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Manfred Frühauf & Peter Liebelt (Editorial board)

Consequences of land use and climate change for landscape water budgets, soil degradation and rehabilitation in the forest steppe zone of Bashkortostan

Results of an international and interdisciplinary joint project (sponsored by the VOLKSWAGEN-Foundation) between German and Russian scientists

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Titelbild / cover picture

Cover photos by Peter Liebelt (taken in the forest steppe of the Republic of Bashkortostan during the project period)

(On top, from the left to the right: 1. Typical landscape in the forest steppe zone - in the foreground: Fallow land, with forms of water erosion; 2. Implementation of new technologies for Minimum Soil Tillage on the "Artemida" - Test Plots
Below, from the left to the right: 3. Gully erosion in the region of Tujmazy; 4. Meteorological station at the "Water Balance Station"; 5. On-side damage of water erosion caused by melting water on field, managed by conventional soil tillage)

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0 Introduction

Although Russia is the country with the largest area in the world, it has, due to its specific geographic position, a proportionately small area which can be used for agricultural purposes (13%), esp. for ploughing (7%) (Stolbovoi & Sheremet 1995).

Among all regions, most suitable for agricultural use is the forest-steppe zone, which is, consequently, subjected to a heavy pressure of exploitation (Chanyshev 2008).

The Republic of Bashkortostan geographically encompasses great portions of the forest-steppe zone of Russia and, by this, constitutes one of the main agrarian regions of the country (Ismagilov 2005, Bashstat 2013).

During the Soviet land use epoch, especially under the new agrarian politic (1954 – 1963), a considerable intensification of the agrarian land use took place in Bashkortostan (Russian Academy of Science 1979, Bashkortostanstat 2007, Ismagilov 2005).

However, the way of land use, not sufficiently adapted to the natural conditions, and its intensity led to an increasing degradation of soils, which manifested itself in a decrease of soil fertility and, particularly strong, in the increase of water erosion (Gabbasova 2004).

These degradation phenomena endanger, apart from important ecological functions of the forest-steppe, especially the utility function of this – not only for Bashkortostan – important agrarian area (Lal et al. 1998, Stolbovoi 2002, Scheffer & Schachtschabel 2002, Gabbasova 2004, Khaziev 2007, Khabirov 1995).

After the breakup of the Soviet Union, new economic and political framework conditions, as well as climate change led to new patterns in the complex interaction between land use and soil degradation, out of which arose, in turn, new ecological as well as economic consequences (Chernyakhovsky & Tishkov 2002, Bashkortostanstat 2007, Liebelt 2010 [unpublished]).

This problem has been addressed by the two interdisciplinary research undertakings sponsored by the VW – foundation: in the year 2007, the first research titled "*Development of Land Use and Soil Degradation and their Consequences for the Forest Steppe Zone of Bashkortostan*" has begun. The subsequent project extension with the topic: „*Consequences of (post-socialist) land use and climate change for landscape water budgets, soil degradation and rehabilitation in the forest steppe zone of Bashkortostan*" (2010-2013) was mainly attempted to analyze the impact land use change has on soil degradation in the context of climate change.

With the incorporation of further project partners from different research and education institutions, the interdisciplinary character of the undertaking has been broadened significantly with the aim to increase the quality, as well as the applicability and sustainability of the project results through the obtained synergy effects. The methodology used in this respect has been oriented towards different work packages, which made the cooperation more effective and eased the realization of the project.

In correspondence with the thematic core elements of the project, work packages have been created, each of which was under the responsibility of the respective project partner.

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1 Topic: Economic and political conditions and their effects on land use

The effects of political and economic factors on agricultural land use

Yumaguzhina, D.R.

Introduction

In Russia, the XXth century had been a challenging period of numerous transformations, which had their impact on every aspect of life of an individual. And one of the most important problems the reformers in Russia faced was the issue of private ownership of agricultural land. Without delving deep into the history of land reforms in Russia, we will start with the fact that by the end of the 1980-s the state system of land ownership, instituted by the Land Code of the RSFSR of October 30, 1922, had proved its ineffectiveness in this or that way, and in the of 1990 a course was taken on agricultural lands privatization.

The main goal of land relations reform in Russian Federation was breaking up the state ownership of land, creating conditions for a land market and its participants – land owners with private property rights - to emerge. It was assumed that instituting private land ownership and developing a free land market would create conditions for a situation, in which these land plots end up being distributed among the most effective land owners – those who have the most optimal combination of personal qualities (entrepreneurship skills, quick adaption to market economy mentality, etc.) and resources (financial means and enterprises). As a result of market mechanism at work those owners, who would fail adjusting to market agriculture, would supposedly leave the sector of the economy, selling (or leasing) these plots to the more successful farmers, who would bring out the agricultural sector from stagnation while competing with each other in price and quality of produced goods.

At the beginning of the property relations transformation in Russia in the early 1990-s 11,8 million of rural people were given land shares in the shared land ownership rights. But in the result of combined effect of numerous political, economical, social and psychological factors, property relations transformation have turned into a complicated, contradictory and protracted process, still in run in many regions in Russia. The resulting ambiguous legal status of the privatized lands lead to ineffective use of these lands, which in its turn lead to significant decrease of the area of arable lands in both Russia and Bashkortostan.

In the joint scientific research project “Consequences of (post-socialist) land use and climate change for landscape water budgets, soil degradation and rehabilitation in the forest steppe zone of Bashkortostan” with the colleagues from Martin Luther University Halle-

Wittenberg we tried to ascertain the interaction of different political and economical factors and its influence on land use in the Republic of Bashkortostan.

Methodology

During the research and study works our group used legal acts of the Russian Federation, the RSFSR, the Republic of Bashkortostan, the Bashkir ASSR, the data provided by the statistics services Rosstat and Bashkortostanstat, annual state reports of various ministries and federal agencies, state departments (Ministry of Agriculture of the Russian Federation, Ministry of Agriculture of the Republic of Bashkortostan, Ministry of Finance of the Republic of Bashkortostan, the territorial branches of Rosreestr, Rosselkhoznadzor, Rosprirodnadzor on the territory of the Republic of Bashkortostan), analytical reviews of agricultural markets, monographs and studies, articles of Russian and foreign researchers written in 1995-2012, financial reports of some farms and agricultural enterprises.

The research works were divided into four stages:

I. General economic description of the agricultural production and land use processes in the Republic of Bashkortostan.

II. Investigation into the economic factors influencing agricultural production and land use processes in the Republic of Bashkortostan

III. Analysis of political factors influencing agricultural production and land use processes in the Republic of Bashkortostan.

IV. Study of the interaction and correlation of the two factor groups influencing agricultural production and land use.

Ideas and concepts of institutional economics worked as the theoretical basis of the research. To study the economical aspects of political factors we used concepts of "land property (ownership) institution", "formal land use rules", "informal rules of land use", "property rights specification", etc. To analyze economical factors we used indicators as profitability level, total output, land use efficiency rate, price level changes, structure of an enterprise's material costs, level of equipment stock, etc.

When analyzing indicators of total output and land use dynamics we grouped all the agricultural business units into three categories – agricultural enterprises, private peasant farms, private household farms.

The first category includes:

- large and average-sized enterprises – agricultural production cooperatives, business partnerships and societies, state and municipal companies;
- small enterprises – agricultural production cooperatives, business partnerships and societies;
- subsidiary farms of non-agricultural enterprises.

The second category (private household farms) includes private farms, individual farms for grocery, cattle-breeding, etc. A private household farm is a farm in which a citizen, or a citizen and his family members living together with him, is engaged in agricultural activity for satisfying their own personal needs (not market oriented) on a land plot, purchased or granted for private household farming.

Third category - private peasant farms. A private peasant farm is an association of citizens, related by blood and (or) property, sharing common assets (property) and carrying out together production and other economic activities (production, processing, storage, transportation and marketing of agricultural products), based on their personal involvement. Such farming can be created by one citizen, too.

To differentiate two groups of common (collective) land ownership we used terms “collective-shared ownership”, when the land plot is divided into shares, each for a certain individual, and “joint-collective ownership”, when the land plot is assigned to a certain group of people, but with no shares defined.

Results

In our research we have studied several influencing use of agricultural land factors, which we divided into two groups - economic and political.

The economic factors include:

1. Lack of funds, financial resources and low profitability;
2. Low stock of means of mechanization and equipment;
3. Disparity in prices of agricultural and industrial products;
4. The high costs of oil and fuel goods;
5. High costs on enrichment and restoring soil fertility means;
6. Limited access to credit.

The political factors include:

1. Inaccurate and contradictory land legislation;
2. Low level of legal education of the rural population;
3. Clash of formal and informal rules while distribution and turnover of land resources;
4. High transaction costs of converting the ownership form of land and privatized enterprises;
5. Former collective leaders’ and managers’ inclination towards opportunistic rent-seeking behavior.

Economic factors

Lack of funds, financial resources and low profitability

According to Bashkortostanstat, the level of profitability of the enterprises in the agricultural sector in 2008-2012 decreased. By the end of 2012 the all-activity profitability level, with including subsidies into calculation, in the agricultural organizations was equal to 8.4%, whereas in 2008 this figure was 16.9% [12]. The sharp decline in profitability has been due to the financial and economic crisis of 2008-2009 and severe natural conditions of 2009-2010. In addition to these random shock factors, there has also been influence of factors such as low yields and high costs of agricultural business, insufficient stock of mechanization means and equipment, etc. on the overall financial situation of the enterprises.

Supporting the financial condition of agricultural producers in this severe economic situation was placed upon the specifically designed program of government subsidies. But the current system of direct subsidy payments and compensations has several disadvantages.

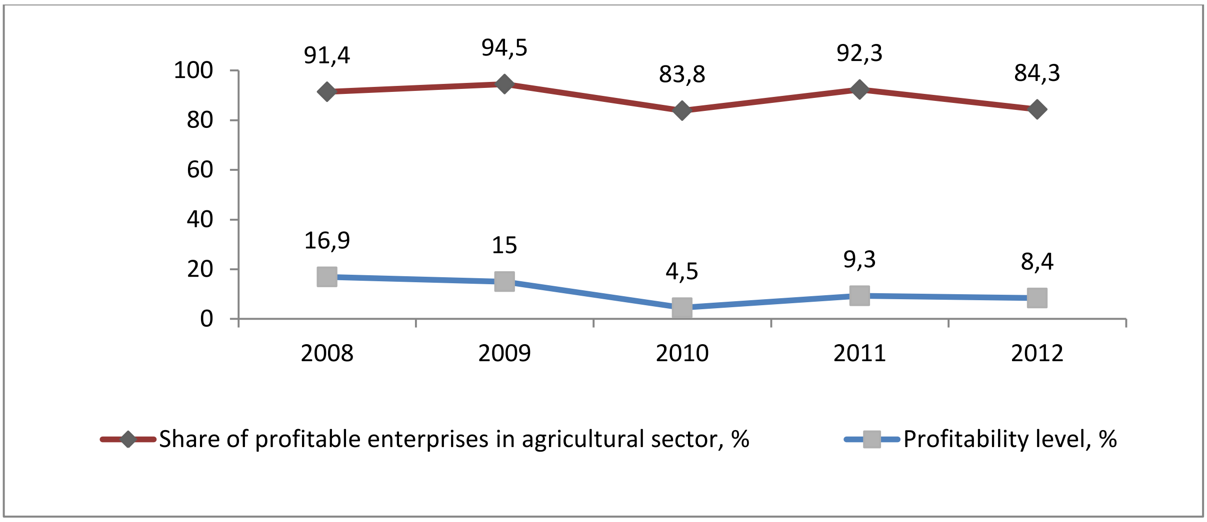

Fig. 1: Share of profitable enterprises in agricultural sector and average profitability level (by %) in 2008-2012 in the Republic of Bashkortostan [12]

For example, the amounts of subsidies received by agricultural producers are taxed, because according to its intended purpose subsidies are granted to the recipients as “at no-charge and irrevocable basis in order to generate income”. However, taxing subsidies significantly reduces the already low level of profitability of agricultural producers.

Agricultural producers lacking the financial resources is not only influencing the output and quality of the products, or the level of income of the rural population. It also influences use of land resources – according to the reports of branches of Rosselkhoznadzor and Rosprirodnadzor in the Republic of Bashkortostan, the largest share of violations in agricultural land use by land users belongs to “failure to provide measures to protect the land from the overgrowth with weeds” and “cluttering of soils”. We should note, though, that the reasons for such violations are the lack of financial funds to provide works on protection and improvement of the land and for cultivation of all the available space, which poses a serious threat to the state land fund of the republic.

Low stock of means of mechanization and equipment

As we can see from the Table 1, in 2001-2010 the number of agricultural machinery used in production, significantly decreased, and the degree of wear on the equipment used increased.

