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Ob river floodplain mire

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Mires occupy 40% of the Ob river floodplain within the taiga zone. Their forming started about 8 or 9 thousand years ago. Floodplain mires are highly productive ecosystems. Total standing crop is 4.0 or 6.5 t*ha-1. Standing crop of living phytomass takes 50-60% of the total standing crop. The peak of living phytomass (4.5 t*ha-1) is registered in sedge-brownmoss fen, the minimum (4.3 t*ha-1) is in pine-shrub ridge. Net primary production (NPP) is 2.7 t*ha-1*yr-1 in sedge-brownmoss fen, it decreases to 2.0 t*ha-1*yr-1 in pine-shrub ridge. Above-ground production (ANP) takes 7-10% of NPP, below-ground production (BNP) is 75%, brown mosses production is 15-18%. Mass losses of litter have changed from 25 to 85% in the last two years depending on fraction and species. Brownmoss litter losses about a quarter during one-year decomposition. Herewith element losses are following: 90% for Na and K, 73% for Mg and 3% for Ca.

Keywords: floodplain mire, standing crop of phytomass, above-ground production, below-ground production, decomposition, element losses.

Introduction

Mires occupy about 35-40% of the Ob river floodplain within the taiga zone of Western Siberia. The Ob valley consists of 4 or 5 terraces formed during the Late Pleistocene and Holocene periods [1]. Peat layer of 5-8 m thick was formed in the Holocene and is deposited on the youngest terrace. Clay and silt layers occur inside the peat as a result of river flooding. Mire nutrient base are outlets of ground waters rich in calcium and moisture going into the floodplain from the higher valley levels. Additional water sources are spring river overflow and precipitation. Bed streams often play indirect role ponding local terrace water during the high water [2].

Under the long-term surface and ground overmoistening in the near-terrace floodplain part and in the central part of depressions eutrophic peatlands are formed. Available radiocarbon dates show that the floodplain mires within the taiga zone started forming about 8 or 9 thousand years ago [3]. Distinct micro-relief is formed with sedge hummocks and mire herbs take a great part in the vegetation cover. In the mire near-terrace part open herb-reed community (Fig. 1), sedge-brownmoss fens and rich ridge-fen complexes are spread. Dwarf birch-sedge-brownmoss communities of high flooding are specific to the places of abundant ground water outlets. Birch-*Carex cespi-*

Figure 1. Herb-reed (*Phragmites australis* (Cav.) Trin. ex Steud.) community.

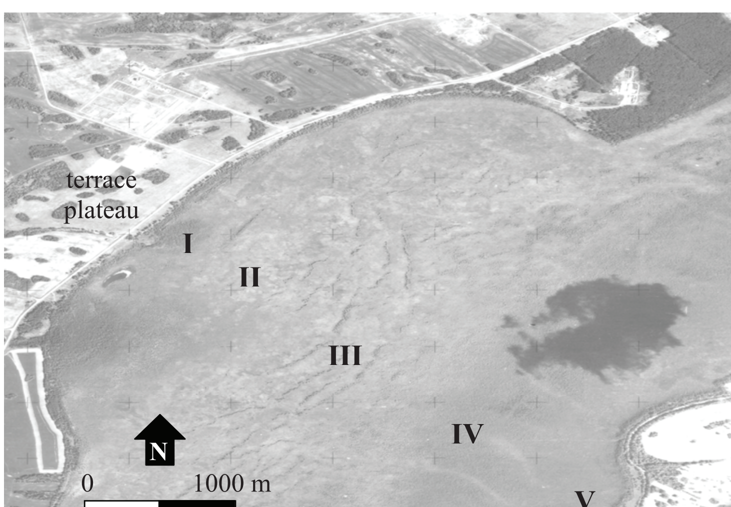


Figure 2. Vegetation communities of the Ob mire transect (Schipper et al., 2007): I – herb-reed community, II – bogbean-sedge-brownmoss fen, III – rich ridge-fen complex, IV – sedge-brownmoss fen, V – willow-sedge community.

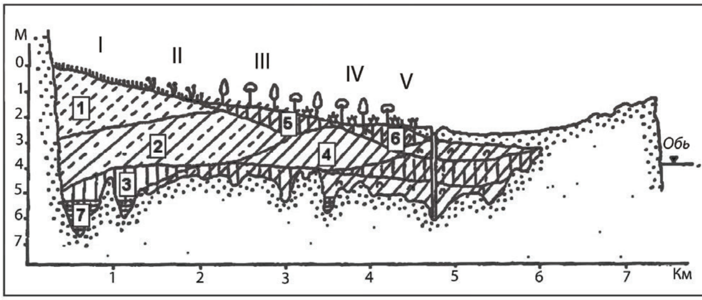


Figure 3. Vegetation communities and peat types of the Ob mire transect (Lapshina, 1987): I – herb-reed community, II – bogbean-sedge-brownmoss fen, III – rich ridge-fen complex, IV – sedge-brownmoss fen, V – willow-sedge community. Peat types: 1 – brownmoss peat, 2 – sedge radicel-brownmoss peat, 3 – wood peat, 4 – sedge radicel peat, 5 – wood-sedge radicel peat, 6 – sedge radicel eutrophic peat, 7 – clay.

Figure 4. Birch-shrub-sedge-brownmoss fen.

Figure 5. Location of the study area.

Figure 6. Bogbean (*Menyanthes trifoliate* L.) – brownmoss fen. Pine-shrub ridge with birch is behind the fen.

Figure 7. Sedge-brownmoss fen with *Carex lasiocarpa* Ehrh. and *Cicuta virosa* L.

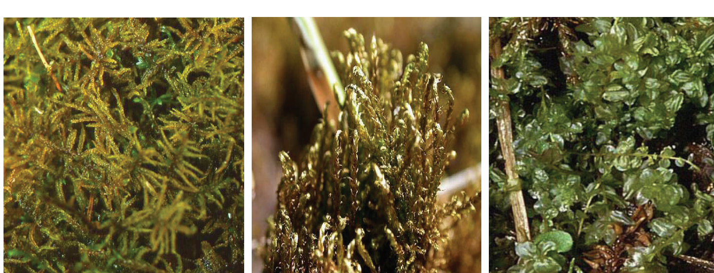
Figure 8. Vegetation community with *Carex appropinquata* Schumach. and *Typha latifolia* L.

A B C

Figure 9. The *Cyperaceae* species: A – *Carex rostrata* Stokes, B – *C.lasiocarpa* Ehrh., C – *C.chordorrhiza* Ehrh.

A B C

Figure 10. The *Orchidaceae* species: A – *Dactylorhiza incarnata* (L.) Soo, B – *Epipactis palustris* (L.) Crantz, C – *Herminium monorchis* (L.) R. Br.



A B C

Figure 11. The brown mosses: A – *Helodium blandowii* (F.Weber & D.Mohr) Warnst., B – *Drepanocladus aduncus* (Hedw.) Warnst., C – *Plagiomnium ellipticum* (Brid.) T.J.Kop.

A B C

Figure 12. Mire herbs: A – *Polemonium caeruleum* L., B – *Ranunculus lingua* L., C – *Lysimachia vulgaris* L.

Figure 13. Pine-shrub ridge with birch.

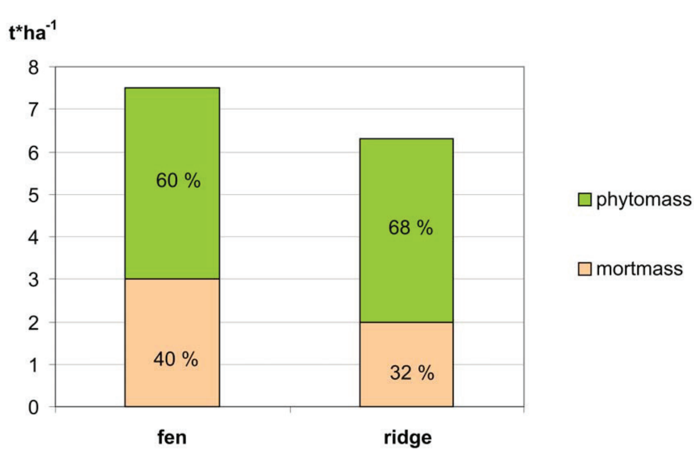


Figure 14. Standing crop in rich ridge-fen complex.

tosa L. and birch-willow-*C. cespitosa* communities are spread in the central part of the mire. Stripe-shaped *C. cespitosa* communities bound mires on the side of near-bed bank (Fig. 2, 3, 4).

The transverse profile of the present floodplain surface is characterized with the highest marks at the mire terrace bottom, lower central part and slightly raised near-bed bank. As for mineral mire bed, it is on the level of the present river low water. Floodplain peatlands are characterized with asymmetric peat body shifted towards the near-terrace part with maximum deposit thickness at the terrace bottom and its gradual decreasing towards the river bed. Asymmetry is also seen in the deposit stratigraphy in the peatland near-terrace, central and periphery (near-bed) parts [4].

The aim of the given investigation is to reveal the present state of the floodplain mire productivity and the peculiarities of standing crop distribution and structure within the taiga zone.

Study Sites, Sampling and Analyses

The study site is the Ob mire (56°30' N – 84°01' E). The mire stretches approximately 150 km along the Ob terrace in the northern part of its upper flow on the left bank near Melnikivo, Tomsk region. The mire system width fluctuates from 1 to 5 km (Fig. 5).

The vegetation of the Ob mire is a combination of rich sedge-brownmoss, bogbean-sedge-brownmoss (Fig. 6), shrub-sedge-brownmoss fens and stretched ridges with sparse trees. The ridges run parallel to the Ob river. Wide sedge-brownmoss fens occupy the most part of the Ob mire (Fig. 7). Dominating species of such communities are *Carex lasiocarpa* Ehrh., *C.rostrata* Stokes, *Menyanthes trifoliate* L. and *Thelypteris palustris* Schott. Thick hummocks of *Carex appropinquata* Schumach. and small sedges of *Carex limosa* L., *C.diandra* Schrank and *C.chordorrhiza* Ehrh. also occur (Fig. 8, 9). Orchids of *Dactylorhiza incarnata* (L.) Soo, *Epipactis palustris* (L.) Crantz and *Herminium monorchis* (L.) R. Br. play their role in fen vegetation diversity as well (Fig. 10).

Inflorescences of *Cicuta virosa* L. and *Rumex aquaticus* L. rarely rise above this vegetation cover. Brownmoss cover is mainly presented by *Drepanocladus aduncus* (Hedw.) Moenk., *Helodium blandowii* (F. Weber & D. Mohr) Warnst., *Plagiomnium ellipticum* (Brid.) T.J. Kop. and *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb. (Fig. 11). Brown mosses form round pillow-shaped hummocks of 30-50 cm diameter. *Galium palustre* L., *G. uliginosum* L., *Parnassia palustris* L., *Saxifraga hirculus* L. and other small herbs grow above brownmoss surface. Schrubs of *Betula fruticosa* Pall., *Salix rosmarinifolia* L., *S. cinerea* L. and *S. lapponum* L. of 0.5-2.0 m high occur among the fens. Here and there *Betula nana* L. grows thicker. *Lysimachia vulgaris* L., *Naumburgia thyrsiflora* (L.) Rchb., *Cicuta virosa, Polemonium caeruleum* L., *Ranunculus lingua* L. and *Rumex aquaticus* L. occur sporadically (Fig. 12). While going towards the river bed the fens change their aspect. Abundance of shrub willows and birch increases forming thickets in the near-bed mire part. In the herb tier sedge hummock *Carex appropinquata* and *C. cespitosa* take greater part and *Phragmites australis* (Cav.) Trin. ex Steud. appears as well (Fig. 1, 8).

