecības īpatsvars IKP ir līdzīgs Čehijas rādītājam (2%), bet rūpniecības nozare atpaliek no pārējo pakalpojumu nozares īpatsvara par 5 procentpunktiem. Latvijā lauksaimniecībai ir lielāks pievienotās vērtības īpatsvars salīdzinājumā ar Čehiju un Zviedriju. XX gadsimta beigās Latvijā IKP struktūrā bija ievērojami lielāks īpatsvars rūpniecības nozarei, un, pateicoties straujai tirdzniecības attīstībai, tuvs 2009. gada Zviedrijas rādītājam. Savukārt, desmit gadu laikā šajā nozarē straujāk krita apgrozījuma īpatsvars IKP nekā pārējās nozarēs – mīnus 8 procentpunkti, savukārt, lielākais pieaugums bija vērojams komercdarbības un finanšu starpniecības sfērā – par 11 procentpunktiem.

Lai redzētu, kā mainīsies lauksaimniecības un rūpniecības īpatsvars IKP sastāvā pēc 11 gadiem, tika lietotas dinamikas rindas analīzes formulas.

Vidējā augšanas tempa formula:

$$\overline{T_b} = \sqrt[n-1]{\frac{Y_n}{Y_1}} \qquad (1)$$

kur $\overline{T_b}$ – bāzes vidējais augšanas temps,

Y_n – beigu perioda vērtība,

Y_1 – sākuma perioda vērtība,
n – izpētes perioda gadu skaits.
Augšanas tempa līmeņa pieauguma formula:

$$T_b = \overline{T^n} \qquad (2)$$

kur T_b – bāzes augšanas tempa pieaugums,
$\overline{T}$ – noteiktais vidējais augšanas temps,
n – izpētes perioda gadu skaits.

Latvijas IKP 2020. gada prognozes pēc pasaules tirgus izpētes kompānijas *Euromonitor International* atskaites datiem uz 1 cilvēku sastāda 17 029 ASV dolāru vai 12 770 eiro[1] (http://www.euromonitor.com/World_Economic_Prospects). Savukārt, pēc Austrijas Zinātņu akadēmijas prognožu datiem 2020. gadā iedzīvotāju skaits Latvijā varētu būt 1,803 miljoni (Scherbov *et al.*, 2008). 2020.gadā Latvijas iekšzemes kopprodukta apjoms varētu būt 24,17 miljardi eiro, kas ir 1,3 reizes lielāks par 2009. gada IKP apjomu.

Rūpniecības nozarei periodā no 1998. līdz 2009. gadam Čehijā un Zviedrijā ir gandrīz līdzīgi vidējie augšanas tempi: attiecīgi 1,03 un 1,00. Latvijas 2035. gada gala prognožu rezultātos pēc Zviedrijas datu scenārija rūpniecības nozares īpatsvars tika proporcionāli pielīdzināts galvaspilsētas un tās tuvākās apkārtnes (Rīgas un Pierīgas) reģiona un lielpilsētu teritoriju īpatsvaram no kopējā Latvijas IKP. Saskaņā ar oficiālajiem statistikas datiem, galvaspilsētas un Pierīgas, kā arī lielpilsētu reģionu rūpniecības nozares īpatsvars sastāda ap 56% no kopējā Latvijas rūpniecības nozares apgrozījuma (sk. 3. tabulu).

Saskaņā ar 2. tabulā apkopotajiem statistikas un aprēķinu datiem Čehijas 2009. gada modernā industriālā nekustamā īpašuma tirgus apjoms sastāda 31% no Stokholmas tirgus apjoma, bet tas vairāk nekā 7 reizes pārsniedz Latvijas kopējo šīs tirgus nišas piedāvājumu. Ja salīdzina rūpniecības nozares pievienotās vērtības salīdzināmās cenās, Stokholmas galvaspilsētas rādītājs ir tikai 5 reizes mazāks par Čehijas rūpniecības nozares pievienoto vērtību.