Table 1: Stock and depreciation of agricultural machinery and equipment in 2001-2010 [12, 13]

№	Type of the equipment	01.01.2001		01.01.2010		
		stock, units	wear degree, by %	stock, units	wear degree, by %	average age
1	tractors	37278	73	18532	87	18,8
2	combine harvesters	10687	58	3237	81	14,1
3	foragers	3153	59	1049	63	11,8
4	beet harvesters	1183	63	341	91	17,1
5	grain drills	14766	73	9339	83	-
6	cultivators	14700	71	7917	85	-

Despite the significant financial support from the government (in 2011-2012 1,34 bln. rubles were budgeted as subsidies to partially compensate the cost of acquisition of agricultural machinery) , fleet renewal in the agricultural sector has not allowed to reach target indicators of technical and technological modernization of agriculture established by the State Program Of Agriculture Development. In 2011 renewal ratio of tractors was 3.8%, combine harvesters - 7.7%, forage harvesters - 17.6% (according to the program, the indicators should have been equal to 9.2%, 11.5% and 12.0 %, respectively).

Low stock of means of mechanization and equipment is due to the low level of profitability in enterprises, relatively high purchase prices of new domestic and foreign agricultural equipment, reluctance of the majority of agricultural producers to invest in unprofitable production, etc.

As a result, there are large areas of arable land assigned to the various agricultural organizations, which in fact are not cultivated or used for its intended purpose, which causes the degradation of soil, on the one hand, and land cluttering, on the other, which ends in them being withdrawn under the pretext of non-use and converted into other land categories.

Disparity in prices of agricultural and industrial products

Another factor aggravating the economic and financial situation of agricultural producers is the disparity in prices of agricultural and industrial products. In the 1990-2000, prices of agricultural products grew much slower than the prices of the goods of other industries. Thus, according to the World Bank report, from 1991 to 1999 the prices of agricultural products sold increased by only 2,7 times (considering the ruble denomination in 1998), while prices for industrial goods and services purchased by agriculture has increased 8 times [17]. Over the same period of time prices on fuels and lubricants increased 17.4 times and electricity charges - 13.2 times.

According to the calculations by Sokolova I.A. [16], during this period the prices of agricultural products rose by 2.6 times, while the prices of industrial products and services - 13.1 times. More than 300 billion rubles has been withdrawn from agriculture to other sectors through price disparity mechanism over these years [16]. According to Bashstat, too, in 2000-2010 the imbalance in the ratio of prices on agricultural products and prices on other commodities has increased significantly.

Table 2: The ratio of the prices on some goods purchased by agricultural organizations, with the producers' selling price of wheat in 2000-2010 [12, 13]

	2000	2005	2006	2007	2008	2009	2010
Wheat (tones)	1	1	1	1	1	1	1
Motor gasoline (tones)	3	5,8	5,5	4	4,4	4,6	5,5
Diesel fuel (tones)	2,5	5,5	5,1	3,5	4,3	3,7	4,4
Tractors (units)	122	374,7	390,1	308	395,5	431,9	397,6
Harvesters (units)	305	1029	948,9	690,8	870,1	1137,7	1201,1
Fertilizers and nitrogen compounds (tones)	0,7	3,5	3,5	2,8	4,4	4,4	5,6

Bashstat's data also show the growing disparity in prices of agricultural products and prices of goods in other industries (Table 2). So, if in 2000 the price of 1 ton of gasoline was 3 times higher than the price of 1 ton of wheat, in 2010 the difference was 5.5 times. There was even more increase of the difference between selling price of a ton of wheat and purchase price per unit of combine harvester - in 2000 to buy a unit of a combine harvester a producer had to sell 305 tons of wheat, and in 2010 - 1201.1 tons of wheat, because price per ton of wheat in 2000-2010 increased 1.77 times, and price per one unit of harvester - almost 7 times.

Disparity in prices of agricultural and industrial products has not only direct but also indirect effect, resulting in higher prices for fuel and tillage means.

High costs on acquiring petroleum, oils, and lubricants

Another factor that despite subsidies coming from the state budget complicates the situation for farmers is the steady rise trend in oil prices and fuel.

In 2012 500.0 million rubles subsidies for diesel fuel were transferred from the agricultural budget of the Republic of Bashkortostan [13]. But as a result of unfavorable factors of 2008-2010 fuel prices grew annually at fastest pace in comparison to other rural resources, and the share of costs of their purchase reached 40-45 % of the total costs for material and technical means used in agricultural production, which significantly increases the cost of agricultural products.

It is obvious that with the current price ratio agricultural producers are at a disadvantage – their costs of production and products delivery to the consumers certainly does not pay off. Moreover, the increase in fuel prices and means of transport led to the situation in which producers of agricultural products (population of villages) are distanced from large consumer centers (urban population) and do not have lots of chances to contact customers directly, because they just don't have enough money to do so. This created favorable conditions for the development of a level between the producers and the customers – intermediaries, who sell the agricultural products at prices several times higher than the prices they purchased at.

High costs on enrichment and restoring soil fertility means

In the studied period there was a significantly increase of the purchase prices on agricultural fertilizers – in 2000 the average price per one ton of fertilizer was about 1604 rubles, and in 2012 – about 28492,5 rubles. A similar trend is observed for plant protection means (chemical weed and pest killers) – during the last 10 years the cost of 1 kg of insecticides increased 3.7 times [12, 13] .

Rising prices on chemical weed and pest killers, fertilizers and means of restoring soil fertility do not allow the average agricultural producer to provide a full range of activities, conditioned by the laws and regulations. For example, the standard rate of mineral fertilizer is 8-10 centners [1]per 1 hectare in forest-steppe zones, and according to the data of Bashstat in 2012 the average rate in the agricultural enterprises of Bashkortostan was 0,14-0,19 centners per 1 hectare of area sown under crops. We should note, though, that with vegetables, potatoes and sugar beet the situation the situation is more favorable [12,13]. Limited access of agricultural organizations to mineral and organic fertilizers is also indicated by the fact that in 2012 mineral fertilizers were used only on 27 % of the cultivated area, and organic fertilizers – on 8.5%.

Limited access to credit

As we can see from figure 2, the majority of loans is drawn by agricultural enterprises, whereas private peasant farmers and private household farms attract a small share of loans.

In 2011, the total amount of loans to agricultural producers issued by the financial institutions in Bashkortostan was equal to 8.4 billion rubles. Of these, 7.2 billion rubles were given to agricultural enterprises, including 5.2 billion of short-term loans, 0.6 billion rubles of

[1] 1 centner corresponds in Russia 100 kg

8-years investment loans and 1.4 billion rubles of 10-years loans raised for technical and technological modernization of agricultural business.

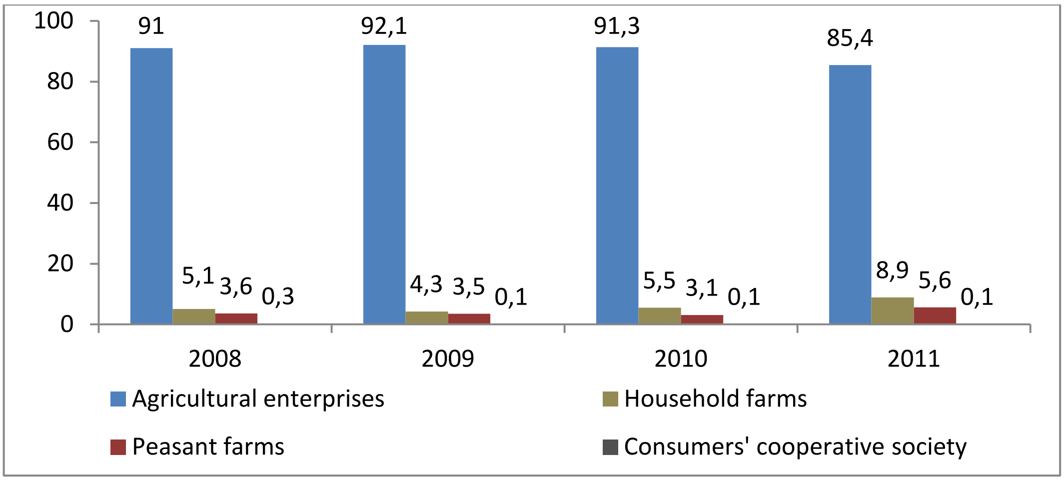

Fig. 2: Structure of loans raised by agricultural producers in 2008-2011[13]

The main constraint factor for the expanding the agricultural credit is the absence of liquid assets. Most of the agricultural producers can't take part in a credit transaction because of high depreciation level of fixed assets, lack of easy-convertible securities and a developed land market.

In this regard, introducing and expanding land security transactions could be a promising direction in solving the problem of limited access to bank credit and loans for agricultural producers.

Political factors

For reference

State land control of agricultural land use is mainly carried out by the three agencies – Rosprirodnadzor, Rosselkhoznadzor and Rosreestr, as well as by other ministries and departments within their established authority. Rosprirodnadzor and its branches over the territory of the Russian Federation exercise control over the land use, land conservation and land enrichment; Rosselkhoznadzor exercises control over the soil treatment and the use of pesticides, agrochemicals, etc., Rosreestr monitors the implementation of land legislation, land ownership relations and land use.

Land ownership relations in the Russian Federation are regulated by the Land Code of the Russian Federation, the Civil Code of the Russian Federation and a number of other specific legal acts.

Three forms of land ownership are recognized today in Russia – individuals' land ownership, ownership of legal entities and state land ownership.

The main law regulating the agricultural land turnover is the Federal Law of July, 24, 2002 №101-FZ «On the turnover of agricultural lands». This law regulates relations connected with land possession, land use and disposition of land, sets the rules and restrictions that apply to the land turnover and land shares, determines the terms for granting land plots from agricultural land category, owned by the state or in municipal property, to individuals and legal entities, etc.

According to the data provided by the territorial branch of Rosreestr in the Republic of Bashkortostan, on January 01, 2012 the total area of agricultural lands was7691.9 hectares; 2239.1 thousand hectares (29.11%) of agricultural land were owned by citizens, 3.2 thousand hectares (0.04%) – by legal entities, 5449.6 thousand hectares (70.85%) were in the state and municipal property (figure 3).

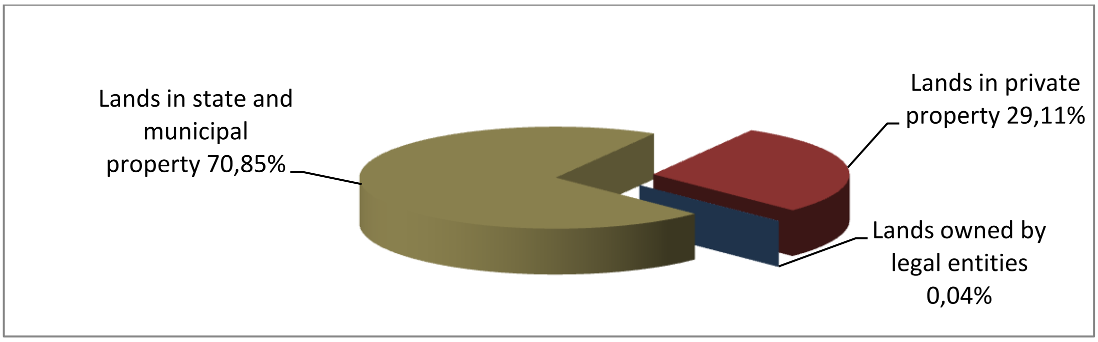

Fig. 3: Agricultural lands by ownership forms in Bashkortostan on January 1, 2012 [11]

The large share of agricultural land owned by the state can be explained by the incomplete land reform which started in the 1990-s.

In the Republic of Bashkortostan land privatization process evolved in two stages:

- from 1992 to 2005, when on the territory of the Republic of Bashkortostan regulations restricting the free circulation of land shares and land plots were implemented;

- January 01, 2006 till July 01, 2013, when processes of free registration of land property rights (state tax levied only) were actively implemented on the territory of the Republic of Bashkortostan, and land plots and land shares turnover was regulated by the federal laws and was free of state (or local administration) control.