The ridges of 250-300 m long and 5-7 m wide rise to 50-80 cm over fens with distance 300-500 m from one ridge to another making several rows from the near-terrace floodplain part to the river bed (Fig. 2). First *Pinus sylvestris* L. and *Picea obovata* Ledeb. with addition of *Betula pubescens* Ehrh. dominate in the ridge wood tier (Fig. 13). While going from the terrace, conifers on the ridges gradually change to birch. The distinct ridge shrub

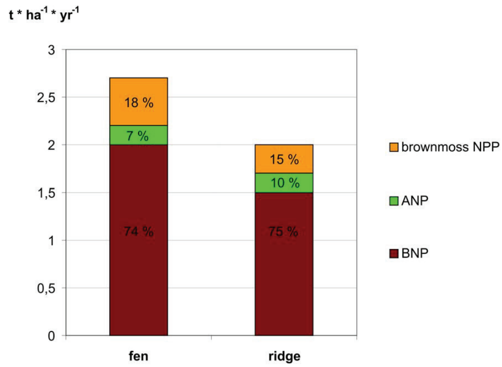


Figure 15. Net primary production (NPP) in rich ridge-fen complex: ANP – above ground production, BNP – below ground production

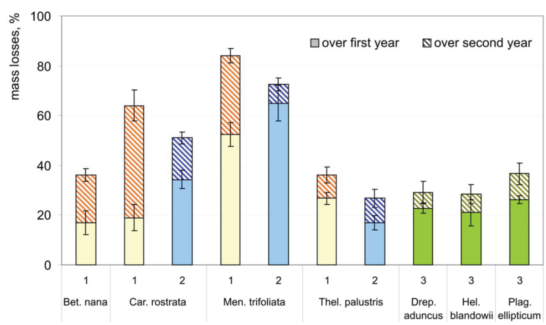


Figure 16. Litter decomposition over two years in sedge-brownmoss fen: 1 – leaf litter, 2 – roots and rhizomes, 3 – brownmoss litter.

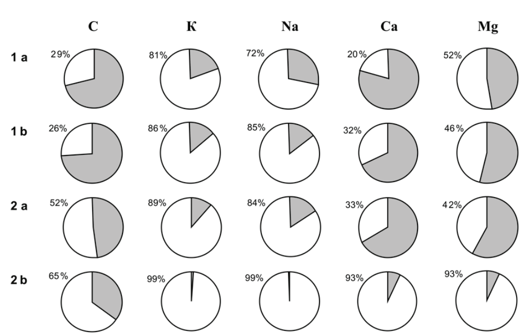


Figure 17. Element losses are during litter decomposition in sedge-brownmoss fen over one year: total circle is initial element content (100%), white sector is percentage of element loss, gray sector is percentage of element remain. 1a – leaf litter of *Carex lasiocarpa*, 1b – roots and rhizomes of *Carex lasiocarpa*, 2a – leaf litter of *Menyanthes trifoliata*, 2b – roots and rhizomes of *Menyanthes trifoliata*.

tier in the near-terrace mire part is presented with *Lonicera pallasii* Ledeb., *Ribes hispidulum* (Jancz.) Pojark. and *Rosa acicularis* Lindl. and on the ridges more distant from the terrace it is presented with shrub willows. The ridge herb cover under coniferous canopy is presented with taiga small herbs of *Maianthemum bifolium* (L.) F.W. Schmidt, *Moehringia lateriflora* (L.) Fenzl, *Pyrola rotundifolia* L. and *Poa palustris* L. On the ridges with birch domination in the wood tier small herbs change to mire vegetation of *Menyanthes trifoliata, Thelypteris palustris*, *Equisetum fluviatile* L. and different sedge species.

Results

Standing crop of phytomass and net primary production

During two vegetation periods standing crop of phytomass and structure were assessed for sedge-brownmoss fen and pine-shrub ridge. The wood tier was not considered and the below-ground phytomass was assessed in the layer 0-20 cm.

Phytomass division into above-ground and below-ground layers for mires is generally done on moss cover. Above-ground phytomass only takes 10% of total standing crop. The brownmoss cover structure of fen is rather complex. Thick brown mosses hummocks have slightly prominent surface and are consist mostly of some species [5].

First 3-5 cm deeper from the brownmoss hummock surface are occupied with a photosynthetic layer. Brownmoss litter, i.e. moss dead parts keeping their structure are located lower. Brownmoss litter is the substrate where vascular plant roots grow. Brownmoss amount decreases at 20 cm lower. Below-ground parts of herbs and shrubs are presented with the following fractions: roots, rhizomes, sedge stem bases and shrub stems. Living below-ground parts of vascular plants are mostly concentrated within 0-30 cm. Roots and rhizomes of sedges, ferns and some other plants form something like quagmire on densely interlacing. Dead roots share increases sharply at 30-cm depth.

The horizon of 20-40 cm has more friable structure than the upper and lower horizons. At this depth a whole system of hollows filled with mire water is formed. It is noteworthy that the peat deposited into this mire ecosystem mainly consists of sedge and fern root residues (radicel peat).

Standing phytomass in the described communities is unequally distributed. Total standing crop of living and dead phytomass is on average 6.5 t*ha^{-1} and fluctuates during vegetation season and from year to year in each phytocenosis. Living phytomass takes 50-60% of total standing crop. It gets greatest values of 4.5 t*ha^{-1} in the fen in the middle of the vegetation period (Fig. 14).

Net primary production of the fen is of 2.7 4.5 t*ha^{-1}*yr^{-1} average (Fig. 15). The most important role in the fen structure belongs to herbs. Rich herbs cover that mainly consists of perennial plants gives on average 0.2 t*ha^{-1}*yr^{-1} (7%) of above-ground production and 2.7 t*ha^{-1}*yr^{-1} (74%) of below-ground production. Herb below-ground production is 10 times greater than the above-ground one.

The second in production value in fen phytocenosis is brownmoss tier. Brown mosses are more subjected to the influence of mire water level fluctuations than perennial plants. With a high level of mire water most part of moss hummocks are flooded and brownmoss production decreases to 0.3 t*ha^{-1}*yr^{-1} while in low-flow years it can reach 0.6 t*ha^{-1}*yr^{-1} (18%).

A quite different situation is observed in the pine-shrub ridge. Small taiga herbs grow under wood canopy. The ridge soil is a thick well-decomposed peat. Standing crop of living phytomass reaches the greatest value of 4.3 t*ha^{-1} in July. Net primary production of 2.0 t*ha^{-1}*yr^{-1} in the ridge is 25% less than that in the fen. The percentage of production compounds is similar to that of the fen. The largest part of 1.5 t*ha^{-1}*yr^{-1} (75%) goes to below-ground production and the smallest one of 0.2 t*ha^{-1}*yr^{-1} (10%) belongs to photosynthesizing phytomass fraction of vascular plants. 0.3 t*ha^{-1}*yr^{-1} (15%) goes to brownmoss production (Fig. 14, 15).

Decomposition and element losses

Fen depositing of root peat is connected with high root production and incomplete root decomposition. Plant residues decomposition results from microorganisms and other soil invertebrates' activity. A complete decomposition is only possible under certain consecutive substitution of some microorganisms for other ones. The succession of plant residues mineralization is stipulated by nutrient elements available for the following groups and mainly depends on the plant chemical composition.

The investigation results of litter decomposition rate showed that bogbean leaves, roots and rhizomes were subjected more than other plants in sedge-brownmoss fen (Fig. 16). Bogbean litter losses of the mass were 75-85% over two years. The half of sedge root initial mass decomposed over two years. Sedge leave litter decomposed more (65% over two years). *Betula nana* leave litter, *Thelypteris palustris* litter and roots, brownmoss litter mass losses were about a third of their initial mass over two years [6]. In the following years herb leave litter and brownmoss litter decomposition continued at slow-down rate. A specific chemical composition of sedge and fern roots prevents their complete decomposition and contributes to radicel peat deposition (Fig. 3).

The rate of macroelements carry-over under plant residues decomposition decreases in K, Na, Mg and Ca row (Fig. 17). Bogbean roots and rhizomes have greatest losses in all four investigated elements - 92-99% of their initial amount. The lowest sodium losses are recorded for below-ground parts of *Carex lasiocarpa* (34%); the losses of the rest fractions are rather great and similar to potassium losses. The lowest magnesium losses of 22% under decomposition are revealed for *Carex rostrata* roots and rhizomes that are close to calcium losses of the fraction. Great magnesium loss of 73% is recorded for brownmoss litter. Calcium loss is less than other investigated macroelements and most fractions lose from 20% to 33%. The smallest calcium losses (3%) are recorded under brownmoss litter decomposition.

Conclusions

Global and regional ecological problems are often related to irreversible environment changes. The disorder in the flood regime of the Ob upper stream causes a decrease in nutrient elements' supply to fen ecosystems, which results in the changes in vegetation distribution over the profile from the terrace to the near-bed bank. Associated investigations of phytomass growing and peat accumulation processes in the floodplain mires enable us to reveal functional connections between certain structure blocks of biological cycle and their quantity characteristics.

Floodplain mires are highly productive ecosystems with a fast carbon cycle. Total standing crop of living and dead phytomass are 6.5 – 7.0 t*ha^{-1} average and vary during vegetative season and from year to year for each phytocenosis. Average standing crop of living and dead phytomass for the fen are 7.0 t*ha^{-1} and 14% less for the ridge that is 4.5 t*ha^{-1}. Living phytomass takes 50-60% of the total standing crop. Floodplain mire standing crop of living phytomass change a little from 4.0 to 4.5 $t*ha^{-1}$. It gets its maximum growth (4.5 $t*ha^{-1}$) in the fen in the middle of vegetation period.

The average fen net primary production is of 2.7 $t*ha^{-1}*yr^{-1}$ and that of the ridges is 2.0 $t*ha^{-1}*yr^{-1}$ than for 25% less. Herbs play the most important role in the fen structure. Rich herbs cover that mainly consists of perennials plants gives on average 0.2 $t*ha^{-1}*yr^{-1}$ (7%) of the above-ground production and 2.7 $t*ha^{-1}*yr^{-1}$ (75%) of the below-ground one. The below-ground production is 10 times greater than that of above-ground. The second in production of the fen phytocenosis is brownmoss tier. Brown mosses are more subjected to fluctuations of mire water level than herbs. With a high level of mire water most part of hummocks are flooded and brownmoss tier production decreases to 0.3 $t*ha^{-1}*yr^{-1}$ while in low-flow years it can reach 0.6 $t*ha^{-1}*yr^{-1}$ (18%).

Decomposition goes very intensively in floodplain mire ecosystems, especially in the fen. Plant residues are completely mineralized over 2-3 years, except for roots. The greatest decomposing rate and macroelement losses are registered for all bogbean (*Menyanthes trifoliata)* fractions. A part of leave litter not decomposed over the first year is completely decomposed in the second one. The slowest decomposition rate is registered for fern (*Thelypteris palustris)* rots of 25% over two years. Brownmoss litter loses about a quarter of its initial mass in the first year decomposition process. Herewith elements losses are 90% for Na and K, 73% for Mg and 3% for Ca. Vascular plants lose about 40% of ash elements on average a year and brown mosses lose 15% of them.

References

[1] Evseeva N.S. 2001. Geographiya Tomskoj oblasti (Prirodnie usloviya i resursi [Geography of Tomsk region) (Nature conditions and resources)]. Tomsk. *TSU*. 223. (in Russian)

[2] Lapshina E.D. 2010. Rastitelnostj bolot jugo-vostoka Zapadnoj Sibiri. [Mire vegetation of south-east Western Siberia]. Khanty-Mansijsk. *Yugra State University*. 184. (in Russian)

[3] Blyakharchuk T.A. 2003. Four new pollen sections tracing the Holocene vegetational development of the southern part of the West Siberian Lowland. *Holocene*. **13**, 715-731.

[4] Schipper A.M., Zeefat R., Tanneberger F., Zuidam J.P., Hahne W., Schep S.A., Loos S., Bleuten W., Joosten H., Lapshina E.D. and Wassen M.J. 2007. Vegetation characteristics and eco-hydrological processes in a pristine mire in the Ob River valley (Western Siberia). *Plant Ecology*. **193** (1), 131-145.