2035. gada prognozes Latvijai paredz, ka vidēji par nedaudz vairāk nekā 2 procentpunktiem lauksaimniecības īpatsvars samazināsies pret esošo 2009. gada rādītāju, absolūtajā izteiksmē pievienotajai vērtībai samazinoties par 40% (sk 3. tabulu). Faktiskajās cenās šī tendence bija pretēja – pieaugums 2,6 reizes no esošā līmeņa, kas faktiski nozīmē ievērojamu PCI pieaugumu.

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[1] 1.00 USD = 0.75 EUR (http://www.xe.com/ucc/convert.cgi?Amount=1&From=USD&To=EUR&image.x=66&image.y=9&image=Submit)

3. tabula. **Latvijas prognozes 2035. gadam pētījuma rezultāti, IKP un pievienoto vērtību daļa sniegta salīdzināmās cenās, tūkst. eiro (2000. gads = 100)**

Rādītāji / Valstis		Pēc Čehijas datiem	Pēc Zviedrijas datiem	Vidējais svērtais rezultāts
Scenārijs		OPTIMISTISKAIS (1)	PESIMISTISKAIS (2)	VIDĒJAIS (3)
Iekšzemes kopprodukts	2020. gada prognoze, eiro	24 164 563 551		
Lauksaimniecība, medniecība un zvejniecība	Pievienotā vērtība	162 120	294 000	228 000
	Īpatsvars no IKP, %, 2020. gadā	0,67	1,22	0,94
	Vidējais augšanas temps (T_b)	0,97	0,99	0,98
Rūpniecība, ieskaitot enerģijas apgādi	Pievienotā vērtība, kopā Latvijā	3 041 200	1 271 500	2 156 350
	Īpatsvars no IKP, %, 2020. gadā	12,60	5,26	8,90
	Pievienotā vērtība, lielpilsētu reģioni, %	-	55,75%	-
	Pievienotā vērtība, lielpilsētu reģioni	-	708 834	-
	Vidējais augšanas temps (T_b)	1,03	1,00	1,02
Moderno industriālo platību tirgus, m^2		184 660	767 600	248 000
Rūpniecības IKP uz 1 m^2 moderno industriālo telpu platību, eiro/m^2		16 500	927	8696

Avots: oficiālie statistikas dati (http://www.scb.se/default____2154.aspx, http://www.czso.cz/csu/2009edicniplan.nsf/engkapitola/0001-09-2009-0700, http://www.csb.gov.lv/), publicētie tirgus dati (http://www.xe.com/ucc/convert.cgi?Amount=1&From=USD&To=EUR&image.x=66&image.y=9&image=Submit, http://www.kingsturge.com/) un raksta autoru aprēķini

3. tabula atspoguļo pētījuma mērķa aprēķinu rezultātus. Ir sastādīti 3 scenāriji Latvijas moderno industriālo telpu tirgus attīstībai.

Table 3 obtains the research target analysis results. Three scenarious (pesimistic, optimistic and moderate) are proposed for the development of the Latvian modern industrial real property.

Saskaņā ar pētījumā iegūto informāciju, ja vērtē pēc rūpniecības attīstības scenārijiem, Čehijas scenārijs ar augstāku rūpniecības attīstības tempu un lēnāku lauksaimniecības nozares attīstību ir apzīmēts kā optimistiskais scenārijs.

Čehijas tirgu raksturo zems piedāvājuma (salīdzinājumā ar tirgus pieprasījumu), bet liels nozares apgrozījuma apjoms, savukārt, Latvijā pārāk liels platību apjoms un augsts vakanto platību līmenis, jo tas pārsniedz tirgus pieprasījumu un atbilst zemām ražošanas kapacitātēm. Tomēr ir svarīgas atšķirības – Latvijas industriālā nekustamā īpašuma tirgus ir mazattīstīts, netiek izmantots izdevīgā ģeopolitiskā stāvokļa potenciāls, kā arī ir nopietni šķēršļi jaunu ražotņu ienākšanai (neadekvāta nodokļu politika, infrastruktūras attīstības trūkums un citi iemesli) (Štaube and Geipele, 2010).