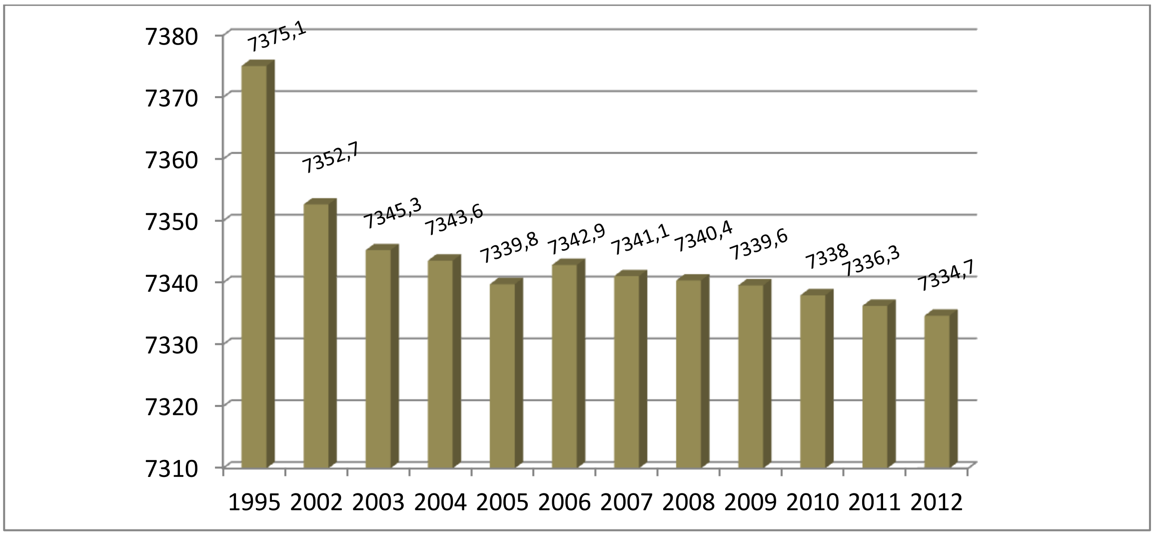

Fig. 4: Total area of agricultural land in the 1995-202 in Bashkortostan [11]

In the result of transformation processes in 1995-2012 years the area of agricultural lands has decreased from 7375.1 thousand ha to 7334.7 thousand ha, while the area of arable land decreased from 4562.0 thousand ha to 3665.0 thousand ha (by 897.0 thousand hectares.) Reduction of arable land area was mainly due to the ongoing processes of converting degraded arable land into grasslands, which resulted in an increased area of hayfields and pastures. But it should be noted that often the degraded arable land is the result of the fact that many land owners and land users do not hold the full range of soil fertility conservation and restoration activities, and this, in turn, is caused by lack of financial resources, as well as numerous legal difficulties of proper registration of land use rights.

Inaccurate and contradictory land legislation

Our research has shown that in practice the entitling legal documents at the beginning of the land reform were often issued incorrectly due to the fact that at the beginning of land privatization the prescribed format of the title documents was not established, which in turn subsequently led to numerous land disputes. For example, many resolutions and legal acts of local authorities did not specify sizes of shares, land plot areas, the list of potential proprietors, etc. Moreover, the entitling document was to be issued only once – and it was handed to the head of the enterprise in reorganization (privatization). And handing copies of these documents to the individuals – potential owners of the land shares in a joint property – was not provided.

There were also problems when issuing right confirming documents, too [18], such as state act on land ownership rights, lifetime inheritable possession rights, permanent land use rights; certificate on land ownership, certificate on rights of ownership on a land plot and certificate of state registration of land ownership rights. Each of these documents, which replaced each other at different stages of privatization, had its drawbacks. For example, the state act on land ownership rights (or any other right) used the title of agricultural enterprises, although some of the land plots could belong to individuals on the right of joint-collective or collective-shared ownership, and was handed to the head of the enterprise; and individuals could get the same information about the size of their share only after applying for information to the Land Committee. Other example – the certificate on land ownership did not specify the list of participants of collective ownership on land plot in a collective-shared ownership or in a joint-ownership on a land plot. The third document – certificate on rights of ownership on a land plot – had no reference to the entitling document, which was the basis for a right of a collective-shared ownership or a collective-joint ownership to emerge in the first place.

Such ill-prepared entitling and confirming rights documents play against individuals – after some period of time even the reasons why the certificates were given to these agricultural organizations in the first place are forgotten.

Another factor that hinders the process of allotting lands to the landowners are the differences between the federal and regional land laws. The federal government passed the responsibility to establish the size limits of formed land plots to regional authorities [2]. For example, land legislation in the Republic of Bashkortostan set the maximum size of a total area of land that can be simultaneously in the ownership of an individual at 3 hectares, though the land share in the republic varies from 3.7 ha to 15.5 ha [10]. This creates the situation when the allocation of land share for private household farming is not allowed by the legislation.

There were other shortcomings, too – for example, the average size of an allocated land share (which is approximately 6 hectares) is insufficient for effective farming [9]. To run the without-loss production a farmer needs more land, for example to rent a land plot or several, but this requires financial means, which are unachievable for an average farmer.

Low level of legal education and awareness of the rural population

The research has shown that in the early stages of privatization public awareness of the procedures of land plots and land shares registration, as well as of rights and responsibilities of share-owners was incredibly low.

Lack of easy accessible for a villager information, its distortion due to the low qualification of local specialists , deliberate manipulation of information flows by local administrative elites led to the fact that collective-farm workers often did not understand either the idea of the concept of «shared ownership» or legislation regulating the use of land shares [14] .

An important role belonged to the fact that the flow of information concerning the rights of rural residents and land registration procedures at the time was not controlled by the state. Most people did not have access to the central newspapers, which published the legislative acts concerning land relations. In addition to the fact that the villagers had troubles with understanding juridical language, in some Russian regions (including Bashkortostan) there was another barrier – local rural population did not know Russian language adequately, communicating in everyday life on their native one. And, despite the fact that in such regions there were two officially recognized languages – Russian and local – there was almost no adequately translated legal acts.

In addition, information about the possibility of allotting a land plot was often primarily distributed among those locals, who were related or had friendly ties with the civil servants of local administration. Such households had the chance to choose the most fertile and favourably-located plots.

Clash of formal and informal rules in the field of distribution and circulation of land resources

In accordance with the new laws reforming land ownership relations and the reorganization of agricultural enterprises, the employees of these organizations had to resign if they wanted to allot their plot and acquire property rights on it. For an employee of an enterprise to allot his own share-plot from the agricultural land formerly in collective ownership meant to oppose the former co-workers economically and psychologically. Confrontation between collective economic interest, aimed at preserving the existing forms of land ownership, and economic interest of an individual, who wanted to obtain his share of land in private ownership, was an important factor which slowed down the process of forming new land relations.

Considering that land in common ownership differed in quality or location, and all employees wanted to get the best farm land, it was difficult to talk about any approval or consent among the workers [15] when allocating the share-plots. In practice, it was difficult to reach the agreement among the all the co-owners of the land plot – there could be dozens of candidates on the same plot, while on the other there could be no one.

This confrontation caused by imperfections of formal institutions was another result of a lack of thoroughness in making land laws regulating the reorganization of land relations and the formation of new land ownership relations.

High transaction costs of converting the form of ownership of land and privatized enterprises

Issuing documents on land planning and registration of private land ownership meant significant costs. In 2008-2010 each resident, who had the right to privatize the land plot from agricultural lands, would spend on the procedure around 5-10 thousand rubles. Not all the villagers could afford themselves spending such amounts of money to obtain private ownership over a land plot, therefore, not all of them could turn into owners, which is also pushed back and postponed the process of land privatization.

As we can see from figure 5, unregistered property rights (when the owner has no entitling documents), limits his/her abilities of making any transactions with the land plot – it is not possible to make a selling or leasing contract, as well as carry out any other transactions, suggesting the transfer of rights. Adding this to the reasons mentioned above, a situation is created when an individual share holder had to enter a collective contractual relationship with the former kolkhoz's, now a privatized company, management over the lease of land shares. In such a contract, one party is a collective of a former kolkhoz, now shareholders, and the other party - the company's management, their employer. The result is a situation where each individual share holder becomes dependent, on one hand, from the collective of an agricultural enterprise, because he can't exit the contract at will, and on the other hand – from the current employer, as he is simultaneously acting as a tenant. This dual dependence resulted in many breaches of rent payments, wage payments, etc. Often such contracts with shareholders were not registered at all. Some rural residents, in the absence of alternative sources of employment and income in rural areas, just exited from the land users, and did not use their property rights.

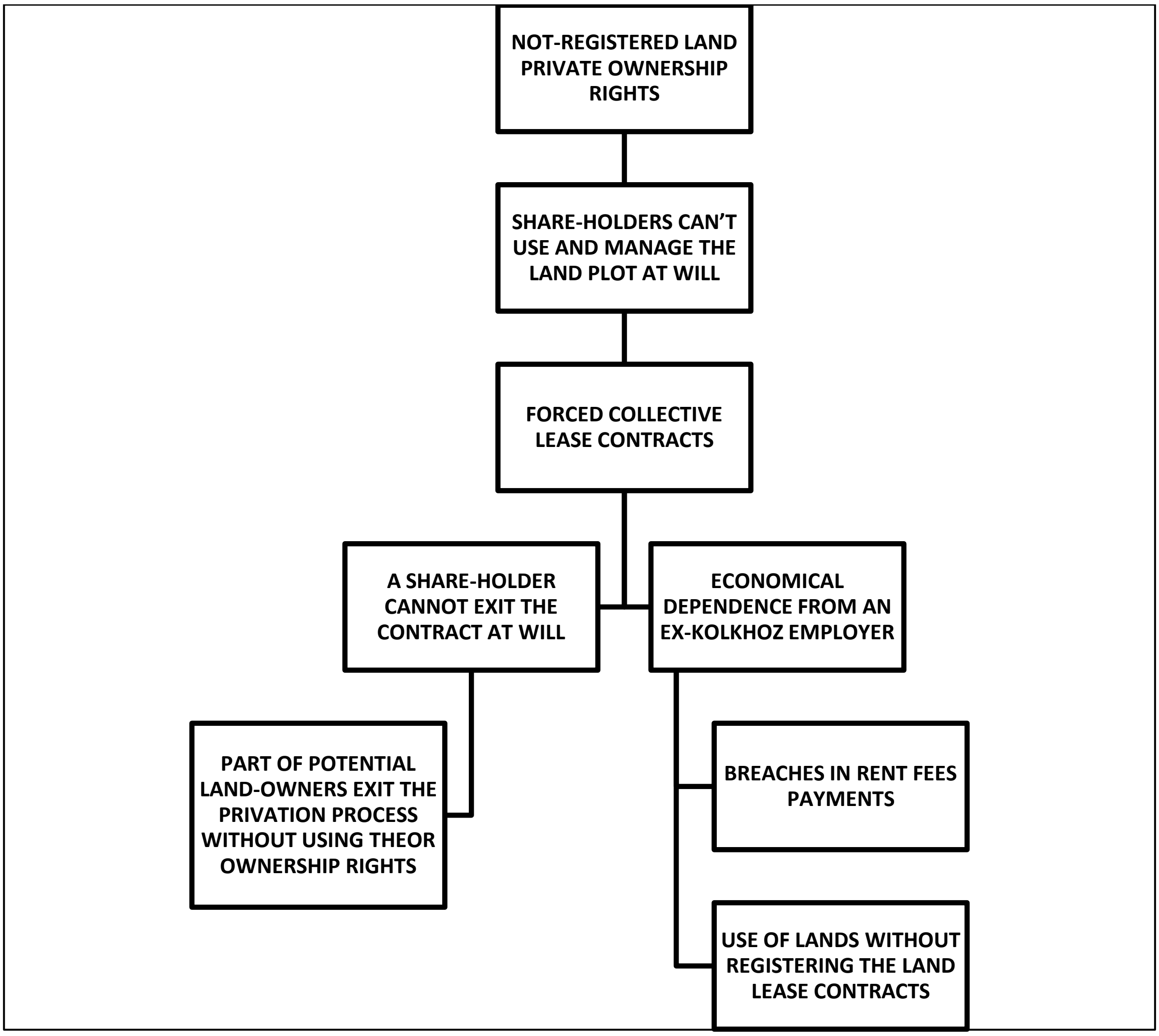

Fig. 5: Consequences of agricultural land property rights blurring

Unregistered property rights do not provide incentives and motives for the land users to use resources effectively, to increase their fertility, especially if it is a lease of land owned by the state, because in this case there is always the possibility of opportunistic behavior on the part of public servants.

Former collective propensity leaders and managers in the field for opportunistic rent-seeking behavior

Failure of property rights specification resulted in the fact that the certificates on a land share or a land plot under various pretexts were withdrawn from former kolkhoz workers in favor of new enterprises, societies and associations created by the ex-kolkhozes' chairmen and heads of local administrations. In practice, most often the real owner of a land plot was someone from a local bureaucracy, which developed many ways to withdraw lands from agricultural category and transform it into lands of suburban areas, making it easier to sell and lease these land plots at their own price, etc.

The research has also shown that when looking from a tenant's prospective short-term lease of agricultural land is a risky venture. For example, if the lease agreement was concluded for a short period of time, the official responsible for monitoring the land, knowing that the current tenant of land values the plot he is using (as he has already invested money in improving the quality and fertility of the land plot) may try to derive beneficial rents from his administrative position, demanding a bribe for prolonging the contract, or giving the land for a higher bribe to another tenant.