[5] Kosykh N.P., Koronatova N.G., Naumova N.B.and Titlyanova A.A. 2008. Above- and below-ground phytomass and net primary production in boreal mire ecosystems of Western Siberia. *Wetlands Ecology and Management*. **16** (2), 139-153.

[6] Mironycheva-Tokareva N.P.and Parshina E.K. 2007. Dinamica zolnih elementov pri razlozhenii rastitelnogo veschestva v bolotnih pochvah pojmi reki Obi [Ash element dynamics during litter decomposition in ob river floodplain mire]. Siberian soils: genesis, geography, ecology and rational use. Novosibirsk. *NSU*. 109-111. (in Russian)

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Evaluations of temperature ranges for the growing season period and their use in agriculture in South-Western Siberia

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the article presents the of results of the use of methodological approaches to assessing the characteristics of the modes of the stable transition average daily temperature over 0, 5, 10, 15 °C in the south of Western Siberia, the length of temperature setting periods, related microcirculation processes, as well as the evaluating of growing season weather conditions influencing crop yield. The estimation of tendencies of variability of the specified characteristics is carried out. Therefore, the information of this kind is necessary for researchers to find out dependencies for their prediction. Our methods of evaluating climatic conditions (atmosphere circulation, statistic of temperature change over definite values) can be applied to weather forecast for the appropriate period as well as to estimation of expected crop yields in the study region. Early evaluation of weather trends in spring must be used as adjustment in decision making while developing the agronomical strategy for the field season.

Key words: agroclimatic parameters, macrocirculatory conditions, South-Western Siberia.

Introduction

The monitoring of temperature in current climate changes is of the utmost interest for Russian and foreign climatologists [1, 2, 3]. Maximal warming, either observed or expected, spread over a considerable part of the Russian territory. In general, changes in the surface air temperature averaged for a year as well as for longer annual periods (i.e. halfyear, season, month) are considered for the northern hemisphere, large geographical locations and economic areas. The variations in daily temperatures ranged at 0, 5, 8, 10, 15, 20 °C in Western Siberia have not been studied yet. These ranges are considered to be boundaries of warm (above 0 °C), growing (>5 °C and >10 °C), heating (8 °C), "hot" (>15 °C) and dry (>20 °C) periods. In addition, the length of temperature changeover (the time when the temperature was fixed for the first time up to its stable setting) and the duration of the periods mentioned above are studied. The assessment of parameters given above is crucial for the region with highly developed power and agricultural industries.

A longterm and qualitative evaluation of meteorological conditions affecting both economic complex and human activities as well as the possibility of responding to predicted weather change depends on the numerical characteristics determined for a certain territory at a definite time scale.

This research is aimed at studying the dates of stable surface air temperature change over 0, 5, 10, 15 °C, the length of temperature setting periods, related circulation processes as well as the evaluation of growing season weather conditions influencing crop yield. Therefore, the information of this kind is necessary for researchers to find out dependencies for their prediction.

Materials and methods

The climatic data used in this study were obtained from 14 weather service stations located in Tomsk, Novosibirsk, Kemerovo and Altai regions for the from 1961 to 2005 period. The stations' data included daily mean surface air temperatures and daily total precipitation range. The circulatory conditions of interseasons were evaluated using planetary high altitude frontal zone (PHAFZ) parameters [4,5,6], elementary circulatory mechanisms (ECM) by B.L. Dserdseevsky indices [7]. In addition, the obtained from 1970 to 2005 data on crop yield in Altai and Tomsk regions were used in the study.

Dynamics of agroclimatic indices of temperature ranges during growing season period

For the total understanding of atmosphere temperature it is necessary to evaluate the data on stable daily mean temperature change over 0, 5, 10, 15 °C – D_0, D_5, D_{10}, D_{15}, respectively. Hence, the selection of a method to define the date of a stable surface air temperature change over threshold values proves essential. At present use is made of D.A. Ped's method [8]. Based on D.A. Ped's method, the algorithm of automatic date definition was developed. Implementing this algorithm we succeeded in defining the dates of the stable surface air temperature change over 0, 5, 10, 15 °C in spring and autumn for weather service stations in Tomsk, Kolpashevo, Rubtsovsk, Barnaul for a 70-year period. The dates defined, the length of the change periods P_0, P_5, P_{10}, P_{15} was calculated (Table 1).

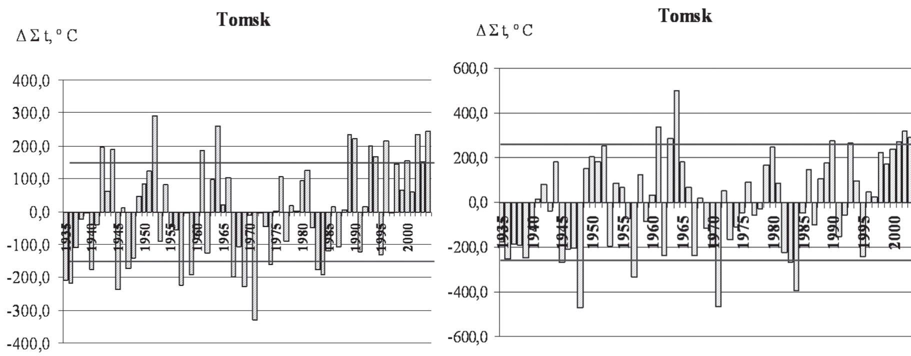
Table 1. Mean values for the period of surface air temperature change over 0 °C

Station	Characteristics	Transition date in spring	Transition date in autumn	Period duration, days
Tomsk	Mean least value	March, 30	October, 9	177
	Mean value	April, 12	October, 20	192
	Mean largest value	April, 26	October, 31	208
Kolpashevo	Mean least value	April, 5	October, 6	165
	Mean value	April, 18	October, 17	183
	Mean largest value	May, 4	October, 27	200
Rubtcovsk	Mean least value	March, 24	October, 21	199
	Mean value	April, 3	October, 31	212
	Mean largest value	April, 14	November, 9	226
Barnaul	Mean least value	March,24	October, 18	192
	Mean value	April, 5	October, 28	207
	Mean largest value	April, 14	November, 5	224

In agrometeorology it is considered reasonable to use the data on daily total temperature and precipitation range. The dynamics of daily total temperature deviation from their mean values are shown in Fig. 1.

Mean value or norm was derived as $X\varepsilon \pm \sigma$, where σ – standard deviation.

In deviation sign (positive or negative) of periods duration, total temperature and precipitation range in the warm period from their mean values, distinct recurrence with different time intervals is observed. Taken as a whole, the values are within the norm although significant deviations are observed in individual years. For temperature change over 0 °C the deviations are: total temperature range – 171–202 %, total precipitation range – 217–238 %, period duration – 214–250 %.



a) *b)*

Fig. 1. Total temperature deviation from mean values for *a)* the warm period, *b)* < 10 °C period (±σ position is presented by solid lines)

For the temperature changing over 5 °C period the variability of values is more than for the similar rows of warm period and deviations from norm are observed more often (total temperature range – 189–223 %, total precipitation range – 225–276 %, duration period – 214–250 %).

The variability among the values for >10 °C period is less than among the values for >5 °C period (total temperature range – 166–193 %, total precipitation range – 182–218 %, duration period – 321–346 %). Variability among values for >15 °C period increases, the deviations from the norm are: total temperature range – 121–159 %, total precipitation range – 204–239 %, duration period – 118–143 %.

The substantial positive deviation of values from their mean has been observed for total temperature range since 1979, for total precipitation range – since the mid 1980s and for period duration above 0 °C since the late 1980s. For the period >5 °C the positive trend in values vas been observed since 1989, especially for the stations located in the Altai region. As far as total precipitation range is concerned, this trend is typical only for the Altai region from 1990 to 1991 period.

For >10 °C period the positive trend was noticed from the end of 1980 to the beginning of 1990, for >15 °C period it was noticed from the end of 1990 to the beginning of 2000. The observed growing trend of the parameters under study in the last 20–30 years is supported by the results of their investigation received within 5year terms, precisely the positive dynamics of duration and total temperature range in the warm period is observed from 1980 to 1990 period. The relevant information for the station in Tomsk is given in Table 2.

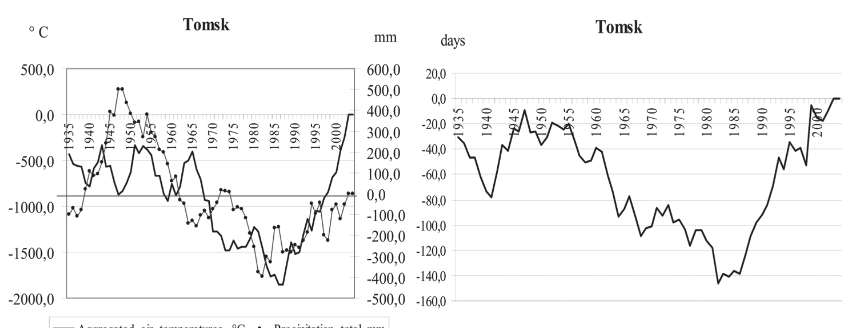
Table 2. Mean values for temperature changing above 0 °C period within 5year terms

№	Period	Precipitation total, mm	Accumulated air temperatures, °C	Transition date in spring	Transition date in autumn	Period duration, days	Transition duration in spring, days
1	1936–1940	330.4	2119.0	April, 15	October, 14	183	24
2	1941–1945	392.6	2278.3	April, 10	October, 20	194	12
3	1946–1950	415.6	2133.1	April, 11	October, 22	194	35
4	1951–1955	300.8	2329.7	April, 14	October, 23	193	22
5	1956–1960	331.9	2127.1	April, 20	October, 23	187	19
6	1961–1965	296.8	2300.1	April, 14	October, 18	188	24
7	1966–1970	338.8	2150.4	April, 15	October, 17	185	25
8	1971–1975	365.6	2122.5	April, 5	October, 18	197	16
9	1976–1980	320.5	2239.5	April, 14	October, 18	188	23
10	1981–1985	309.0	2192.2	April, 15	October, 16	185	24
11	1986–1990	352.1	2237.5	April, 6	October, 21	198	23
12	1991–1995	363.5	2328.2	April, 6	October, 27	205	22
13	1996–2000	338.7	2290.0	April, 10	October, 17	191	25
14	2001–2005	390.7	2401.0	April, 7	October, 26	203	34

The mean values are considered to be stationary and it is difficult to note visible fluctuations in the shortterm process curve. They are more expressed in residual mass curves enabling cycles duration (epochs) to be distinguished. Longterm periods of enduring trend are referred to as epochs (cycle). The duration of epoch is defined as the distance between the extremes in the curve. This method is widely used in meteorology in order to determine the epochs of atmosphere circulation.

The residual mass curves make it possible to determine the epochs of growth and decrease in the dynamics of duration, total temperature and precipitation range for the above 0 °C period, 1950–80 epoch of decrease being completed. This epoch is 20–30 years for duration, 25–30 years for total temperature range and 25–50 years for total precipitation range.

We can conclude that more negative deviations from mean values were observed in the territory at that time. The epoch of growth proceeding the epoch of decrease cannot be seen entirely in the curves because of insufficient length of data sets. However, it is supposed to be 30 years on average and is part of quasi60 year cycle peculiar to the forms of atmosphere circulation. The epoch of decrease was followed by the epoch of growth of study parameters, which confirms their positive dynamics in the last decades.



b) a)

Fig. 2. Aggregated deviations from mean values *a* – the total daily temperature and precipitation range, *b* – the duration of warm period

The residual mass curves of the total temperature and precipitation range and >15 °C duration period are apt to point out the epoch. The epoch of decrease accounts to 30 years average for the stations, falling at the beginning of 1950 and ending up in the late 1980s. Thereafter the epoch of growth starts in the early 1990s.