Saskaņā ar iegūtajiem rezultātiem (sk. 4. tabulu), ja realizējas pirmais scenārijs, 6 reizes augstāko rūpniecības nozares ražīgumu var panākt, pastāvot moderno industriālo platību tirgus apjomam, kas ir mazāks par esošo. Savukārt, Zviedrijas scenārijs atspoguļo situāciju, ka 2000. gada salīdzināmajās cenās Zviedrijas rūpniecības ražīgums ir diezgan zemā līmenī. Tas ir izskaidrojams ar zemākajiem inflācijas tempiem Zviedrijā (vidējais ikgadējais reģistrētais cenu izmaiņas indekss sešām vadošajām ekonomikas nozarēm (sk. 1.tabulu) 2000. gada salīdzināmajās cenās no 1998. gada līdz 20009. gadam ir 0,8% Čehijā un 1% Zviedrijā. Ja Zviedrijas nekustamā īpašuma tirgus statistiskie dati būtu plašāk pieejami, iespējams, tas mainītu rezultātu pozitīvā virzienā, palielinoties pievienotajai vērtībai rūpniecības nozarē uz 1 m^2 moderno industriālo telpu platību.

4. tabula. **Latvijas 2035. gada prognožu un 2009. gada salīdzinājums, reizēs**

Rādītāji / Scenārijs	1	2	3
Lauksaimniecības nozares IKP	0,43	0,78	0,60
Rūpniecības nozares IKP	2,36	1,00	1,67
Īpatsvars no IKP 2020. gadā	0,54	0,38	0,46
Moderno industriālo platību tirgus	0,41	1,71	0,55
Rūpniecības IKP uz 1 m^2 moderno industriālo telpu platību	5,75	0,32	3,04

Avots: raksta autoru aprēķini

4. tabulā autores analizē tagadējos un prognozējamos datus par katru pētījuma svarīgāko rādītāju (lauksaimniecības un rūpniecības pievienotā vērtība, nozaru īpatsvars IKP 2020. gadā, pētījuma nekustamā īpašuma sektora apjoms un ražošanas kapacitāte).

The authors present the analysis of the main research ratios (added value of agriculture and manufacturing branches, percentage from GDP 2020, stock of the research target real estate sector and manufacturing capacity) for 2009 and 2035 in the table 4.

Saskaņā ar analīzes trīs scenāriju (nosacīti tie apzīmēti kā pesimistiskais, optimistiskais un vidējais) rezultātiem, Latvijas nekustamā īpašuma tirgum un rūpniecības nozares attīstībai ir vairākas perspektīvas.

1. Rūpniecības nozares īpatsvars IKP struktūrā 2035. gadā var palielināties vidēji 1,67 reizes, sasniedzot pieaugumu līdz aptuveni 2 miljoni eiro 2000. gada salīdzināmajās cenās, ja vidējais augšanas temps ir 1,02, kas ir pielīdzināms Čehijas un Zviedrijas rūpniecības nozares attīstības dinamikai.
2. Lai sasniegtu prognozējamo pozitīvas attīstības tendenci, moderno industriālo platību tirgus no pašreizējā kopējā piedāvājuma 450 000 m^2

(http://www.colliers.com) nav jāpalielina, tieši pretēji, pastāvot pašreizējiem ražošanas apjomiem, moderno industriālo telpu piedāvājums var būt 2 reizes mazāks. Pašreiz saskaņā ar oficiālajiem datiem brīvo platību procents kopējā Latvijas moderno industriālo telpu piedāvājumā sastāda ap 34% un ir pieaudzis 10 reizes kopš 2008. gada janvāra (http://www.colliers.com).