But even in the case of a long-term land lease when the land user has extended land use rights and abilities, there are cases, especially in regions with strong informal/family ties, when local officials abuse their powers. For example, termination of lease agreements in cases where the tenant, who has no family or other informal ties with a government official, responsible for land turnover, does not pay the official a bribe. Obviously, this also does not encourage investing in the improvement of soil fertility or effective use of land resources.

It is obvious that for a long time it had been profitable for leaders of agricultural organizations to maintain existing «no-owner» situation in agricultural land turnover. Even if we exclude the possibility of speculating transactions, registration of private land ownership would not only mean the emergence of an open-field system and the reduction of an enterprise's land area, but would increase production costs of the enterprise, which for a head of an ex-kolkhoz was not to be allowed.

Resume

Climatic factors such as soil fertility, rate of rainfall, etc. are key factors in agricultural business - they determine the initial result of any agricultural production.

But economic and political factors play an equally important role. For example, the level of profitability of an enterprise will depend not only on the productivity level, but also on the level of the average market prices, and capabilities of the enterprise to sell its produced goods. In its turn, selling the products and getting the profit for a farm or an enterprise is possible only if its costs are below market prices, and this requires optimizing the costs of an enterprise, for example, through use of innovative cultivation methods and advanced technologies in order to increase productivity. However, the acquisition of new technologies and their use in production requires additional costs and even at profitability level of 20-30% it is difficult to find additional funding. Therefore government support is required – subsidies, tax breaks, simplified schemes of loans, etc. But, as a rule, obtaining these types of assistance requires gathering certain documents, which mean additional costs and time.

Our research has shown that the main producers of agricultural goods are the private household farms (they produce 60-65 % of crop output), but the main land users are the agricultural enterprises (they produce about 30% of total crop output), which are usually engaged in the cultivation of cereals, while peasant farms and household farms are engaged in the cultivation of grocery such as beets, potatoes, etc. If we look at the data of yields and profitability of grain and leguminous crops, we can make a conclusion that, in general, agricultural enterprises show low profitability, but due to the nature of the industry itself large agricultural enterprises remain the major crop producers and the most effective form of farming in crops growing.

The research has also shown that the main problem during the reform of land relations was insufficient level of elaboration of institutions (legal acts and regulations, and organizations/establishments/departments controlling their execution), designed to build up the new socio-economic relations of land ownership.

To this day the land property rights registration processes are incomplete, which is one of the factors dampening the investment and loans flows in the agricultural sector and limiting land resources turnover, involving the transfer of land ownership rights to economic entities capable of ensuring their effective and efficient use: unregistered and unconfirmed land rights don't allow the landowners to enter mortgage transactions, lease land plots and take the land plot rent, not to mention the fact that unspecified property rights increase the risk of farming land use, and as a result, land users do not risk making capital investments into increasing the land fertility and improving the efficiency of land use.

Incomplete property rights registration processes lead to other negative phenomena as well – trespassing the ownership rights of an individual by other individuals and entities, increase of the total amount of transaction costs – costs caused by changes in the system of land rights registration, planning plot for a transaction costs, costs on re-registration of land ownership and land use rights, the costs of obtaining the inheritance rights on a land share or a land plot, the cost of re-registration of right on lifetime inheritable possession or permanent (perpetual) use of a land plot for forming a private peasant farm, costs on allotting a new land parcel when dividing the land plot in a collective-shared or joint-collective ownership, etc.

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Motivation and agro-economic factors affecting the establishment of innovative technologies in agricultural land use

Tulibaeva G.I., Lukmanov D.D., Liebelt P.

Introduction

In recent years, many agricultural producers of the Republic of Bashkortostan have used innovational technologies for agricultural purposes. When referring to innovational technologies, we mean new methods of tillage which are characterized by a decrease in the proportion of mechanical processing coupled with the use of resource-saving machines for seeding and cropping. The optimal use of the new technical methods of tillage contributes to the rebuilding of the disrupted humus potential of agricultural lands. Throughout the last droughty years, the use of these methods increased the crop yield of agrarian cultures at a number of agricultural enterprises in the region, and at some enterprises - that of plant production. Hereby, at a number of enterprises the use of new technological methods of tillage resulted in an increase of the average costs of agricultural production.

We shall discuss the gathered experience of the use of new technological methods of land-use in more detail and attempt to verify the main factors affecting their development at a number of agricultural enterprises in the Republic of Bashkortostan

Methods

The scientific analysis was carried out by using the following methods: statistical, inductive, deductive, the methods of analysis and synthesis, as well as by means of computer programs (use of the table creator processor “Excel”).

Results

There is a tendency of a shortening in the machinery stocks at agricultural enterprises of the Republic of Bashkortostan (see figure 1). Due to the shortening in the number of machinery, production technology in many enterprises has been disrupted, the work load on the available machinery increased, and the costs of maintenance grew. A consequence of these developments has been a tendency towards a decrease in the crop yield, the costs of agricultural production and the profitability of regional agrarian production.

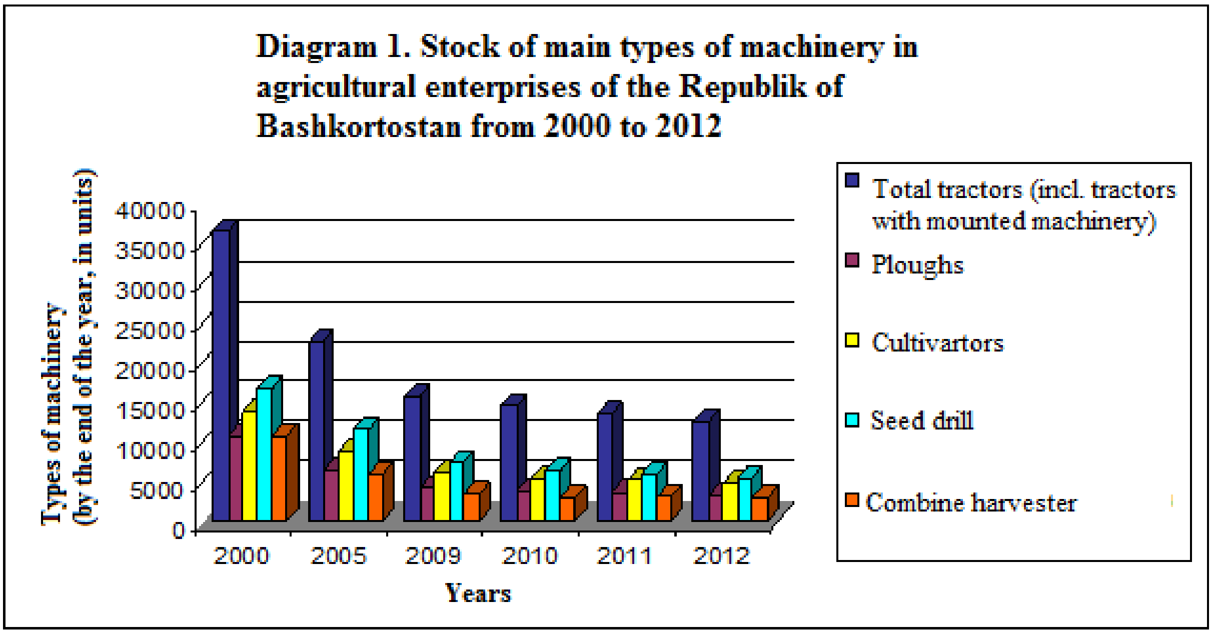

Fig. 1: Main types of machinery in agricultural enterprises *(Bashkortostanstat 2013)*

The results of the use of innovational technologies in land-use were analyzed and generalized in view of the influence of agro-economic factors on the process. Agro-economic factors consist of two components: agronomic and economic. The agronomic component – crop yield, influences the volume of the produced product. The economic components, such as the sale prizes of agricultural products and the costs of production affect the end result of the economic activity of the enterprise, namely – the profits.

The agronomic factors of agricultural production are greatly influenced by natural-climatic factors. Under these conditions, the main role is given to the full adherence of the production technology for agricultural goods and the need to replenish the machinery stock becomes apparent which would alleviate the influence of the natural-climatic factors. The current degree of equipment with tractors and combines per 1000 ha plough land in the region is low, and has a tendency towards further decrease.

One way to conduct sustainable agricultural production is by using innovational land-use technology. So, while there is a minimum of 10 technological operations required for grain crops production when using traditional tillage, with no tillage applied, the number of technological operations decreased to 3-5. Hereby (particularly valid for the no-tillage method), the work load on the soil lowers considerably, the need for a great number of agricultural machinery and oil decreases as well.

Table 1: Equipment of agricultural enterprises in the Republic of Bashkortostan with tractors and combines from 2000 to 2012

	2000	2005	2009	2010	2011	2012
Tractors per 1000 ha plough land, in units	9	7	5	5	4	4
Ploughing load per hectare, ha	115	137	201	218	233	246
Combine harvesters per 1000 ha plough land, in units	6	5	3	3	2	2
Seeding per one combine harvester, ha	178	220	358	392	409	533

Let us analyze the agronomic component`s influence in reference to the different types of tillage methods used for the gross grain and leguminous crop yield on the example of three enterprises located on the territory of the Republic of Bashkortostan. LLC `Agro`, Abselylovsky district, used the traditional tillage method of ploughing, AE `Krasnaya Bashkiria`, Abselilovsky district, applied the no-tillage method, while LLC `Artemida`, Karmaskalinsky district, used a combined tillage technology, in which ploughing is being applied once in 5 years and for the rest - minimal tillage or no.-tillage technologies are used (see figure 2).

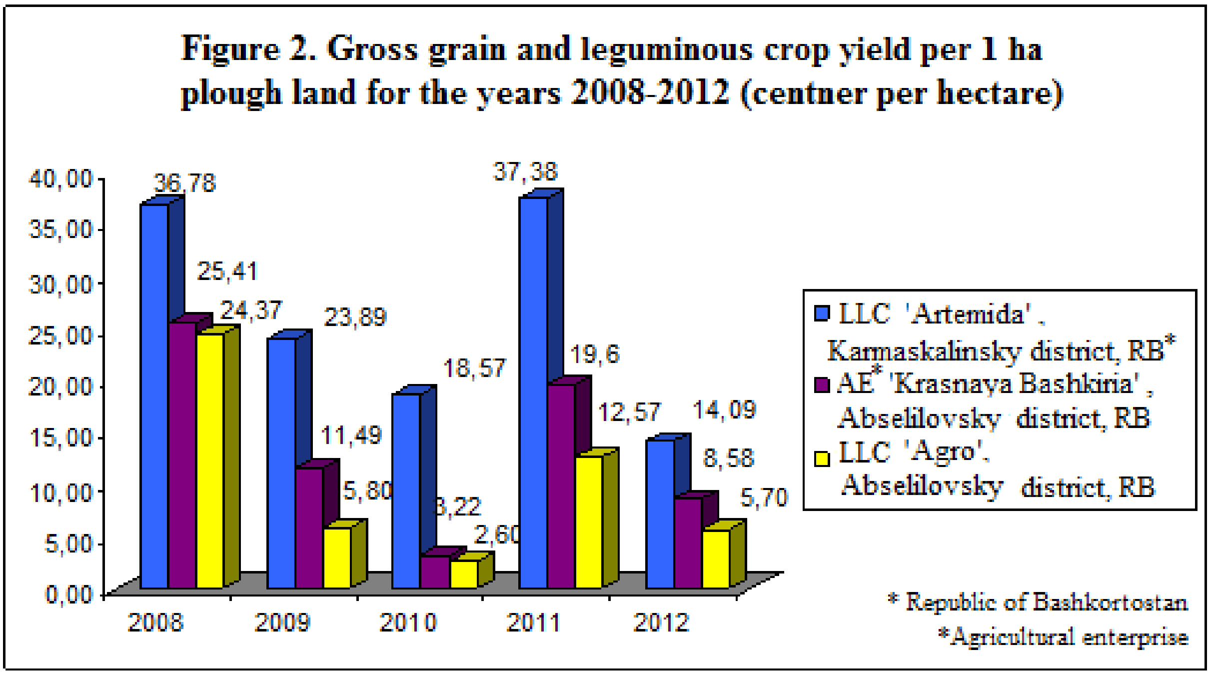

Fig. 2: Gross grain and leguminous crop yield per ha (*Report of the financial and economical situation of agrarian enterprises LLC Artemida, AE Krasnaya Bashkiria and LLC Agro (2008-2012)*)

The main factor influencing the gross crop yield of grain are the natural-climatic conditions. An also considerable role is played by the timely carrying out of technological tillage operations, the humus content of the soils and a whole range of other factors.

As follows from figure 2, the gross crop yield of grain in 2009, 2010 and in 2012, which have all been droughty years, sharply decreased. Further, one can observe that in enterprises applying the no-tillage and combined methods, the gross crop yield of grain and legumes was considerably higher, than in the enterprise using the traditional technology. This can be explained by the presence of an organic cover, which remains on the soil after the cropping. Due to that cover, the soil surface cannot become heat up much, because of which evaporation is lower. So, when using traditional tillage, the soil loses more water, than when using no tillage due to higher evaporation [5].