For temperature changing >10 °C period it is total temperature range sets that point out the epoch of decrease. This epoch accounts for 20–40 years average for the stations.

The residual mass curves of values under study for >15° period exhibit the most complicated range of epoch manifestations, which is typical for northern stations (Kolpashevo, Tomsk) since weather variability is significant in this period.

In general our conclusions correlate with the results of other research carried out in Russia and in other countries, West Siberia included [9, 10, 11]. In particular, B.M. Mirvis and I.P. Gusev [12] found out that duration of the warm period tends to be steady to a large extent in the south of the region. On the contrary, while assessing expected climate change effects on agriculture in Russia, O.D. Sirotenko and I.G. Gringoff [13] failed to reveal large scale macroaridization of climate. This implies that current climate change favors agroindustrial complex in South-Western Siberia.

Macrocirculatory processes in the atmosphere and temperature conditions of the warm period

To identify the factors causing fluctuation of values for temperature change over 0 and 5 °C at Tomsk, Kolpashevo and Barnaul stations, the data on PHFZ condition and ECM kinds by B.L. Dserdseevsky indices from 1961 to 2005 period were used [www.atmosphericcirculation.ru]. Based on statistical analysis [14, 15] the preliminary classification of dates and periods for longterm weather forecast was made:

norm ($\pm$ 0.5σ) – *n*,

abnormally ($\pm$ σ) early/late – *aeD/alD*,

extremally ($\pm$ 1.25σ) early/late – *eeD/elD*,

abnormally short/long – *aqP/alP*,

extremally short/long – *eqP/elP*.

Abnormality is defined as norm $\pm$ 0.5σ whereas extremality is defined as norm $\pm$ 1.25σ.

The resulting cluster which included data on D_0, P_0, D_5, P_5 and PHFZ position in 60, 70, 80, 90° longitude east in March and April (12 parameters) was arranged into 6 distinst steady classes (Figure 3).

The classes were described using PHFZ parameters:

1 – spacial location of PHFZ in relation to the stations under consideration; 2 – temparal variability of PHFZ; 3 – degree of sinuosity (zonal or meridianal configuration).

According to the first parameter PHFZ in the 1, 2, 3 classes was found to locate southward of the study territory; 4, 5, 6 classes describe PHFZ located over the study territory .

According to the second parameter PHFZ in 1, 5, 6 classes kept moving southwards from March to April (winter processes delay); on the contrary, PHFZ in 2, 3, 4 classes kept moving northwards from March to April (spring coming). Classes 3 and 5 are specified by the opposite dynamic from March to April.

According to the third parameter, zoning predominance can be seen over South-Western Siberia; class 2 is specified by the crest extending from south to north (well-

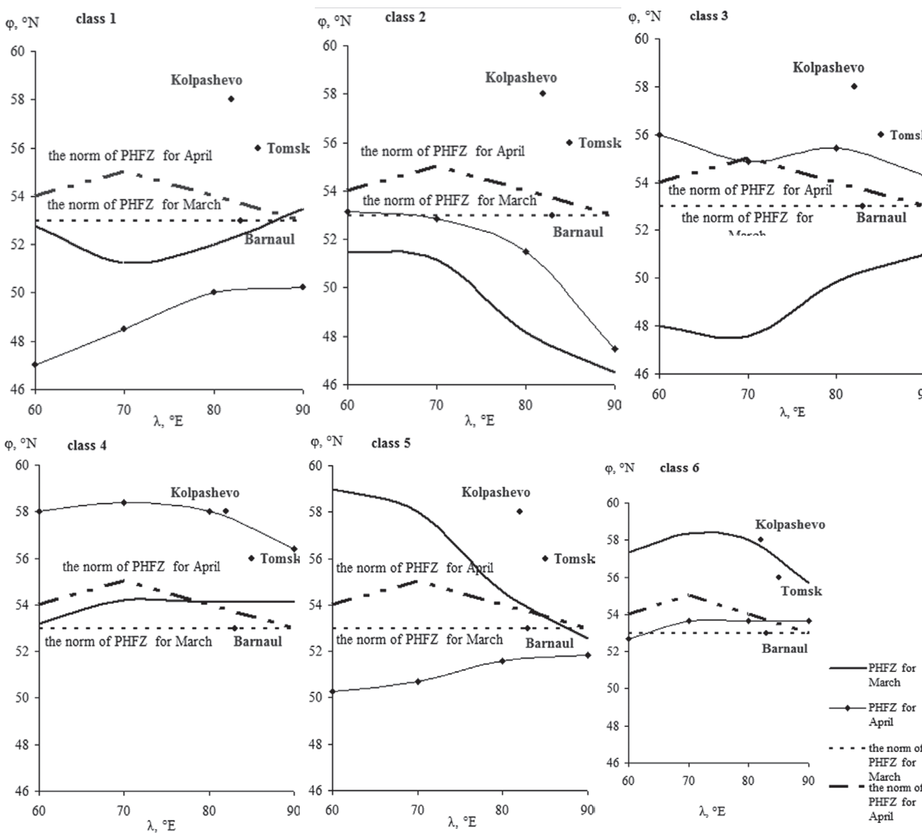


Fig. 3. Geographical position of PHFZ avaraged within classes

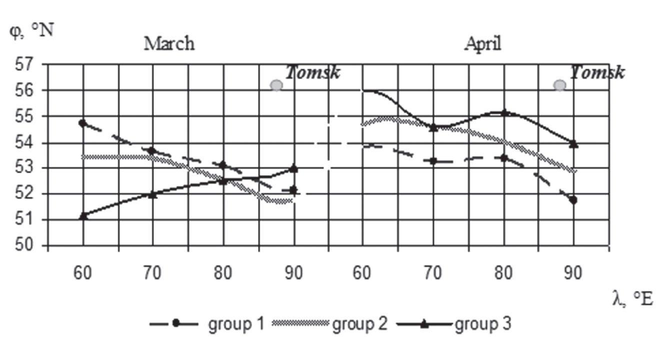


Fig. 4. PHFZ position in groups

expressed meridianality of processes). Classes 1, 3, 5 comprise occurrences of meridianal PHFZ predominance.

Consequently, use of PHFZ as an additional criterion in classifying the parameters under study proves possible.

Furthermore, P_5 data set was arranged into 3 groups according to change rate: 1 – rapid, 2 – normal, 3 – slow. PHFZ position according to 3 groups is shown in Figure 4.

One can see that PHFZ for the period between March and April is located southwards from Tomsk, in the south of Western Siberia and in the Altai foothills. What is more, its shift northwards at 2º longitude from March to April is well expressed. There are some differences in PHFZ position in 3 separate groups. Thus, PHFZ is in the most northern position in the “slow change” group. Consequently, Tomsk region is influenced by the active cyclonic processes, with polar air masses migrating into the back cyclones and passing its fronts. These weather conditions prevent bedding surface and surface air from warming up. On the contrary, in the “fast change” group the most southern PHFZ position is observed. Under these circumstances surface warming is attributed to the peculiarities of dominant anticyclonic processes over the study territory.

There is one more point to be discussed. Ascribing individual springs to the definite class is likely to require our classification to be widened at the expense of additional parameters of circulation and atmosphere condition in the periods of stable positive temperatures setting up.

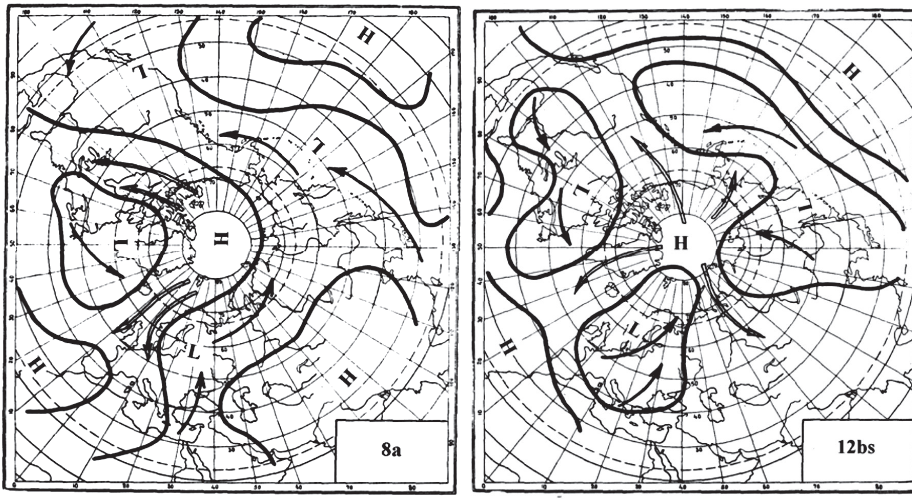
Therefore, elementary circulatory mechanisms (ECM) by B.L. Dserdseevsky indices were used to calculate the frequency of every one of 13 elementary circulatory mechanisms in change – group P_0, P_5 (Table 3).

Table 3. ECM frequency (%) in groups

Transition group P_0, P_5	ECM																		
	1a	1b	2a	2b	2c	3	4a	4b	4c	5a	5c	5d	6	7 aw	7 as	7 bw	7 bs	8a	8 bs	8 cw
rapid	0	0	5	2	0	3	0	2	3	0	0	0	0	2	10	0	2	5	2	2
norm	2	1	3	1	1	3	2	3	2	2	1	0	3	1	2	1	2	8	3	1
slow	1	1	3	0	0	0	1	3	3	0	0	1	1	3	4	0	1	4	1	0
Итого	0		7			3	5			0			0	14						
	3		5			3	7			3			3	6						
	2		3			0	7			1			1	8						

Transition group P_0, P_5	8 cs	8 ds	8 dw	9a	9b	10a	10b	11	11a	11b	11c	11d	12a	12 bs	12 bw	12 cs	12 cw	12d	13s	13w
rapid	0	2	2	11	2	2	2	0	0	2	0	0	11	8	0	3	7	2	10	2
norm	1	2	2	5	5	5	4	1	1	1	0	3	10	6	1	5	1	2	6	4
slow	4	0	1	7	3	4	4	0	3	1	1	3	6	7	3	4	1	1	6	6
Итого	9			13		4		2					31						12	
	12			10		9		5					23						10	
	5			10		8		8					12						12	

“Norm” group is characterized by the lagest frequency of ECM 8a and 12bs, which pertain to meridianal northern group and are featured by polar jet migrating to Asia, through Taimyr to the Ob river basin, or from Novaya Zemlya to the Yenisey river basin (Fig. 5). Quite often the blocking of western shift by Arctic anticyclone interlocking with Siberian crest is created. The least frequency in processes belonging to this group is observed in ECM 17.



a) b)

Fig. 5. ECM subtype dynamic scheme a) 8a, b) 12bs; *1 – generalized trajectory of cyclones; 2 – generalized trajectory of anticyclones; 3 – demarcative lines dividing cyclonic and anticyclonic areas* [16]

None of the zonal circulation groups is observed in "rapid" group (ECM 1, 5 and 6), the lagest frequency of meridianal groups being 7, 8, 9, 12, 13 ECM. Maximum repeatability is of type 12 (12a, 12bs, 12cw). 10 and 11 ECM processes are sufficiently weakened as compared to the groups "norm" and "slow".

"Slow" group has uniform frequency of ECM 713, whereas ECM10 and 11 increase and ECM 12 frequency noticeably decreases. When ECM 10 is brought about, the study territory is in the low pressure area, meanwhile the blocking crest is over Eastern Europe, which correlates to the PHAFZ position identified above for slow change (when PHAFZ occupies the most northern position).