3. Sekojot Zviedrijas ražošanas un loģistikas tirgus attīstības scenārijam, moderno industriālo telpu piedāvājums var maksimāli pieaugt par 2 reizēm, pastāvot nosacījumam, ka lielāko daļu no industriālajām telpām tiks izmantotas pakalpojumu nozares vajadzību apmierināšanai (piemēram, loģistikas vajadzībām). Izpētes rezultāti liecina par lauksaimniecības nozares attīstības turpinājumu efektivitātes paaugstināšanās virzienā, apzinot to nepieciešamības pakāpi un tirgus pieprasījuma prognozes. Zviedrijas scenārija gadījumā ir jāpārvar vairāk šķēršļu un, iespējams, efektīvā nevis ekstensīvā attīstība tiek piemērota šīs valsts teritorijā, lai apgādātu savu tirgu un arī apmierinātu citu valstu pieprasījumu. Kā zināms, 2009. gadā Zviedrijas investīciju apjoms ražošanas nozarē ārzemēs sastādīja ap 180 miljardiem ASV dolāru, kas ir gandrīz vienāds ar uzkrāto ārvalstu investīciju apjomu Zviedrijas ražošanas nozarē (Štaube and Geipele, 2011). Otrajā scenārijā paredzētie attīstības tempi tiktu vairāk piemēroti, ja valsts interesēs būtu ekonomiski pamatota lauksaimniecības nozares attīstība.

Starp rūpniecības politiku ietekmējošiem būtiskākiem faktoriem jāmin kvalitātes nodrošināšana, uzņēmējdarbības veicināšana un uzņēmējdarbības vides pilnveidošana, ilgtspējīga attīstība (Šatrevičs and Zvanītājs, 2010).

Saskaņā ar Reģionālās attīstības un pašvaldības lietu ministrijas dokumentu „Zemes politikas pamatnostādnes 2008.–2014. gadam" (http://www.zm.gov.lv/doc_upl/pamatnostadnes.pdf) Latvijā par problēmu ir uzskatāma neefektīva zemes izmantošana, bet citās valstīs tiek runāts par izmantojamās zemes trūkumu. Eiropas Komisijas paziņojumā Eiropas Padomei un Eiropas Parlamentam „ES pamatnostādnes zemes politikas izstrādes un reformu procesu atbalstam jaunattīstības valstīs" tiek uzsvērts, ka „zemes jautājums atkal ir kļuvis aktuāls sakarā ar pieaugošo zemes trūkumu, bažām par konfliktiem saistībā ar zemi, kā arī nabadzību laukos".

Savukārt, vairāki ārzemju investori un uzņēmumu apvienības no Eiropas un Krievijas izsaka vēlēšanos un gatavību izvietot Latvijā meitas uzņēmumus, kas pārstāvētu viņu kompāniju Baltijas reģionā. Tomēr joprojām tiek atzīmēta infrastruktūras attīstības un nekustamā īpašuma tirgus piedāvājuma neatbilstība pieprasījumam.

Lisabonas programmā ir noteikts nodrošināt makroekonomikas un finanšu sektora stabilitāti, ņemot vērā pastāvošo izteiktas un ilgstošas lejupslīdes risku. Autores saista vietējā tirgus nestabilitāti un nesabansētību ar tirgus nesakārtotību un konsekvences trūkumu, kā arī saskata šajā ieteikumā piesardzīgu pieeju ekonomistu optimistisko scenāriju veidošanā (Štaube and Geipele, 2010).

Pasaules ekonomikas līderes ietekmē pārējās valstis ne tikai sakarā ar savu teritoriju zemes resursu bagātības augsto līmeni un ietekmi citās teritorijās, bet arī ražošanas jaudām un tehnoloģiskajiem risinājumiem, zināšanu augsto līmeni, kā arī rūpniecības uzņēmumu racionālo izkārtojumu citās teritorijās.

Pašreiz Latvijā vidējais svērtais zemes kvalitātes novērtējums[2] ir 38 balles, kas, ņemot vērā Latvijas klimatiskos apstākļus, tiek uzskatīts par minimālo auglības līmeni attiecībā uz lauksaimniecībā izmantojamo zemi, lai varētu nodrošināt komerciāli dzīvotspējīgu lauksaimniecību (http://www.em.gov.lv/images/modules/items/tsdep/zin_2009_2.pdf). Eiropas Savienība arī subsidē zemniekus, kas īstermiņa un/vai vidējā termiņa periodā neapstrādā konkrētas teritorijas. Latvijas neizmantotās lauksaimniecības zemes var reģenerēties. Tas labvēlīgi ietekmētu zemju auglību nākotnē. Eiropas Kopējā lauksaimniecības politika ir virzīta uz lauksaimniecības liberalizāciju, kurai vietējais tirgus vēl nav gatavs. Mūsu valstij būtu nepieciešams veicināt iekšējo lauksaimniecības un ražošanas sektoru ekonomiski pamatotu politiku. Veiktās izpētes rezultātā autores saskata, ka optimāli ir ievērot nozares vidējo augšanas tempu 0,98 tuvāko 26 gadu laikā.