Let us consider the influence of economic factors on the results of land-use, namely, that of the sale prices of grain and leguminous cultures, as well as production costs of 1 centner of grain or leguminous cultures in the respective enterprises (see figure3).

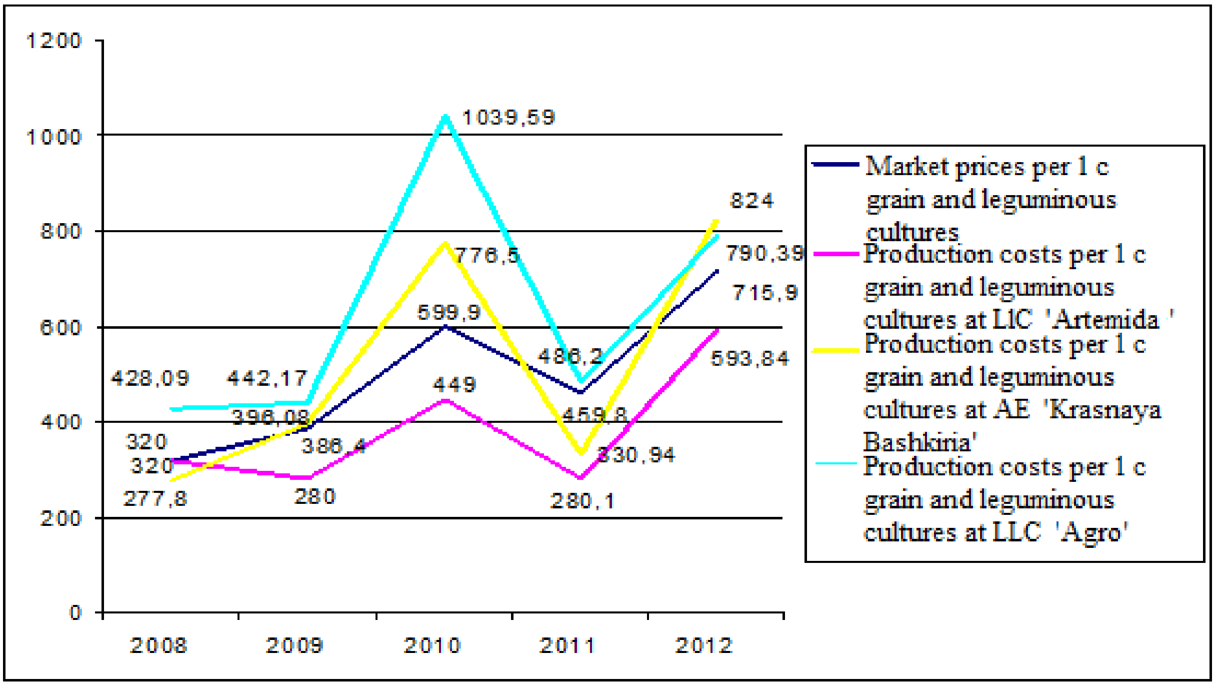

Fig. 3: Market prices and production costs of 1 centner grain and leguminous cultures in selected enterprises of the Republic of Bashkortostan *(Bashkortostanstat 2013)*

Using the data reflected in figure 3, following conclusions can be drawn:

- at the LLC `Agro` the production costs are much higher than the market sale prices, which indicates that the given enterprise not only does not receive any income from selling the grain and leguminous cultures, but does not even compensate the production costs;

- it has been 5 years since the AE `Krasnaya Bashkiria` has switched to the no-tillage technology. As follows from other countries` experience, during the first 5 years after this technology`s introduction, the production costs have been maximal, which has been confirmed by the data illustrated in figure 3;

- LLC `Artemida` has been using combined technologies for more than 5 years, which is the reason for lower production costs, than that of the other enterprises

The remaining part of this piece will be dedicated to the analysis of the profitability (the pay-back) of the production of 1 c gain and leguminous cultures for the years 2008-2012 (figure 4).

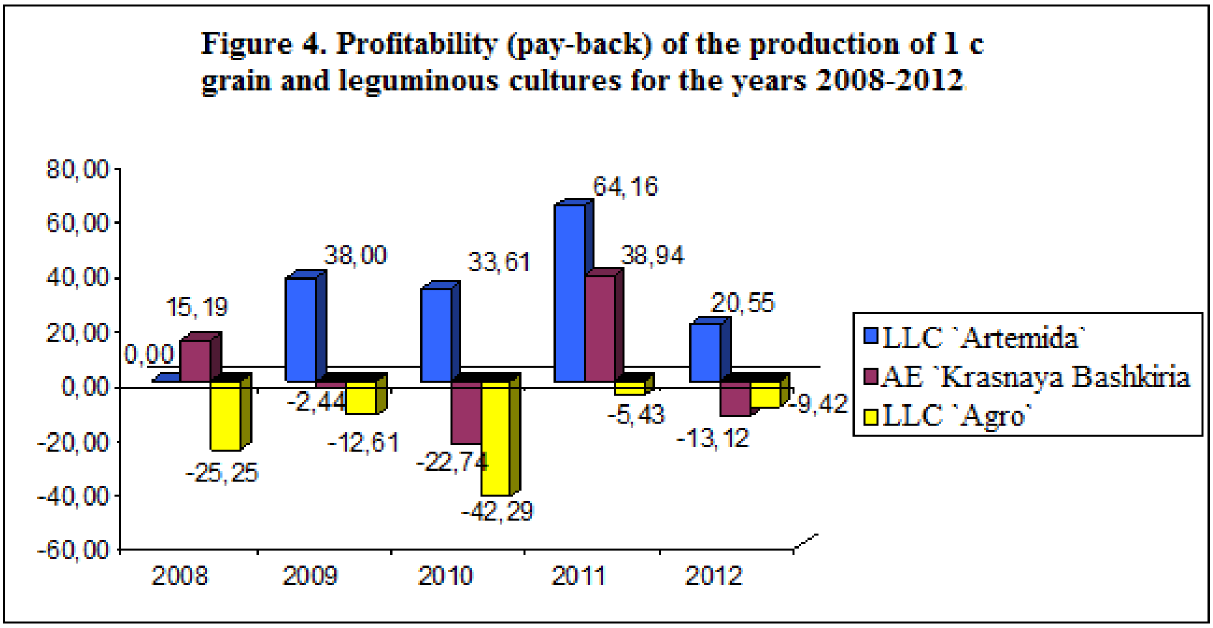

Fig. 4: Profitability *(Report of the financial and economical situation of agrarian enterprises LLC Artemida, AE Krasnaya Bashkiria and LLC Agro (2008-2012))*

The results presented in figure 4 indicate that the production of grain and leguminous cultures during the research period has been profitable only for the LLC `Artemida`. In the AE `Krasnaya Bashkiria`, the profitability alternates with the pay-back (unprofitability), from which follows that the production of grain cultures based on the use of no-tillage technologies only does not produce positive sustainable annual results. This is mainly a consequence of climatic conditions, as well as the increase in the prices of fertilizers, and herbicides and pesticides, which are necessary during the initial phase of the introduction of new technologies.

During the research period, the production of grain and leguminous cultures in the LLC `Agro` has turned out to be unprofitable, which indicates that the traditional technology of agricultural production does not provide for sustainable crop yields and does not allow to receive profits under conditions of frequent droughts.

Conclusion

On the basis of the conducted analysis it can be concluded that in order to receive profits and for an efficient management of agricultural production, modern agricultural producers should vary between the different land-use technologies. The variation between land-use technologies should be carried out in dependence of the natural-climatic conditions, location of the enterprise and the chosen type of agrarian culture. A positive example of the use of a combined land-use technology is the experience gained at the LLC `Artemida`, Karmaskalinsk district, RB. Consequently, on the territory of the Republic of Bashkortostan it is advisable to use diverse technologies of tillage, such as the traditional (ploughing), no tillage (or minimal tillage without ploughing), or combined ones. The advantages of no tillage manifest themselves under conditions of drought. So, those technologies should be used by producers, located on territories of the South Urals, because this region is most prone to the effects of drought.

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2 Topic: Indication of the changes in the post-soviet land use and their consequences for soil degradation

Soil degradation in the forest-steppe zone of Bashkortostan: an introduction

Liebelt P. & Frühauf M.

Owing to their favouring soil- and climate conditions *(Yaparov et al. 2005)* the forest-steppe zone of Bashkortostan is to 70-80 % dominated by agricultural area.

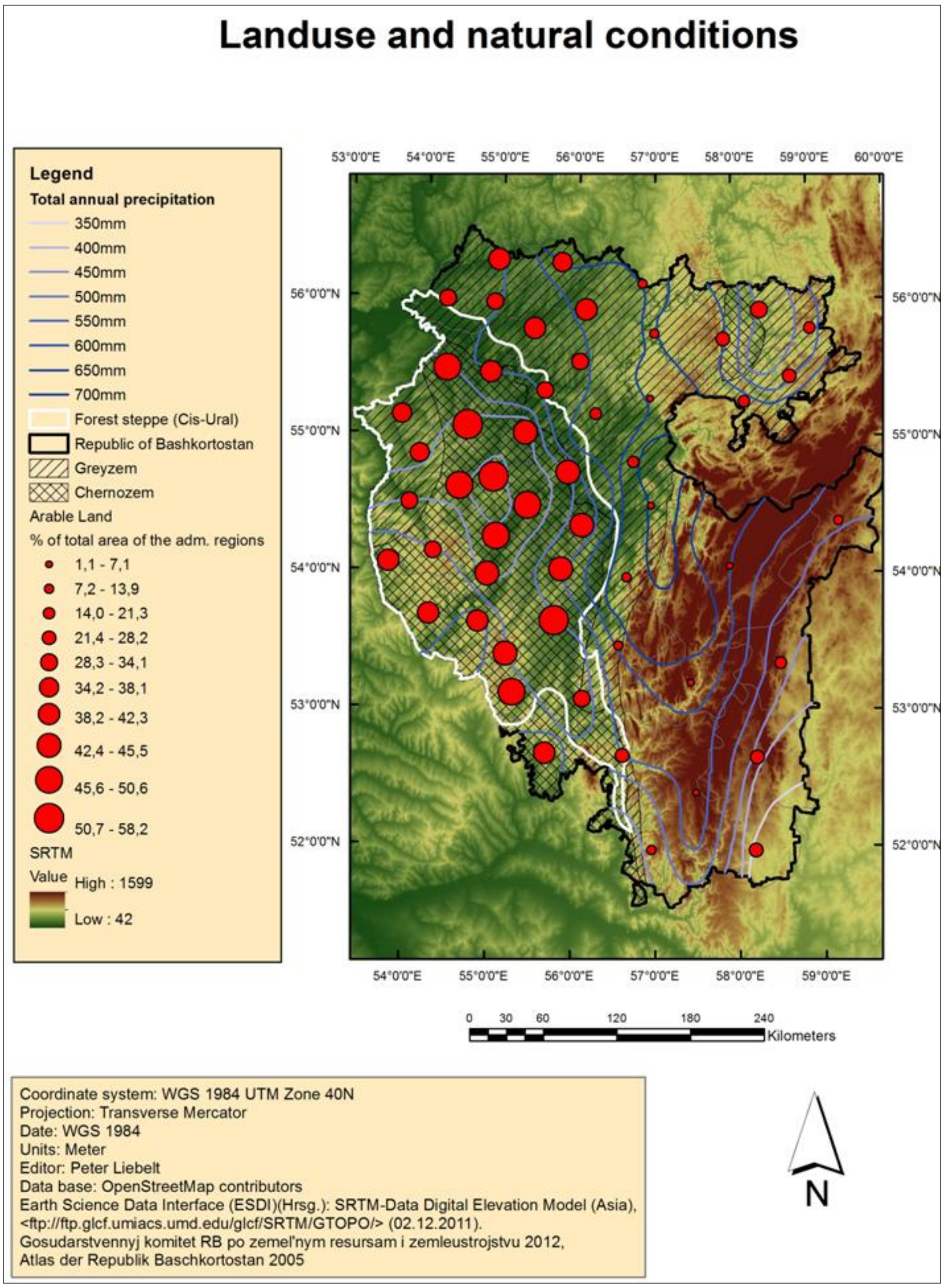


Fig. 1: Natural conditions and agricultural land use in Bashkortostan *(Liebelt 2014)*

Especially the fertile chernozems, which dominate this landscape zone, determine this area´s suitability for crop farming.
The result of the intense crop farming - often coupled with an exploitation praxis, which is insufficiently adapted to the concrete locational conditions - in interrelation with the factors of the natural environment are diverse forms of soil degradation (*Gabbasova 2004, Khaziev 2007, Stafichuk 2002)*.