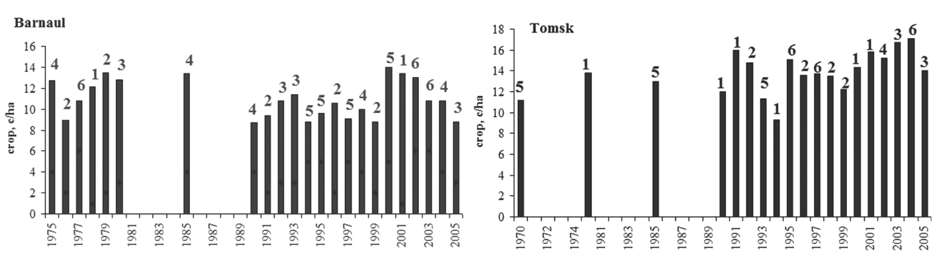


Fig. 6. Classes and crop yield

Crop yield and temperature range in growing season period

The classes of date changes classified using PHAFZ parameters were compared with the data on crop yield that varies greatly through years (Fig. 6 and Table 4). The observed variability is appointed to the fluctuation of agrometeorological conditions since crop yield biological factors such as crop genetics, soil fertility are more or less stable.

Our results suggest that there is no entire correlation between the classes and crop yield caused by insufficient records of weather factors in spring.

In Barnaul, the high crop production is fixed in classes 1 and 6 (12.6 dt/ha and 11.5 dt/ha, respectively). Class 1 is characterized by early 0 and 5 °C setting and their change length within norm. In this case, favorable temperatures are found to set up rapidly. Long and late change to 0 °C as well as normal growing period setting is peculiar to class 2. Low crop production is fixed in classes 2 and 5 (10.2 and 10.4 dt/ha, respectively). Class 2 is characterized by late and rapid 0 °C setting and normal change to 5 °C, class 5 – chronologically early and rapid 0 °C setting but normal by change length of growing period setting.

Table 4. Average class parameters and average crop production (dt/ha) in classes for Barnaul and Tomsk stations

Barnaul					Tomsk				
Class	Average class parameters			Average crop production	Class	Average class parameters			Average crop production
1	D_0	29.3	early	12.6	1	D_0	9.4	norm	13.5
	P_0	17	norm			P_0	22	norm	
	D_5	15.4	early			D_5	2.5	norm	
	P_5	17	norm			P_5	23	norm	
2	D_0	9.4	late	10.2	2	D_0	27.4	late	13.5
	P_0	6	rapid			P_0	24	norm	
	D_5	25.4	norm			D_5	1.5	norm	
	P_5	16	norm			P_5	4	rapid	
3	D_0	9.4	late	11.1	3	D_0	11.4	norm	15.4
	P_0	16	norm			P_0	22	norm	
	D_5	14.4	early			D_5	19.4	early	
	P_5	4	rapid			P_5	8	rapid	
4	D_0	27.3	early	11.1	4	D_0	24.4	late	15.2
	P_0	3	rapid			P_0	49	long	
	D_5	30.4	late			D_5	3.5	norm	
	P_5	34	long			P_5	9	rapid	
5	D_0	25.3	early	10.4	5	D_0	15.4	norm	11.8
	P_0	3	rapid			P_0	16	norm	
	D_5	9.4	early			D_5	17.5	late	
	P_5	16	norm			P_5	31	long	
6	D_0	11.4	late	11.5	6	D_0	30.3	early	15.3
	P_0	33	long			P_0	2	rapid	
	D_5	24.4	norm			D_5	29.4	norm	
	P_5	13	norm			P_5	30	long	

In Tomsk high crop production is observed in classes 3, 4 and 6 (15.4, 15.2 and 15.3 dt/ha, respectively). In class 3 weather conditions of spring changeover correspond to normal 0 °C setting and early and rapid 5 °C setting. Class 4 is characterized by late and long changeover to positive temperatures, normal by date changeover but rapid, if account is taken of the changeover length, by growing period setting. In class 6 early and rapid 0 °C setting and normal by the date but long by changeover length 5 °C setting is observed. This implies favorable conditions for keeping winter moisture content in soil. Stable changeover to positive temperatures within normal range and late and long growing period setting correspond to class 5, which is featured by low crop production (11.8 dt/ha).

Climatedependent increase in crop yields in Western Siberia accounted for 6 % in the last decade, implying a considerable increase in regional crop production on account of effective use of soilclimatic resources [17].

Based on bioclimatic potential estimation across Russia, the expected crop yield in combination with effective agriculture in modern climate condition may count for 55 dt/ha in Western Siberia.

Conclusion

Our methods of evaluating climatic conditions (atmosphere circulation, statistic of temperature change over definite values) can be applied to weather forecast for the appropriate period as well as to estimation of expected crop yields in the study region.

Early evaluation of weather trends in spring must be used as adjustment in decision making while developing agronomical strategy for the field season.

References

[1] Anisimov, O.A., Belaluckaya, M.A.,and Lobanov, V.A. 2003. *Sovremennye izmenenija klimata v oblasti vysokih shirot severnogo polushariya* [Current climate changes in the high latitudes of the Northern hemisphere]. *Meteorology and Hydrology*, **1**, 18–30. (in Russian)

[2] Budyko, M. I. and Vinnikov, K. Y. 1976. *Global'noe poteplenie* [Global warming]. *Meteorology and Hydrology*. **7**, 16–26. (in Russian)

[3] Gruza, G.V. and Rankova, E.Y. 2003. Kolebaniya i izmeneniya klimata na territorii Rossii [Climate changes in Russia]. *Izvestiya RAN. Atmospheric and Oceanic Physics*. **39**(2). 66–185. (in Russian)

[4] Katalog parametrov atmosfernoy cirkulyacii. Severnoe polusharie. 1988. [The catalogue of atmosphere circulation parameters. Northern hemisphere]. *Obninsk* [in Russian]

[5] Monitoring obshhey cirkuljacii atmosfery. Severnoe polusharie. Bjulleten' 1986–1990, 1991–1995, 1996–2000. [Monitoring the atmosphere circulation. Northern hemisphere. Bulletin 1986–1990, 1991–1995, 1996–2000]. 1992, 1997, 2002. *Obninsk*. 112–134. (in Russian)

[6] Sinopticheskiy bulleten' Severnogo polushariya. Ch. 1 (elektronnaya versiya) [Meteorological bulletin of the Northern hemisphere]. 1997–2005. Moscow. *Izdanie Gidrometcentra Rossii* (in Russian)

[7] Kononova, N.K. 2009. Klassifikaciya cirkulyacionnyh mehanizmov Severnogo polusharija po B.L. Dzerdzeevskomu [Classification of circulation mechanisms by B.L. Dzerdzeevsky]. Moscow. *Voentehinizdat.* (in Russian)

[8] Ped, D.A. 1951. Ob opredelenii dat ustojchivogo perehoda temperatury vozduha cherez opredelennye znacheniya [On determining the dates of the stable changes of air temperature in particular values] **10**, 38–39. (in Russian)

[9] Gandin, L.S. and Kagan, R.L. 1976. Statisticheskie metody interpretacii meteorologicheskih dannyh [Statistical methods of meteorological data interpretation]. Leningrad. *Gidrometeoizdat*. (in Russian)

[10] Michelle D., Monahan A. And Jonathan N. Wiley. 2011. Implications of climate change on Russia. New York. *Russian Political, Economic, And Security Issues.*

[11] Sharmina, M., Anderson, K. and BowsLarkin, A. 2013. Climate change regional review: Russia. *Wiley Interdisciplinary Reviews: Climate Change.* 4(5). 373–396.

[12] Mirvis, V.M. and Guseva, I.P. 2006. Ocenka izmeneniya prodolzhitel'nosti bezmoroznogo perioda vegetacii na territorii Rossii i sopredel'nyh gosudarstv v XX veke [The assessment of the duration of a no-frost period of vegetation in Russia and neighbouring countries in the XX century]. *Meteorology and Hydrology*, 1. 106–113. (in Russian)

[13] Sirotenko, O.D. and Gringof, I.G. 2006. *Ocenki vlijaniya ozhidaemyh izmeneniy klimata na sel'skoe hozyaystvo Rossiyskoj Federacii* [The assessment of the climate changes impact on Russian Federation agriculture]. 8, 92–101. (in Russian)
[14] Gruza, G.V. and Rankova, E.Y. 2009. Ocenka predstoyashhih izmeneniy klimata na territorii Rossijskoy Federacii [The assessment of forthcoming climate changes in Russian Federation]. *Meteorology and Hydrology*, 11. 15–29. (in Russian)
[15] Soshnikova L.A. and Tamashevich V.N. 1999. Mnogomernyy statisticheskiy analiz [Multivariate statistical analysis]. Moscow. *UNITI*. 482. (in Russian)
[16] Dzerdzeevsky, B.L., 1957, *Cirkuljacionnye shemy sezonov goda v Severnom polushari*i [Seasonal circulation schemes in the Northern hemisphere]. (Izv. ASUSSR) Geography, 1, pp. 36–42. (in Russian)
[17] Katcov, V.M. and Porfiriev, B.N. 2011. Ocenka makroyekonomicheskih posledstviy izmeneniya klimata na territorii Rossijskoy Federacii na period do 2030 g. i dal'neyshuyu perspektivu [The assessment of macroeconomic effects of climate changes in Russian Federation during the period to 2030 and further]. Moscow. *D'ART: Glavnaya geofizicheskaya observatoriya* (in Russian)

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CLIMATIC DEPENDENCE OF BIOTA IN THE NORTH OF THE TYUMEN REGION (THE QUANTITATIVE ASPECT)

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This article examines the quantitative regularities of the distribution and hierarchy of biotic indices in the north of the Tyumen region. It determines the nature of their zonal distribution and provides formulas for climatic dependence of biota. We estimated the impact of warming on the biota of the region.

Key words: The north of the Tyumen region, climate, indices of dryness and heat, biota, taxa, warming

Introduction. North of the Tyumen region is a territory of Yamal-Nenetski and Hanti-Mansi autonomous areas, the length in the meridian direction of which is 1500 km. It includes eight bioclimatic complexes (BC) [1, 2]. Their names and numeration (I, II, III, ...VIII) are provided in picture 1.

Qualitative indices of biological abundance and diversity of the Tyumen region were studied in works [3, 4, 5, 6, 7]. This article studies the quantitative dependencies in order to determine and estimate the interdependence between the biota, its structure, climatic indices and distribution among the natural complexes and the range levels. Also, this article describes the influence of global warming on the biota.

Climatic indices were provided by the weather stations. Approximates of the dependencies and their veracity (determination coefficient) R^2 were calculated in Microsoft Excel.

Key climatic indices and interdependencies. The key versatility indices are dryness index J = B/Urг (B - annual radiation balance, kcal/cm2; U =0,6 kcal/cm3 – evaporation heat, rг – annual precipitation total, cm) which correlates heat and water ingress into the soil[8] with heat index which is represented by accumulated temperatures S

Zone	Radiation Regime				Air Temperature				Wind	
№	$_{\text{с}}$	$Q_{\text{с}}$	$B_{\text{п}}$	$B_{\text{г}}$	$t_{\text{т}}$	$-t_{\text{х}}$	$-t_{\text{г}}$	$_{\text{т}}$	$V_{\text{г}}$	$V_{\text{х}}$
1	50	60	33	15	6.5	17	10	216	6.8	8
2	62.5	77	42	17.6	8	16.5	7.5	195	6	4.8
3	64.6	80	49	21	10	16	5	175	4.5	4.2
4	71	83	53	25	11	14	3.5	151	4	4.1
Zone	Snow cover				Precipitation		Water Regime			
№	$h_{\text{н}}$	$h_{\text{сн}}$	$_{\text{сн}}$	$_{\text{сн}}$	$r_{\text{т}}$	$r_{\text{г}}$	$S_{\text{п}}$	$S_{\text{о}}$	E	
1	60	28	0.27	250	23	30	7.2	22.5	7.5	14.7
2	70	22	0.25	240	27	35	7.3	19.6	15.4	22.7
3	75	32	0.21	230	29	38	9.4	18.6	18.6	28
4	75	40	0.22	205	36	50	9	30	30	39

There were found quantifications of climatic interdependencies for the conditions of the Tyumen region [2, 11, 13] which allow us to determine the other quantifications if any other EC is known, e.g. heat and dryness indices or July air temperatures. Picture 3 depicts the graphs that link the most significant EC of the north of the Tyumen region (in addition to the designation mentioned in the text here: S

№	S	All Plants(Np)						Herbaceous(Tp)			Ligneous(Д)		
		В	Р	С	П	К	Од	В	Р	С	В	Р	С
1	320	162	74	31	28	4	3	148	67	25	14	7	6
2	480	339	134	46	38	5	4	301	115	34	38	19	12
3	610	358	145	52	41	6	5	311	121	38	47	24	14
4	1010	400	177	57	45	7	5	343	150	42	57	27	15
5	1293	435	214	66	52	7	5	377	186	51	58	28	15

S.N. Gashev researched a zonal distribution of the animal taxa belonging to various hierarchical levels - species (B), genera (P), families (C), orders (O) and classes (K) in the Tyumen region. The data he provided on climatic dependencies were published in [2, 3, 9, 16].