DISKUSIJA

Saskaņā ar iepriekš minētajiem rezultātiem autores nonākušas pie vairākiem secinājumiem.

Ņemot vērā pašlaik nelabvēlīgos apstākļus nekustamā īpašuma tirgus attīstībai, kas saistīti ar ekonomisko recesiju un politisko nestabilitāti, rodas nepieciešamība ievērot vairākus faktorus plānojamā piedāvājuma prognozēšanā Latvijā. Autores piedāvā Latvijas moderno industriālo telpu ilgtspējīgas attīstības modelim, ņemot vērā klimata pārmaiņu datu izpēti, kas pamatojas uz loģiskās pieejas un salīdzināšanas metodēm. Pirmais attēls atspoguļo konkrētā modeļa būtību shematiskā veidā (sk. 1. att.). Autores prezentē apkopotos pētījuma rezultātus par būtiskākajām īpatnībām klimatisko pārmaiņu jautājumā un to piemērošanu Latvijas teritorijā, analizējot vides jautājumu speciālistu viedokļus un pētījumu rezultātus. Tālākajā teksta izklāstā Latvija tiek salīdzināta ar Čehiju un Zviedriju (sk. 2. att.). Apgalvojumi un pierādījumi par PCI ietekmi un ekonomiskie rādītāji salīdzināmās cenās parādīti 3. attēlā. Svarīgākie skaitliskie secinājumi un pierādījumi iekļauti 1.–4. tabulā. Izmantojot vidējā augšanas tempa un augšanas tempa līmeņa pieauguma formulas, skaitliski ir pierādīts, ka esošais moderno industriālo tirgu piedāvājums saskaņā ar Čehijas un Zviedrijas scenārijiem ir pietiekams, bet rūpniecības nozares ražīguma līmenis Latvijā ir zems.

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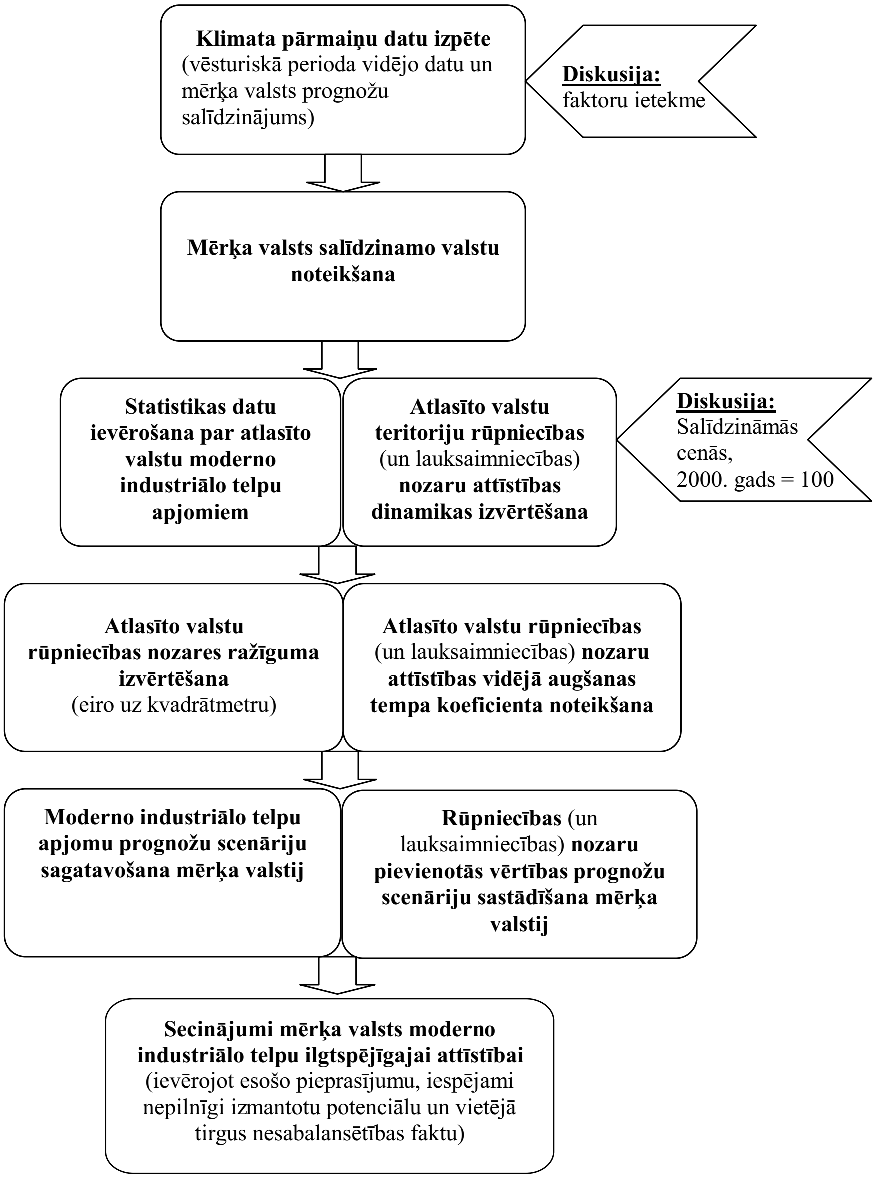
[2] Zemes kvalitātes novērtējums ir aprēķināts rādītājs, kas nosaka zemes ražotspēju, ievērojot augsnes galvenos raksturojošos faktorus un pazīmes (maksimālais rādītājs ir 100 balles).