Consequences are not only impairments of the exploitation itself, which often results in a sharp yield reduction, but also losses of other ecological functions of the soil *(Gabbasova 2004, Khaziev 2007, Roskomzem 1994).*

The geographical scope of soil degradation has been identified through an inventory of plough lands of the Republic of Bashkortostan carried out by the Committee on Land Resources and Regional Development Planning (Goskomzem-RB) and the Ministry of Agriculture (Minsel'khoz-RB) between the years 1996 and 2007: according to its results, approximately 1,2 mil. ha plough land were classified as degraded and insufficiently productive. Thus, for the forest-steppe zone, the proportion of degraded soil makes out between 20 and 25% of the total area, or else approximately 11% of the total area of the forest-steppe zone *(Chanyshev 2008, Goskomzem 2007, Bulatov 2008)*.

The new economic and political framework conditions established after the breakup of the Soviet Union created new conditions for land use change and soil degradation. Hereby, two main trends, or, more specifically, manifestations of the post-soviet agrarian land use change, can be detected: The first one concern the giving-up (disuse) of large areas of plough land, or a more extensive use of those areas as hay meadows and pastures. The other trend indicates a growing enhancement of new methods and processes of sustainable soil cultivation/crop rotation strategies *(Goskomzem 2007, Chanyshev 2008, Liebelt 2010 [unpublished])*.

<u>There are a number of general statements on the problem area „disuse“:</u>
In view of the detected degradation damages on plough lands, the Ministry of Agriculture and the Committee on Land Resources and Regional Development Planning of the Republic of Bashkortostan decided in 1996 to either determine a way of how to use for the degraded areas, or to transform them into more extensive forms of exploitation with the aim to "counter the processes of erosion, to protect and restore soil fertility". To this day, 1.162.000ha of degraded plough land (which is equivalent to 25% of the total plough land area of 1996) were transformed into other forms of exploitation or into set-aside lands *(Bulat 2008, Chanyshev 2008)*.

In this context, statements on the change of cultivation technologies and crop rotation seem meaningful, as they might also evoke consequences for the potential of soil degradation. In the forest-steppe region, a temporally and spatially differentiated trend of a differentiation of the intensity of soil cultivation can be observed. Hereby, in light of the economic need for efficiency increase, as well as efforts to prevent erosion processes and to conduct more ecologically sustainable land use *(Liebelt 2010 [unpublished])*, conservation soil cultivation methods increasingly gain in importance. However, there are currently informational deficits concerning not only the causes of the transition towards conservation soil cultivation methods and their temporal and spatial dynamic, but to a great extent also their ecological and economic effects *(Gabbasova 2004, Khaziev 2007, Chanyshev 2008)*.

A particular problem in this context is constituted by (nationwide) comparable criteria for the detection, evaluation and illustration of soil degradation phenomena. This is why the Russian Committee on Land Resources and Regional Development Planning developed a key - or type - catalogue for the labeling and comparison of the different indicators of soil degradation *(Roskomzem 1994)*. This catalog has, therefore, been used as the methodological framework for the enquiries conducted and conclusions made in the framework of this research project.

Hereby, the main focus of investigations was set on the detection and evaluation of the following two user-relevant indicators of soil degradation:

1. User-initiated loss of humus content (organic soil carbon)
2. Indication of user-accelerated water erosion based on changes in the depth and the composition of the humus horizon

Furthermore, experiences from other projects realized in Russia *(Meinel 2001, Meinel 2003, Frühauf & Meinel 2004, Meinel & Frühauf 2004)* and those carried out by the Russian partners *(Gabbasova 2004; Khaziev 2007)* could be integrated into the process of problem solution.

Taking this into account, the following identification catalogue developed by *Roskomzem 1994 and extended by Gabbasova 2004 was used in order to detect and evaluate the* indicators of degradation „Depth of humus horizon“ and „Humus content in humus horizon“:

Table 1: Indicators of soil degradation *(Gabbasova 2004)*

Stages of degradation	**0**	**1**	**2**	**3**	**4**
Loss of soil profile (A+B horizon)	<3	2-25%	26-50%	51-75%	>75%
Loss of humus content	<10%	10-20%	21-40%	41-80%	>80%

The evaluation key for the indication of the intensity of this soil indicator has been derived on the basis of following characteristics: the profile depth (A + B horizon) as well as the humus content (A + B horizon).

Explanatory notes on the stages of degradation *(Roskomzem 1994)*

0 – not degraded

1 – weakly degraded

2 – medially degraded

3 – strongly degraded

4 – very strongly degraded/ destroyed

The fact that these criteria are wide-spread, accepted and recognized in the practice of soil degradation research in Bashkortostan has been verified by the works of *(Khabirov 1995, Khaziev 2007, Stafichuk 2002 sowie Gabbasova 2004)*.

Soil degradation – Erosion

Soil erosion in Bashkortostan has evolved into one of the strongest factors causing soil degradation. Since the 80-s, the proportion of erosion damages of agriculturally used land increased from 46% (3,4 Mil. ha) to the current 64%. This makes out around 28% of the total area of Bashkortostan. Furthermore, approximately 2,7 Mil. ha area of Bashkortostan is regarded as more or less strongly erosion-prone *(Khaziev 2007)*.

The high proportion of eroded plough land (57%) conveys a direct connection between the type and intensity of the agrarian land use and the different forms and effects of soil erosion as an important scientific, but also agrarian-economic topic.

As illustrated by figure 2, damages caused by water erosion arise with a high proportion of crop farming (up to 60 percent plough lands of the total agrarian area) and intense tillage mainly in the forest-steppe zone.

Different spatial dimensions and stages of intensity can be identified here. The highest proportions of erosion can be found in the agrarian area with the greatest relief differences, which are located in the southwestern part of the forest-steppe region, in the southern parts of the Ural Mountains, as well as near the adjacent forest zone in the north.

The agrarian area of the forest-steppe zone located in the Belaya plain is, on the other hand, proportionally less affected by soil erosion *(Minselkhoz 2000)*.

The reasons for this are to be found in the effects of the relief and climate, but also in the dominating types of soil and its capacity to resist erosion

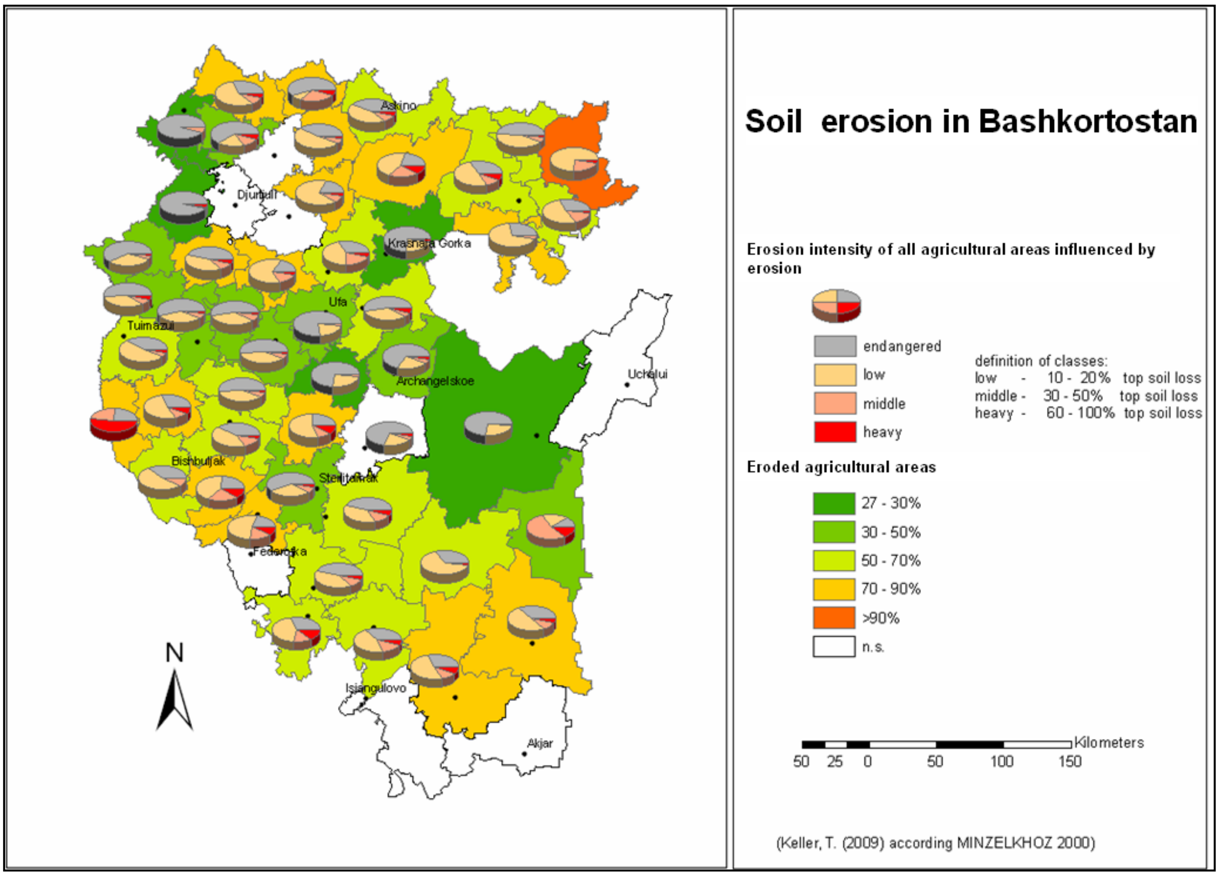
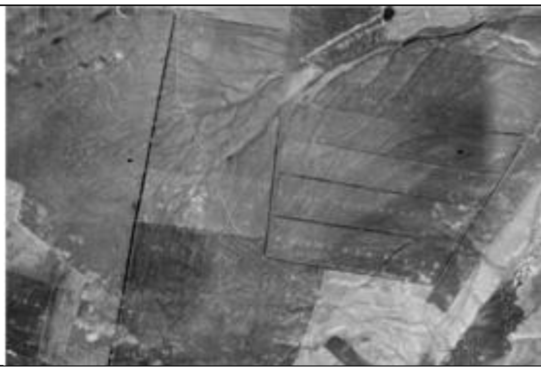


Figure 2: Soil erosion in Bashkortostan *(Keller 2010)*

So, chernozems, which are prevalent in this region, have a considerably smaller vulnerability to erosion due to their high humus content and great depth of topsoil, although the small relief energy encourages erosion development *(Khabirov 1995)*. Overall, it can be seen that in the whole western Cis-Ural, water erosion can be regarded as the formative process of soil degradation due to climatic, relief and soil properties, while wind erosion plays only a secondary role in the process *(Yaparov 2005, Gareev 2010, Bashgidromet)*.

Apart from summer heavy rain, especially during the winter snowmelt period on slopes (approximately 70% of the agrarian area), surface runoff processes (between 50 and 60% of the winter precipitation turn into surface runoff) cause intensified erosion *(Khaziev 2007)*.
In combination with a decrease in the organic substance in topsoil, at agriculturally used locations a decrease in the structural stability of the soils typical for this region takes place where the processes of water erosion are encouraged *(Gabbasova 2004).*

As becomes visible on the areal image taken by the „USATU“ working group, linear and areal forms of erosion are widespread in the research area. The following image demonstrates these erosion phenomena on the example of the Tujmazinskij region (forest-steppe zone) reflecting the manifestations of gully erosion.

	
Fig. 3: Water erosion on a field during snow melting period *(Liebelt 2011)*	Fig. 4: Gully erosion in the Tujmazinskij region (Western part of the forest- steppe zone) *(areal image – data by USATU)*

According to *Khaziev (2007),* water-based erosion processes are responsible for an annual material removal of 38 Mil. t in Bashkortostan. In some cases, the resulting on-site erosion damage is extreme. The accompanying reduction of the Ah-horizon, the leaching of nutrients, the decrease in structural stability and especially the shortening of the usable field capacity induce negative ecological and economic effects.

Table 2: Intermediate development of the depth of the humus horizon of agriculturally used soils (Leached Chernozem) *(Gabbasova 2004)*

Properties	1965-1970	1985-1990	1995-2000
Depth of humus horizon [cm] (forest-steppe zone)	80	75	72

As follows from table 3, the humus horizons (A and AB horizons) shortened since the 1960-ies by (on average) 8 cm. Out of this developed not only disadvantageous consequences for crop yield, but also a higher vulnerability towards erosion, as well as towards water stress *(Gabbasova 2004)*.

The economic consequences manifest themselves mostly in the already mentioned yield effects: So, the average crop yield in the forest-steppe zone on healthy soils with a median Ah- depth of 70 cm amounted to 30 dt/ ha, on medium-strongly eroded soils (median Ah-depth of 40cm) – to 23 dt/ ha and on strongly eroded soils (median Ah-depth of 20 cm) – to 9,5 dt/ha.