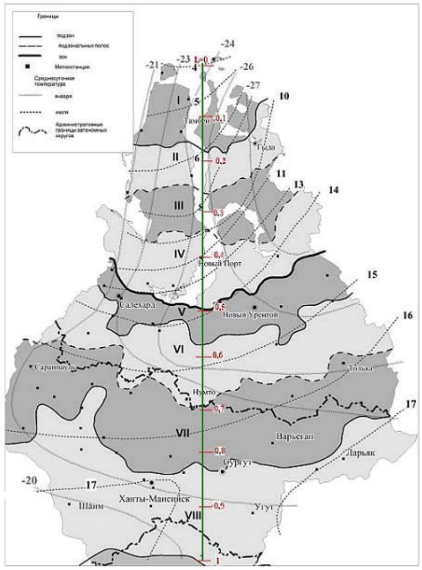
Picture 6 demonstrates the graphs of dependencies of quantities of various taxa of plants (Np) and animals (Na) on the heat index (S

№	1	2	3	4	5
S	320	480	610	1010	1293
Pr	1.9	2.9	3.7	6.1	7.8
Bm	39.7	89.2	118.4	180	210

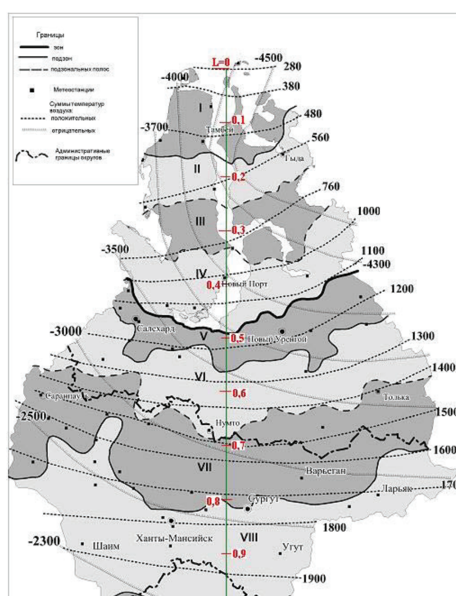
The analysis of the tables and graphs of the dependency of the biotic indices on the heat index demonstrates that a) starting from the level of classes, the quantity of taxa does not depend on climate anymore and becomes approximately equal for all BC; b) general formula of dependency of the biota parameters on S

PB	Taxa	A	B	R^2	PB	Taxa	A	B	R^2
M	species	0.125	53.1	0.92	**L**	species	0.0024	30	0.88
	genera	0.063	34.9	0.93		genera	0.001	16	0.87
	families	0.02	16.1	0.94		families	0.0003	11.3	0.73
	orders	0.008	5.8	0.9	**H**	species	0.09	255	0.99
B	species	0.031	10.3	0.98		genera	0.09	30	0.97
	genera	0.017	10.1	0.95		families	0.02	25	0.94
	families	0.006	6.8	0.96	$\mathbf{N_p}$	species	0.115	285	0.99
	orders	0.001	4.5	0.80		genera	0.096	86.3	0.94
$\mathbf{N_a}$	species	0.176	49.8	0.98		families	0.022	36.4	0.91
	genera	0.091	37.2	0.98		orders	0.021	25.4	0.9
	families	0.029	21	0.98		classes	0.003	3.6	0.86
	orders	0.01	9.2	0.99		phylum	0.0026	2,7	0.84
Pr	–	0.006	0	0.91	**Bm**	–	0.171	0	0.96

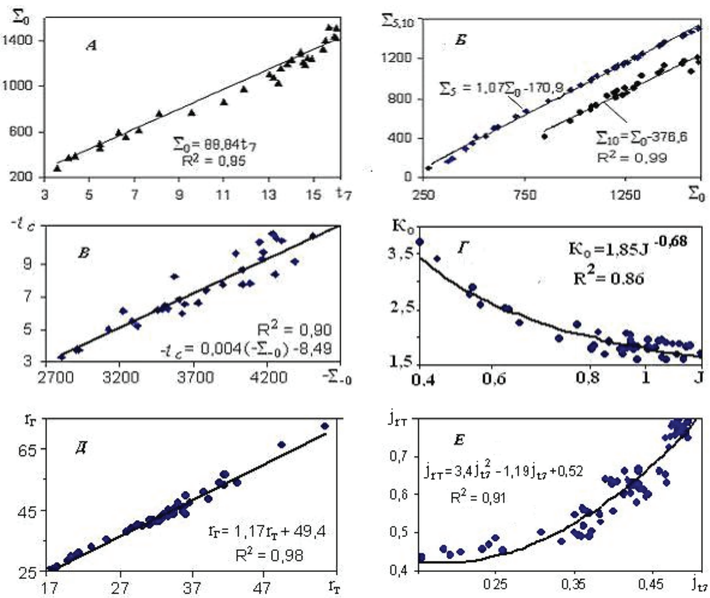
Picture 7в reflects stable linear relations between taxa of flaura and fauna which are invariant to climate.



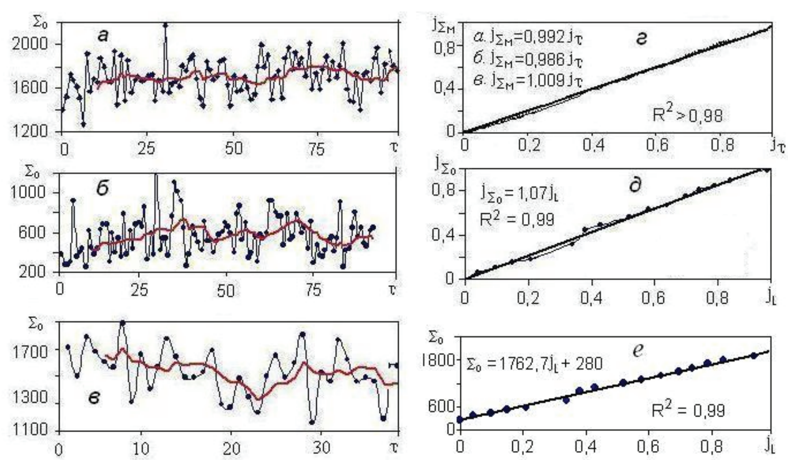
Picture 1. Bioclimatic complexes – BC (I – arctic tundra, II – northern strip of subarctic tundra, III – southern strip of subarctic tundra, IV – subarctic shrub tundra, V – forest tundra, VI – northern strip of the northern taiga subzone, VII – southern strip of the north taiga subzone, VIII – Vertical L=1- grid meridian which may serve as a step scale with division value of ~150 km while determining distance between isolines of EC.



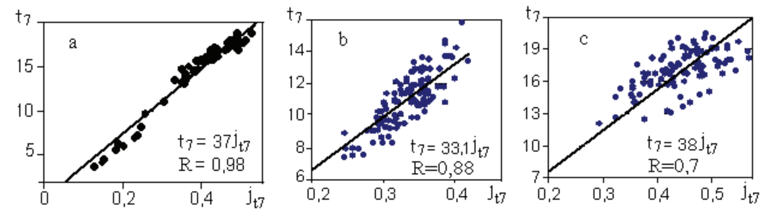
Picture 2. Accumulated positive ($\sum_0$) and negative ($\sum_{-0}$) temperatures (degree-days, dd) in the north of the Tyumen region (designation according to picture 1)



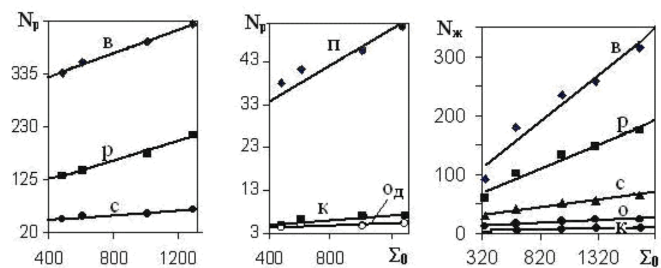
Picture 3. Dependencies of Σ_0 on t_7 – *A*; Σ_5 and $\Sigma_{10,}$ on Σ_0 – Б; t_c on Σ_{-0} – *B*; K_o on J – *Г*; $r_г$ on $r_т$ - *D*; $j_{гт}$ on j_{t7} – *E* (designation in the text).



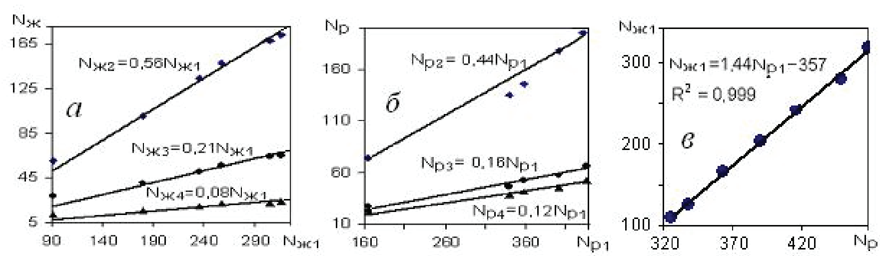
Picture 4. The course Σ_0 (dd) of time τ (years): *а* – in Surgut, *б* – in Salekhard and *в* - in Berezov; dependencies of $j_{\Sigma M}$ on j_τ – *г;* $j_{\Sigma o}$ on j_L – *д* and Σo on j_L – *е* (explanation in the article).



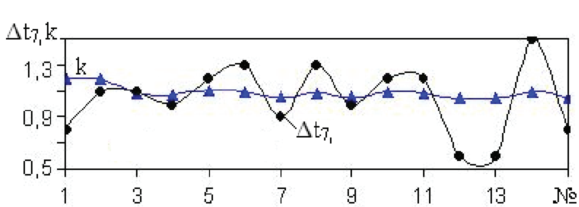
Picture 5. Dependence of t_7 on j_{t7} in the region of the Tyumen region – *a*, only in Salekhard – *b* and Surgut – *c*.



Picture 6. Graphs of dependency of N_a and N_p on Σ_0 for various taxa (letter designation of the taxa could be found in the text).