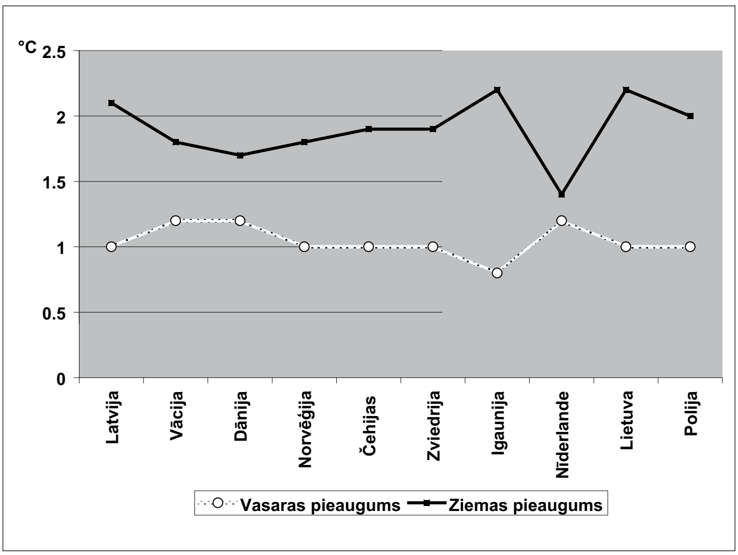
1. att. **Latvijas moderno industriālo telpu ilgtspējīgas attīstības modeļa būtība.**
Avots: autoru piedāvātā shēma.

Shēma atspoguļo galveno ideju un pētījuma pamata procesus ar mērķi, ka to var aprobēt arī citām valstīm un ar laiku papildināt un pilnveidot ar citiem rādītājiem. Diskusija: faktoru ietekme. Šeit autores aicina sadarbībai vides izpētes jautājumu speciālistus turpmākajiem pētījumiem, izvērtējot arī citus klimatisko pārmaiņu faktorus, kas iespējams var ietekmēt rezultātus.

Diskusija: salīdzināmās cenās, 2000. gads = 100. Autores ir atspoguļojušas, ka šī pētījuma pamatā salīdzinātas ekonomiskās dinamiskās rindas ir sastādītas salīdzināmās cenās.