Therefrom not only the need to study the concrete location-based cause-effect relations becomes apparent, but also a respective adaptation of the land use system as well as of the soil cultivation strategies to the regional natural characteristics which can subsequently be recommended to the land user.

The project results received, as well as the extended field experiments conducted by the Ufa State Agrarian University have revealed that especially the conservation tillage methods lead to an improvement of the structural stability of the soil and, hereby, constitute an appropriate measure to counter erosion *(Khaziev 2007)*.

Soil degradation – loss of organic substance

The exploitation-induced reduction of the organic soil substance is mainly the result of an inappropriate way and intensity of agrarian use combined with insufficient re-supplement of the organic soil substance. In this context, an intensified mineralization of the organic soil substance – which damages the soil and evokes stronger greenhouse gas emissions *(Lal et al. 1995)* – plays a decisive role.
De-humification, which results out of these processes, leads to an annual reduction of the organic soil substance on agriculturally used lands in the research area amounting to 0,2-1,5 t/ha *(Khaziev 2007)*.
In this regard, the revealed negative humus balance is mainly the consequence of insufficient input of organic material, such as plant residues or organic fertilizer which could compensate the exploitation-induced, accelerated loss of minerals.
In this context, soil erosion further accelerates the reduction of the organic soil material *(Chanyshev 2008)*.

Research during the period from 1965 to 2000 has verified a remarkable reduction of the humus content of agriculturally used leached chernozems of the Cis-Ural forest-steppe zone.

Table 3: Development of the humus horizon of agriculturally used leached chernozems throughout the last 35 years *(Gabbasova 2004)*

Properties	**1965-1970**	**1985-1990**	**1995-2000**
Humus content [%]	10,2	8,0	7,8
Humus stock (0-50cm [t/ha]	523	385	380

According to the degradation classification used, an averaged medially strong stage of degradation (stage 2) – with regard to the loss on humus - can be verified.
Comparable results on the humus content in differently used soils (intensive land use: ploughing and extensive land use: hay meadow) on a 2-3% slope located at a water balance station (leached chernozem of the forest-steppe zone) could illustrate changes in the different forms of land use. Measurements were carried out from the overhang (1) to the lower hang (4).

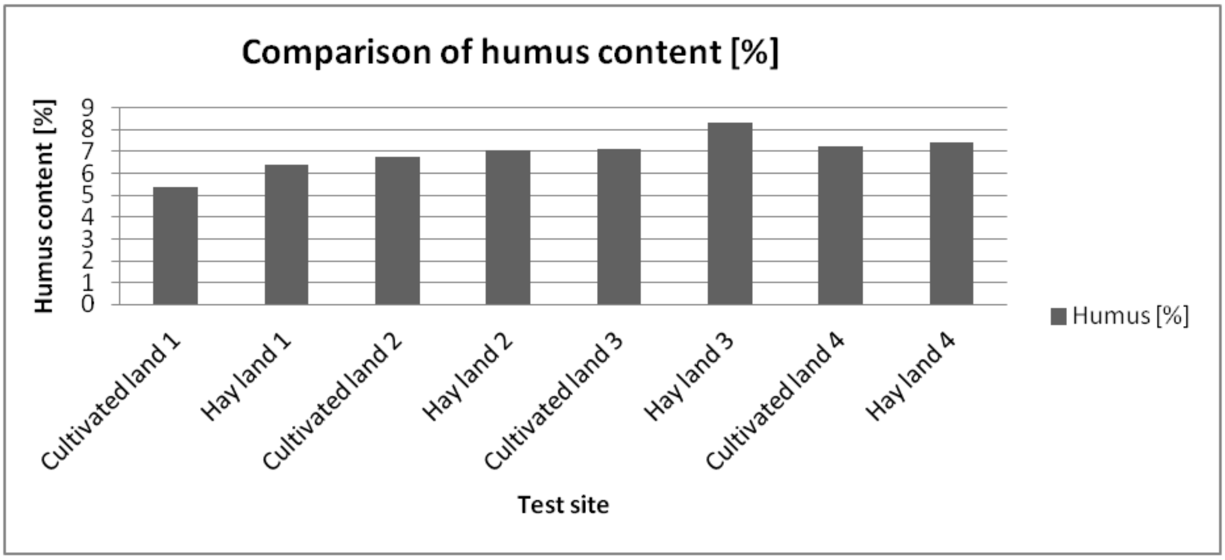


Figure 5: Humus content under different agrarian land use types at the research area of the water balance station *(Project data 2012)*

The location-typical measurements reflect a dependence of exploitation-induced change of the soil humus conditions on climate, relief and the type of soil (*Goskomzem Baschkortostan 2001, Atlas der Republik Baschkortostan 2005).*

So, figure 6 illustrates, apart from the general differences between grey forest soils and chernozems - whereby the former show a stronger reduction in humus due to its higher structural instability - primarily the influences of relief and climate on the reduction of humus *(Gabbasova 2004,* Khaziev 2007).

In order to verify how erosion and humus reduction affect the dynamic of the soil water budget, temporal and spatial high resolution geo-ecological analyses with the focus on on- and off-site effects were carried out at one of the climate/lysimeter stations (Russian water balance station – WBS) run by the Federal State Agency „Bashmeliovodkhoz“ (rus.: Institution for monitoring of melioration areas of the Republic of Bushkortostan) and monitored by the project groups of the Russian Academy of Science, the Bashkir State University Ufa as well as the Martin-Luther-University Halle-Wittenberg.

This research on the cause-effect interrelations between the climatic and soil-hydrological effects was extended through analyses of the effects the different soil cultivation methods and intensities have on the soil water dynamic (and crop yield) by means of a combination of analyses carried out using stationery and mobile technology on the agricultural areas of Artemida.

Figure 7 presents the geographical position of the research areas in the Bashkir forest-steppe zone of the Cis-Urals.

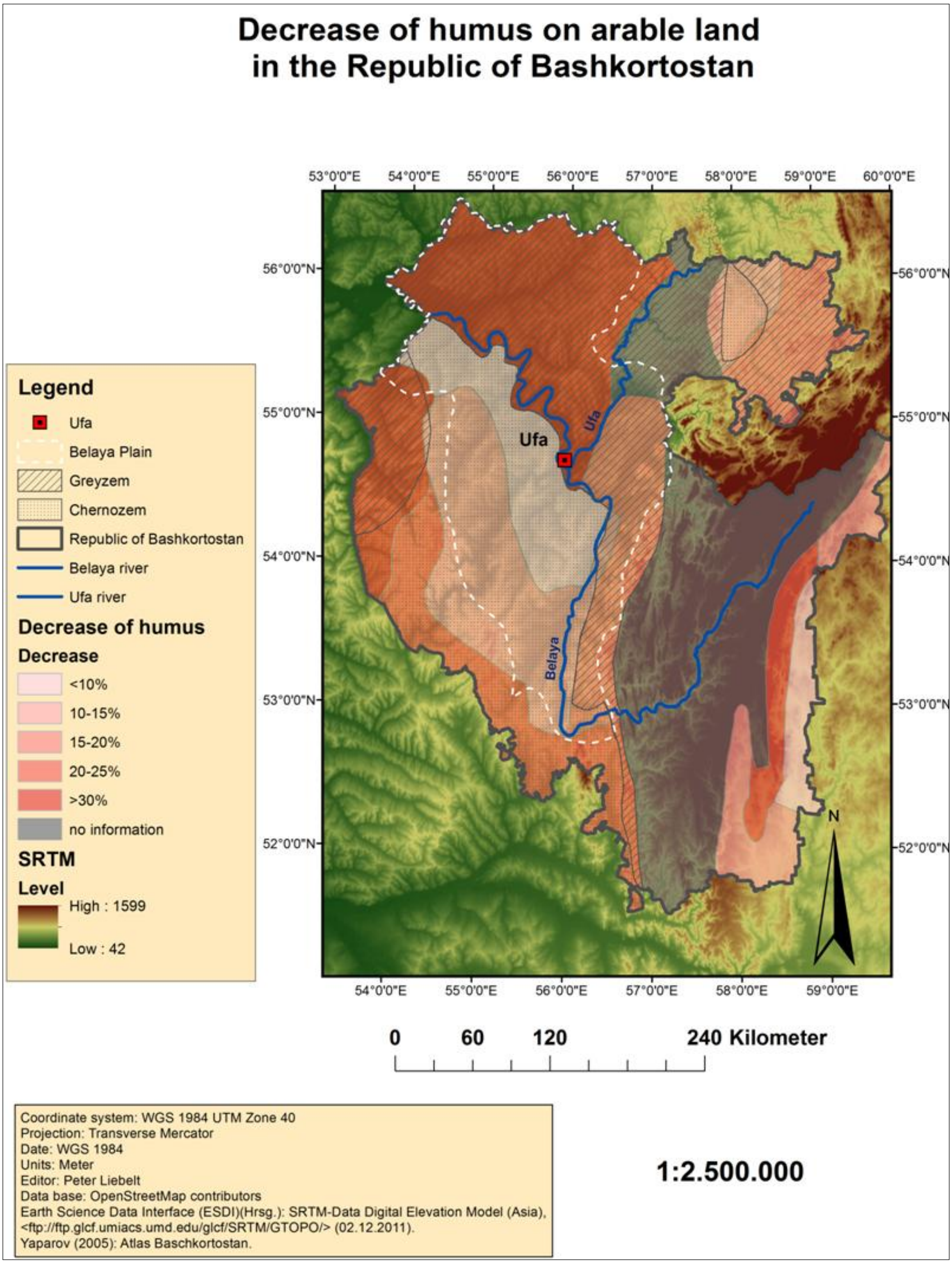


Fig. 6: Decrease of humus in Baschkortostan *(Liebelt 2014)*

The field experiment stations: „Water balance station“ and „Artemida“ are located in the agriculturally intensively exploited Belaya plain with its gentle relief, which lies in the north-eastern part of the forest-steppe zone. With regard to their geographic conditions, both locations are comparable, especially with regard to the soil properties of leached chernozem (rich in humus) and to the climate (approximately 500mm precipitation as well as a balanced up to slightly deficient climatic water balance) *(Yaparov 2005, Khaziev 2007).*

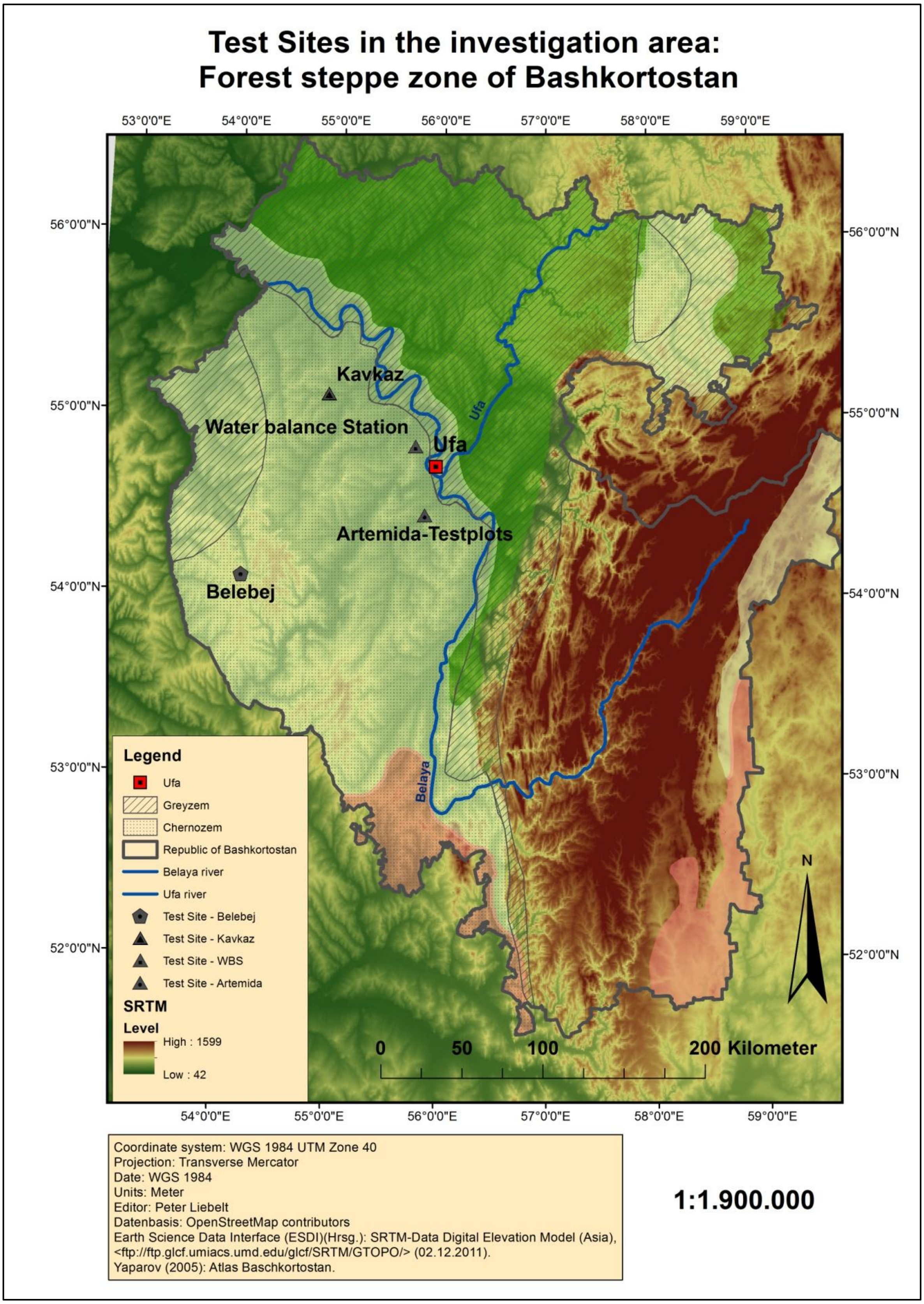


Fig. 7: Places of researches *(Liebelt 2014)*

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Analysis of the land use change, as well as the dynamic of the processes of erosion by means of remote sensing data

Sultanov A.H., Bagmanov V.H., Meshkov I.K., Frühauf M., Liebelt P.