Picture 7. Dependency of $N_{a2} – N_{a4}$ on N_{a1} and N_{p2} - N_{p4} on N_{p1} (*а, б*) as well as N_{a1} on N_{p1}(*в*)



Picture 8. Values of Δt_7 and k in the north of the Tyumen region. (№ -numeration of posts according to Table 1)

Biotic diversity. This index is expressed through various correlations between mass or quantity of various groups of the biota by means of the Shannon index (measure of entropy), the Simpson index (measure of dispersion), etc. (see example [1]). The greater the Shannon index is, the more diverse the biota is. The increase in the Simpson index corresponds with the domination growth. It should be noted that the biota composition, the quantity of its systematic groups (taxa) and the correspondence between them are determined only by calculation (transcription) in the field, i.e. all the indices of the biota diversity are calculated by means of the already known values. Besides, none of the known indices reflect the influence of climatic factors. Nevertheless, climate determines heat and moisture supply and it is a primary factor of the biota segmentation and its diversity. This factor allows, as it is shown below, to estimate, at least approximately, structure of the biota only by means of the climatic data, particularly by the heat index S

BC	I	II	III	IV	V	VI	VII	VIII
J	0.45	0.5	0.6	0.7	0.75	0.81	0.88	0.96
$\sum_0$	340	439	658	877	1097	1316	1536	1700
$\sum_{0-5}$	147	140	125	110	94	79	63	52
$\sum_{5-10}$	193	237	252	267	283	298	314	325
$\sum_{10-t7}$	-	62	281	500	720	939	1159	1343
1	0.43	0.32	0.19	0.12	0.09	0.06	0.04	0.03
2	0.57	0.54	0.38	0.31	0.26	0.23	0.21	0.2
3	-	0.14	0.43	0.57	0.66	0.71	0.75	0.77
Pr	3.2	4.2	6	7.3	8.5	9.3	9.8	10.2
Pr_1	1.38	1.34	1.14	0.91	0.73	0.56	0.41	0.31
Pr_2	1.82	2.27	2.3	2.23	2.19	2.11	2	2
Pr_3	-	0.59	2.56	4.16	5.58	6.64	7.4	7.8
N_p	326	338	364	390	417	449	469	480
N_{p1}	140	108	69	49	36	27	19	14
N_{p2}	185	182	139	119	107	100	96	96
N_{p3}	-	48	155	223	274	316	354	370
N_a	110	127	166	204	243	281	316	324
N_{a1}	47	41	32	26	21	17	13	10
N_{a2}	63	68	63	62	63	64	65	65
N_{a3}	-	17	71	116	159	201	242	249

Table 5 states that the aggregate quantity of biotic species thermophilic biota Np_3 and N_{a3}) within the north of the Tyumen region increases from north to south along with the increase in J and $\sum_0$. Meanwhile, the quantity of the arctic species (Np_1 and N_{a1}) decreases. The quantity of the frost-resistant species (Np_2 and N_{a2}) decreases in the flora and it is almost constant in the fauna.

Global warming and its influence on the biota. Within last 40-50 years, omnipresent warming has been observed and its main feature is an increase in air temperature in the frost-free season and in the average annual expressions. Warming causes numerous adverse consequences of disastrous character e.g. fires, floods, subsidence of the permafrost ground, destructive deformations of engineering structures, etc. It is particularly dangerous for the North where it might cause defrosting of the circumpolar and subterranean ice and release of an enormous water mass which is trapped within the frozen gas. Meanwhile, it is apparent that the increase in air temperatures in the conditions of adequate and excessive humidification, which is typical for the North, has a positive influence on the biota due to the increase in the length of the vegetation period, abundance and species diversity. At least, this is stated in theory.

Current climate was formed 3-4 thousand years ago. Apparently then the composition of the corresponding natural biota was formed. Emergence of new species (with the exception of cultivated plants and domestic animals) in terms of ecology virtually stopped. Emergence of new species that have never grown in this area before is primarily connected with the climate fluctuations which are close to periodic and spatial-temporal shift (cycle) of bioclimatic complexes.

By this time, a new force appeared which had an influence on the biota i.e. human factor which can be compared to the climate and often even exceeds it. Therefore, it is important to consider both of these factors while estimating the biota variations. This work sets a particular goal to estimate a deviation of the biotic diversity only in respect of the climatic factor i.e. the increase in air temperatures within last 50 years in the north of the Tyumen region.

The used climatic indices were taken from the climate data manuals published in 2011 and 1965 [2, 11]. According to the experts, the biota of the end of XX - beginning of XXI centuries approximately corresponds with the climatic indices of the manuals of 1965 [11]. Therefore, the set goal may be achieved by comparison of the data of these manuals and analysis of the results.

Table 6 presents average plurannual values of the average annual (t_c) and July (t_7) temperatures in a number of posts in the north of the Tymen region within the periods prior to 2011and 1965. Picture 6 demonstrates a zonal course of temperature variations within these periods (t_7) and correlation between them ($k= t_{7.a} / t_{7.b}$).

Table 6. Average values t_c and t_7 within the period between 2011 (a) and 1965r.(b) and their deviations within 50 years in the north of the Tyumen region.

№	Point	$t_{c.a, 2011}$	$t_{c.b, 1965}$	$t_{7.a, 2011}$	$t_{7.b, 1965}$	$k=t_{7.a} / t_{7.b}$	$t_7=t_{7.a} - t_{7.b}$
1	Bely island	-11.7	-10.4	4.9	4.1	1.19	0.8
2	Harasavey c.	-10.5	-9.8	6.6	5.5	1.2	1.1
3	Tazovskiy	-8.6	-9.3	14.5	13.4	1.08	1.1
4	Sidorovsk	-8	-8.5	15.6	14.6	1.07	1
5	N.Port	-7.8	-9.4	12.2	11	1.11	1.2
6	Yamburg	-6.3	-6.9	14.3	13	1.1	1.3
7	Salekhard	-6.3	-6.4	14.7	13.8	1.06	0.9
8	Halesavey	-5.3	-5.8	17.2	15.9	1.08	1.3
9	Tarko-Sale	-6	-6.7	16.4	15.4	1.06	1
10	Yar-Sale	-7.3	-7.5	14.4	13.2	1.09	1.2
11	Nadym	-5.9	-6.6	15.9	14.7	1.08	1.2
12	Berezovo	-3.1	-3.8	16.4	15.8	1.04	0.6
13	Surgut	-2.9	-3.1	17.5	16.9	1.04	0.6
14	Nyaksimvol	-2.2	-1.2	17.3	15.8	1.09	1.5
15	Kh.-Mansiysk	-0.8	-1.4	18.3	17.5	1.05	0.8

Table 5 and picture 8 reflect a general tendency towards the increase of July air temperatures within last 50 years: by 0,6 – 1,5°C (in average by 1,04 °C) or by 5-19% (in average by 7 %) with an average velocity: $V_{t7} \approx 1/50 \approx 0{,}02$ degrees/year. There were not observed any spatial (zonal) regularity in distribution of t_7 and k, value of k deviates from post to post negligibly. Therefore, we consider these values constant as a rough approximation and equal to the average value: $t_7 = 1{,}04$ °C; k=1,07.

As for the average annual temperatures, they increase in most of the parts of the region, with the exception of islands and the coast of the Kara Sea (Bely Island and Harasavey Cape) where some decline is observed [12, 13]. This means that warming occurs owing to the increase in summer temperatures.

With the help of the equation of dependency of S

BC	I	II	III	IV	V	VI	VII	VIII
Σ_0	340/**432**	439/**531**	658/**750**	877/**969**	1097/**1189**	1316/**1408**	1536/**1628**	1700/**1819**
Pr	2/**2.2**	2.6/**2.8**	3.9/**4.2**	5.3/**5.6**	6.6/**7**	7.9/**8.4**	9.2/**9.9**	10.2/**10.9**
N_p	327/**335**	338/**346**	364/**371**	390/**396**	417/**421**	449/**457**	469/**472**	480/**491**
N_a	110/**125**	127/**143**	166/**181**	204/**220**	243/**259**	281/**298**	316/**336**	324/**365**

Judging by the data from table 7, the 1°C increase in July temperature and correspondingly the increase in the aggregate of positive temperatures by 93 dd caused an increase in the number of the biota species: the number of plant species increased from 8 in the arctic tundra up to 11 in the middle taiga; the number of animal species increased from 15 in the arctic tundra up to 41 in the middle taiga.

Conclusion

1. Basic climatic indices that determine abundance and diversity of the biota are the heat and aridity indices. The quantity of the biotic taxa within the north of the Tyumen region increases from north to south along with the increase in the value of the above-mentioned indices. Meanwhile, the correlation between quantity of genera, families, orders and the quantity of species is constant. The quantities of species of flora and fauna are in a stable relation, and their ratio is invariant towards climate.

2. Within last 50 years air temperatures of July increased by 1°C, while the accumulated temperatures increased by 93 dd in the north of the Tyumen region. This warming corresponds with the increase in the quantity of species: the quantity of plant species increased by 1-3%, the quantity of animal species increase by 9%. Therefore, there is a positive influence of the climate warming on the biota of the north, though in general this influence is not great and hardly compensates for the adverse factors caused by warming such as fires, floods, etc.

References

Gelashvili D.B., Iudin D.I., Rosenberg G.S. and Yakimov V.N. 2008.Osnovy multifraktal'nogo analiza vidovoy struktury soobschestva [Basics of multifractal analysis of community structure species] . Uspekhi sovremennoy biologii. **128.** (in Russian)

Konovalov A.A. 2014. Strukturirovanie bioty po klimaticheskomu priznaku [Structuring biota on climate sign*]. Agrarnaya Russia*. **4**, 16-20. (in Russian)

Gashev S.N. 2008. Mlekopitayuschiye Tyumenskoy oblasti : spravochnik-opredelitel' [Mammals of the Tyumen region: reference determinant]. Tyumen: *Publishing House of the TSU*. 333. (in Russian)

Il'ina I.S., Lapschina E.M., Lavrenko N.N., Meltser L.I., Romanova E.A., Bogoyavlenskiy B.A. and Makhno V.D. 1985. Rastitelnyy pokrov Zapadno-Sibirskoy ravniny [The vegetation cover of the West Siberian Plain]. *Nauka*. **1**, 21-34. (in Russian)

Rebristaya O.V. 2013. Flora poluostrova Yamal. Sovremennoe sostoyaniye I istoriya formirovaniya [The flora of the Yamal Peninsula. The current state and history of the formation]. SPb . *Publishing House of the ETU "LETI"*. 312. (in Russian)

Titov Yu.V. and Potokina A.F. 2001. Rastitelnost' poymy r. Taz [The vegetation of floodplain of the Taz river] Surgut. *Surgut State University Publishing House*. 141. (in Russian)

Khozyainova N.V. 2007. Flora I rastitelnost' severnoy taygi Purovskogo rayona Tyumenskoy oblasti (Sever Zapadnoy Sibiri) [The flora and vegetation of the northern taiga of Purovsky District, Tyumen region (north of Western Siberia)] . Vestnik ekologii, lesovedeniya I landschaftovedeniya. Tyumen. *Publishing House of the IFSP SB RAS*. **8**. 27-50. (in Russian)

Budyko MI Klimat I zhyzn' [The climate and life]. 1981. *Gidrometeoizdat*. 400. (in Russian)

Konovalov A.A., Gashev S.N. and Kazantseva M.N. 2013. Raspredeleniye I ierarkhiya bioticheskikh taxonov na territorii Tumenskoy oblasti [Distribution and hierarchy of biotic taxa in the Tyumen region]. *Agricultural Russia*. **4**, 48-57. (in Russian)

Khromov S.P. and Mamontova L.I. 1974. Meteorologicheskiy slovar’ [Meteorological dictionary].
L . *Gidrometizdat*. 268.
Konovalov A.A. and Ivanov S.N. 2012. Reconstruktsiya istorii climate po gruppovym palinospektram na primere Zapadnoy Sibiri [Reconstruction of the climate history at the group palynospectra on the example Western Siberia]. Saarbrucken, Germany. *Palmarium academic publishing*. 119.
Scientific-applied directory “climate of Russia, 2011” [Electronic resource]. Access: aisori.meteo.ru / ClspR
Konovalov A.A. and RomanL.T. 1981. Osobennosti proektirovaniya fundamentov v neftepromyslovykh rayonakh Zapadnoy Sibiri [Features of designing foundations in oil producing regions of Western Siberia]. *L .: Stroyizdat*.168. (in Russian)
Spravochnik po klimatu SSSR [USSR Climate Reference Book]. 1965-1966. L . *Gidrometeoizdat*.**17** (I and II).276. (in Russian)
Konovalov A.A., Glazunov V.A., Moskovchenko D.V., Tigheev A.A. and Gashev S.N. 2015.O klimaticheskoy zavisimosti bioty na severe Tyumenskoy oblasti [About biota depending on climate in the north of the Tyumen region]. Materialy III Vserossiyskogo soveschaniya “Chelovek I Sever”. Tyumen. *Izdatel’stvo IPOS SO RAN*. 333-338. (in Russian)
Gashev S.N. Baza dannykh “Rabochee mesto ornitologa”[Data base “Workplace ornithologist”] Svidetelstvo № 2012620405 (zaregestrirovano v reestre baz dannikh 3 may, 2012). (in Russian)

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PHOTOSYNTHETIC PIGMENTS CONTENT IN HEDYSARUM ALPINUM L. LEAVES

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Introduction

The cultivation of plants outside their natural range (introduction) is becoming a means of their conservation, which is relevant in terms of anthropogenic pressure natural ecosystems that include these species are exposed to [1].