The main idea and processes of the research are presented in Figure 1 with the purpose to further prove for other countries forecasts and additing and improving the model by adjusting the other factors and ratios. The bullets mark the discussion and scope for the further adjustment:

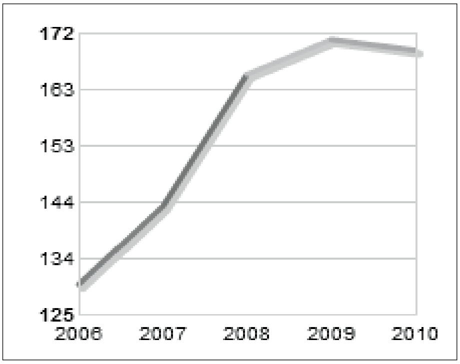
1) Diskusija: faktoru ietekme. Discussion: factors influence means the invitation for the specialists of the environment research scope to measure the relevance and necessity to add more factors of the climate change that possibly may change the results.
2) Diskusija: salīdzināmās cenās, 2000.gads = 100. Discussion: comparitive prices year 2000 = 100. The authors present the part that the system and dynamic row's analysis is carried by applying the comparison approach method considering the official statistics available and comparative.



2. att. **Vasaras un ziemas atmosfēras temperatūras pieaugums no vēsturisko vidējo datu līmeņa līdz prognozētajam 2035. gada līmenim Baltijas jūras reģiona valstīs.**

Avots: ENSEMBLES projekta dati (http://ensembles-eu.metoffice.com/misc_docs.html) un raksta autoru aprēķini

Figure 2 shows the 2035 forecasted atmosphere temperature increase from the historical average level. Data are gathered from ENSEMBLES project for the reflected the Baltic Sea Region's countries.



3. att. Patēriņa cenu indeksa izmaiņas (2000. gads = 100).
Avots: Latvijas Republikas centrālā statistikas pārvaldes informācija http://www.csb.gov.lv/

3. attēls atspoguļo patēriņa cenu indeksa izmaiņas salīdzināmās cenās, Latvijas ekonomikai pārejot no brieduma uz lejupslīdes stadiju. Par pamatu ņemts 2000. gads – Latvijas ekonomikas straujas attīstības sākumposms.

The Figure 3 is adopted from the presentation of the Central Statistical Bureau of Latvia. This shows the consumer price index changes in comparitive prices for the period of mature phase to the economy recession. The year 2000 – the beginning of the rapid economy development of Latvia serves as a basic year.

Neskatoties uz informācijas ierobežojumu, kas varētu potenciāli izmainīt Zviedrijas scenārija prognozes, pētījums konkrēti norāda, ka pašreizējās ražošanas jaudas Latvijā ir zemas, piedāvājuma pieaugums ir neadekvāts un nav nepieciešams. Efektīvi darbojoties, rūpniecības nozares ražīguma potenciāls Latvijā ir vairākas reizes lielāks, ja to attiecina uz rūpniecības nozares apgrozījumu moderno industriālo telpu kontekstā. Te var arī piebilst, ka dotās prognozes vairāk ir attiecināmas uz moderno industriālo telpu piedāvājuma atbilstību ražošanas sektora vajadzībām.

Autores iesāk diskusiju par faktoru daudzveidības pieņemšanas nepieciešamību un komplekso aprēķinu veikšanas iespējām, līdzdarbojoties vides jomas speciālistiem Latvijā un ārzemēs. Lai sekotu izstrādātā modeļa scenārijiem, ir nepieciešams ieviest stingras valsts ekonomikas attīstības un teritorijas ilgtermiņa nostājas, kā arī nozaru attīstību veicinošos un atbalstošos pasākumus. Latvijas zemēm primāri ir jābūt pieejamām nomā nevis īpašumā ārvalstu pārstāvniecību partneriem, stimulējot ražošanas attīstību un ņemot vērā ekoefektīvas ekonomikas nostādnes Eiropā. Iekšzemes zemju potenciāls jāvērtē atbilstoši rūpniecības un lauksaimniecības nozaru attīstības perspektīvām. Autores aicina zinātniekus un profesionāļus detalizēti izanalizēt valsts teritoriju, lai varētu veikt ilgtspējīgas attīstības plānošanu. Izstrādātais modelis ir viens no tirgū piedāvājamām alternatīvām.

PATEICĪBAS

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