Successful adaptation to environmental and climate conditions of the introduction area is necessary for the survival of introduced species in their new habitats [2].

In this connection, the analysis of the flexibility of the photosynthetic apparatus and its ability to adapt to changing conditions plays a significant role in the examination of plants condition. It is known that one of the factors indicating the reaction of plants to environmental changes and the degree of adaptation to new ecological conditions is the content of chlorophylls and carotenoids – the principal photoreceptors in a photosynthetic cell [3].

Chlorophylls are the main pigments in the photosynthetic apparatus of plants. In the course of plant development, the concentration of pigments is determined by the dynamic balance of their synthesis and disintegration. Stress also affects pigments concentration, therefore their ratio is not constant.

The photosynthetic productivity of plants is determined by the efficiency of light conversion in chloroplasts, the rate of photosynthetic metabolites generation and their employment in growth processes and secondary compounds biosynthesis.

The object of the present research is Hedysarum Alpinum L. – a precious fodder and medicinal plant, with a xanthone glucoside mangiferin as an active ingredient.

Hedysarum Alpinum L. is widely used in the production of medicines (based on threshed herbs) since magniferin and isomagniferin possess strong antiviral activity. Such medicaments are used to treat infections caused by herpes simplex virus [4].

The present report is devoted to the study of pigments and adaptation of the photosynthetic apparatus of Hedysarum Alpinum L. plants of different age states at different stages of phenological development.

Materials and methods

Material collection was carried out in June-August 2013 at the experiment sector in the Siberian Botanical Garden of Tomsk State University.

The concentration of chlorophylls *a*, *b* and carotenoids was measured using a spectrophotometric method; the measurement was based on guidelines [5]. Hedysarum Alpinum L. samples of different age states were collected at principal stages of plant development with a three-fold repetition, a weighed amount being 50 mg. Then the extraction of pigments was carried out with 96% ethanol in a laboratory setting. Pigment extracts underwent vacuum filtration. Optical densities of pigment extracts were measured with a double beam spectrophotometer Shimadzu UV-1650 in a cuvette, 1 cm thick at absorption centers: 644 and 662 nm for chlorophylls *a* and *b*, 440.5 nm for carotenoids.

The calculation of chloroplast pigments concentration was based on Vernon formulae. Optical densities were measured at a wavelength of 440.5 nm to assess carotenoids content, and at 665 and 649 nm wavelengths to assess the concentration of chlorophylls *a*, *b,* respectively [5].

Statistical processing of the experimental data was performed on a personal computer with the use of Microsoft Excel program.

Results and discussion

Pigments are compounds capable of absorbing light in the visible region of the spectrum. Pigment content in leaves is widely used as an indicator of a physiological condition of plants depending on external and internal factors [6].

Pigment content of Hedysarum Alpinum L. was assayed under conditions present in the south of West Siberia for the first time. The amount of chlorophylls *a*, *b* in middle-aged plants was 3% and 6% higher than in young species, conversely, the amount of carotenoids was 4% higher in young plants.

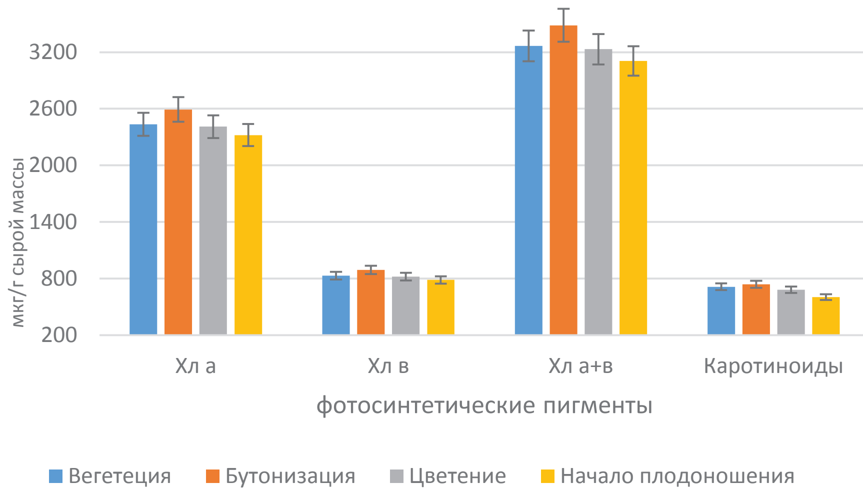
The concentration of pigments was dependent on the stages of plant development and the age. The highest amount of pigments was observed in the first half of July –bud formation phase – then a significant decline by 300 mkg/g of raw mass followed during fruit set.

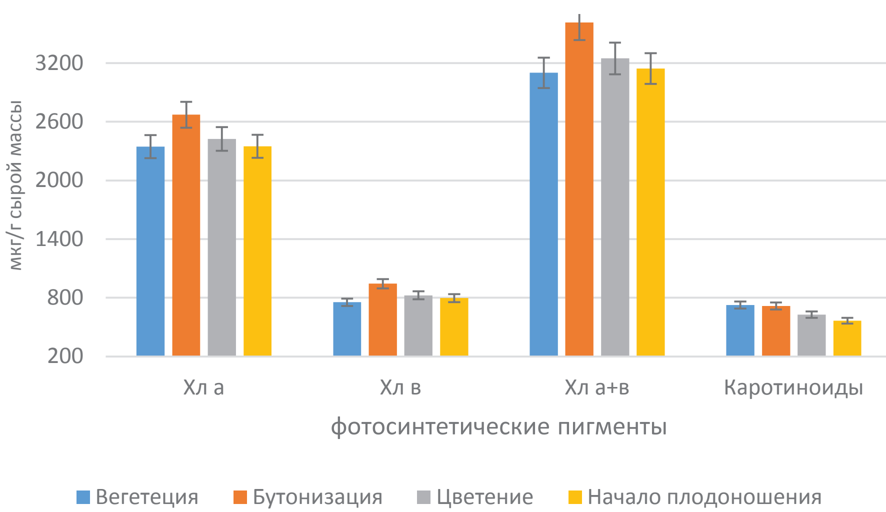
The largest number of pigments was found during bud formation. Most probably, it is connected to high metabolic activity in preparatory period before the realization of a reproductive function, greater consumption of energy and, as a result, active formation of the photosynthetic apparatus.

The minimum values of chlorophyll *a* in middle-aged plants were determined in a vegetative phase and at the beginning of fruit set, they made up 2346.2 mkg/g of raw mass and 2347.9 mkg/g of raw mass, respectively. The maximum pigment concentration was observed during bud formation, the value being 2671.3 mkg/g of raw mass (figure 1).

The minimum values of chlorophyll *b* in two-year-old plants were ascertained in a vegetative phase and at the beginning of fruit set and amounted to 2435.6 mkg/g of raw mass and 2321.3 mkg/g of raw mass, respectively. The maximum pigment concentration was observed during bud formation – 2671.3 mkg/g of raw mass (figure 2).

The analysis of carotenoids content shows that the dynamics is different from that of chlorophylls. The ratio of chlorophylls sum to carotenoids is an important indicator showing how successfully the photosynthetic apparatus functions and it is sensitive to changes in the environment. The ratio of the sum of chlorophylls *a*+*b* to carotenoids content in middle-aged species and plants of young reproductive age was within the normal range and equaled to 5, in young species it was slightly lowered to 4. It follows that the young plants were under stress conditions, which indicates a decline in the light-harvesting function of the pigment complex under inauspicious conditions during vegetative season. Probably, it is connected with a marco- and microelement nutrition deficiency, as well as infavourable weather conditions of the dry summer in 2013.





Conclusion

The result of the present research is the measurement of maximum and minimum values of photosynthetic pigments content in Hedysarum Alpinum L. leaves of specimens of different age under conditions of the introduction to the sub-taiga zone in the south of West Siberia.

The content of photosynthetic pigments in mature specimens is 100 mkg/g of raw mass higher than in young plants.

The maximum values of pigment concentration can be observed during bud formation in specimens of all age states. It indicates active functioning of the photosynthetic apparatus at this stage of development and a decline in activity at other stages. The peak of photosynthetic activity occurs in the first half of July.

Under environmental conditions present in West Siberia the development of the photosynthetic apparatus increased from the beginning of the vegetative stage, a decline was observed by the beginning of reproductive organs development.

Middle-aged specimens possessed a more developed photosynthetic apparatus, which is the consequence of a developed root system, which in its turn provides an efficient supply of macro- and microelement nutrition. The concentration of photosynthetic pigments – chlorophylls and carotenoids – determines efficiency and biological productivity of plants.

It is particularly important to measure quantitative composition of photosynthetic pigments in introduced plants as the functioning of the photosynthetic apparatus can indicate current adaptation processes.

References

[1] Rozno, S.A., 2005. Ecologo-biologicheskiy analiz itogov introductsii drevesnikh rasteny v lesostepi Srednego Povolzhya [Ecological and biological analysis of the results of the introduction of woody plants in the forest of the Middle Povolzhye]. Avtoreferat dissertatsii . Samara. 20. (In Russian)

[2] Bazilevskaya, N.A. 1964. Teorii I metody introduktsii rasteniy [Theories and techniques of plant introduction] .M oscow. *Publishing House of Moscow University* . 131. (In Russian)

[3] Tuzhilkina, V.V . 2009. The reaction of the pigment system on a long coniferous environmental contamination *Ecology*. **4**, 243-248.

[4] Orlovskaya, T.V. and Babayan, M.S. 2006. Macro i microelementarniy sostav korney kopeechnika al'piyskogo [Macro and microelement structure of the roots of Hedysarum Alpine]. *Razrabotka, issledovanie I marketing novoi pharmatsevticheskoy produktsii* . Pyatigorsk . *Pyatigorskaya gosudarstvennaya Pharmatsevticheskaya Academiya*. **61**, 41-45. (In Russian)

[5] Shlyk, A. A. 1971. Opredeleniye chlorofillov I karotinoidov v extraktakh zelenykh listyev [Determination of chlorophylls and carotenoids in extracts of green leaves]. Biochemicheskie Methody v physiologii rasteniy. Pavlinova O.A. (Ed.). Moscow. *Naukha*. 154-170. (In Russian)

[6] Peshkova, A.A. and Dorofeev, N.V. 2011. Adaptatsiya photosinteticheskogo apparata ozimoy pschenitsy v period osennego razvitiya [Adaptation of the photosynthetic apparatus of wheat during the autumn development period]. *Vestnick Irkutskoy gosudarstvennoy sel'skokhozyaistvennoy academii* - **45**, 20-27. (In Russian)

Figure 1. Phenological dynamics of chlorophylls *a*, *b* and carotenoids content in middle-aged species of Hedysarum Alpinum L.

Figure 2. Phenological dynamics of chlorophylls *a*, *b* and carotenoids content in two-year-old species of Hedysarum Alpinum L.

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