Introduction

In recent years, the areas of application of remote sensing data have broadened considerably. Here, the possibility to perform change detection analyses by means of archive pictures with the purpose of detecting the land use dynamic over a long period of time and of analyzing the dynamic of erosion on plough lands is of special interest. Due to a number of diverse natural processes, a constant change in the boarders of the plough, pasture and hayfield areas, as well as of the soil and vegetation properties according to the type of land use at the respective parcel, takes place. All these factors hinder the acquisition of objective, operational information necessary for the creation of a report on the current situation, its assessment and prognostication. At the present time, the use of remote sensing data in agriculture constitutes a vastly developing and promising domain. The material of satellite data can assist both the solution of complex problems in the governing of agricultural territories and in highly specialized areas.

Water erosion [1-4] refers to the destruction of soils under the influence of temporal water streams. Following types of water erosion can be differentiated: sheet erosion, rill erosion, gully erosion and bank erosion. The main cause for their development is the economic as well as other kinds of human activity. In particular, the emergence of new heavy tillage machinery, which damages the soil structure, has constituted one of the reasons for the activation of water erosion during the last decades. Other negative anthropogenic factors are: the destruction of vegetation and forests, overgrazing, mouldboard ploughing, etc. Among the different forms of water erosion, a considerable damage to the environment, in particular to the soil, is inflicted by gully erosion.

Ecological damage done by gullies is huge. Gullies destroy valuable agricultural lands, contribute to an intensive denudation of the soil cover, float small rivers and reservoirs, and create heavily partitioned relief. In the Republic of Bashkortostan alone, the surface area of gullies continuously grows.

Extensive land use in the Republic of Bashkortostan has led to a ubiquitous degradation of plough land soils, and a considerable decrease of their potential fertility. One of the main causes of these negative consequences is the activation of the soil destruction by the processes of water and wind erosion in the anthropogenically transformed landscapes.

A strengthening of the processes of erosion is caused by a sharp decrease in the natural vegetation cover`s protective function and the soil ability to resist erosion caused by long-term agricultural use. The consequence of erosion is a decrease in the soil´s fertility (surface and wind erosion), or a complete destruction of the soil (linear erosion).

Methodology

This article suggests to analyze the processes of erosion caused by land use by means of satellite data, as well as to identify areas of gully formation using a retrospective analysis of satellite data with different spatial resolutions interpreted in relation to other available data. The analysis uses space images taken by the satellite systems SPOT-4 (resolution of images – 10 m and 20 m). The investigation took place in the years 2006-2009, the surface area analyzed amounted to 1,21 km²). For test purposes, a parcel near the settlement "Kavkaz" in the Republic of Bashkortostan was chosen (figure 1).

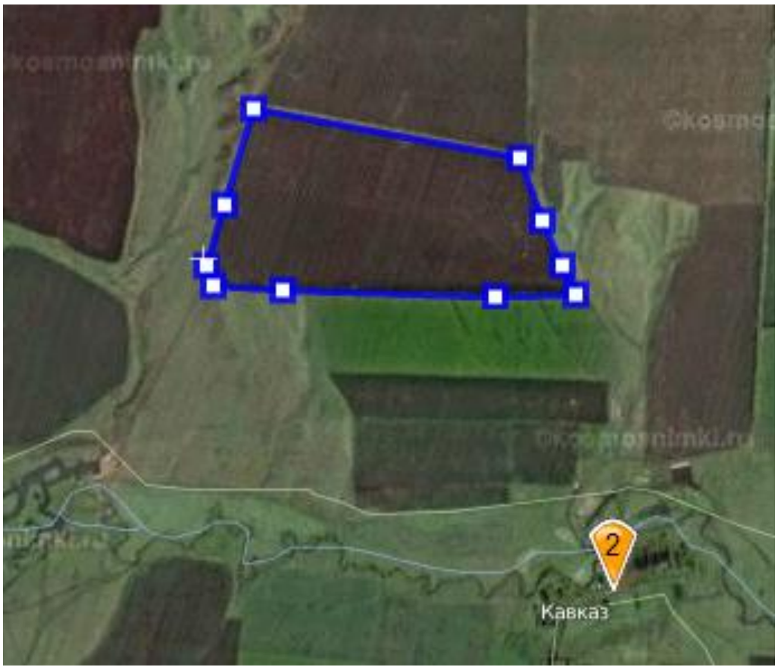

Fig. 1: Scheme of the area studied (the area, in which erosion processes are expressed more strongly is defined with the blue color)

The identifying feature of erosion on remote sensing data is the instability of the acuity characteristics at the different parcels of the image. It is generated by the deeper soil horizons becoming exposed to the surface, the diffusion of the plough and the subsurface layers, as well as an increase of the vegetation biomass on erosive cells resulting out of a transportation of fertile soils along the routes of water streams. These factors affect the character of the spectral curve. For the most types of soil with a normally developed genetic profile, these changes primarily affect the image´s intensity, while the form of the spectral curve remains practically unchanged, whilst all values of the spectral reflection coefficient proportionally grow for all wavelengths. Those changes are characteristic for soils with a monotonously humified soil profile, such as, for example, chernozem. In soils with sharply differentiated genetic profiles or in case great depths of the soil were infested by erosion, the changes in the integral reflection values are accompanied by a change in the tone range. Furthermore, when interpreting images of sectors infested by erosion, the characteristic image shape is of considerable importance.

Results

Figure 2 demonstrate space images of the investigated parcel taken by the SPOT4 satellite. The analysis of the data shows that erosion processes can be identified on the basis of the characteristics of the surface area of the erosion gully and a detection of their growth dynamics.

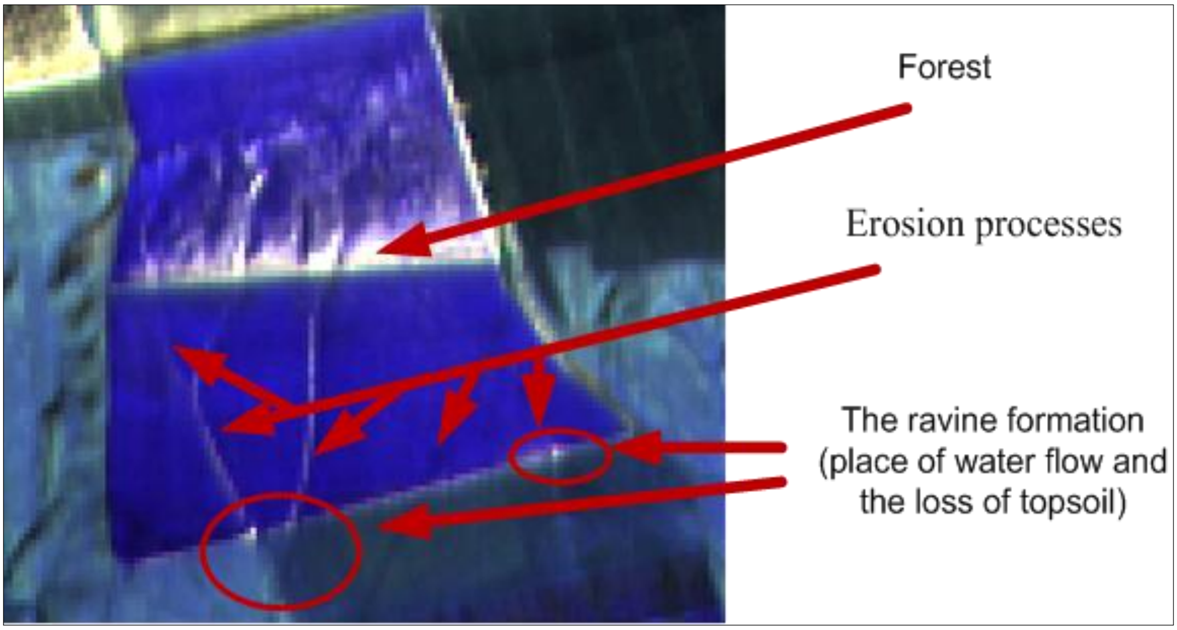

Fig. 2: Determination of objects on the test field (the test side of Kavkaz in the forest-steppe zone)

Figure 3 reflects the object identification afield. At the bottom of the figure, the accumulation zone of the upper fertile soil layer after an denudation by thaw water during snowmelt is encircled. Erosion gullies are well-identifiable at the image, because they accumulate thawed snow.

Determination of the area of erosion gullies

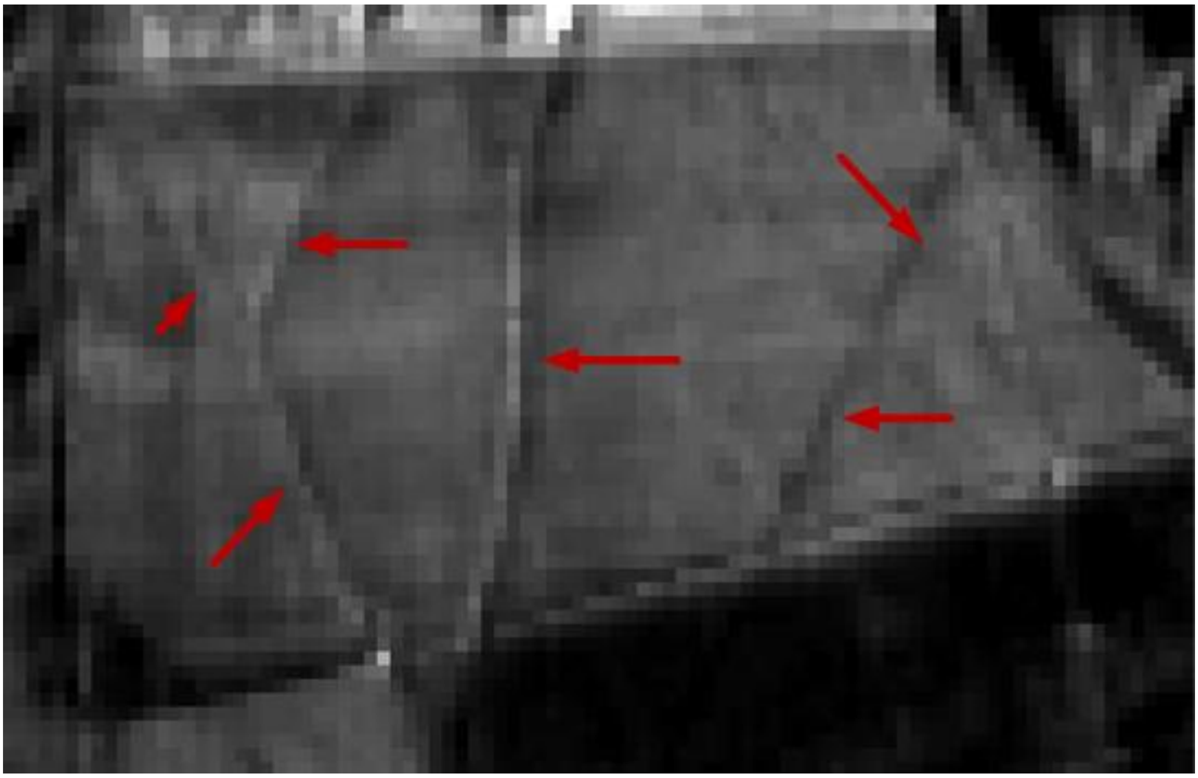

Fig. 3: Image 13.11.08 (20 m), marked erosion gully boarders in channel (Near-infrared 780 – 890nm)

The arrows on figures 3-4 reflect erosion gullies in the near-infrared channel 780 – 890nm, on grounds of which the surface area of the objects and the dynamic of gullying can be identified.

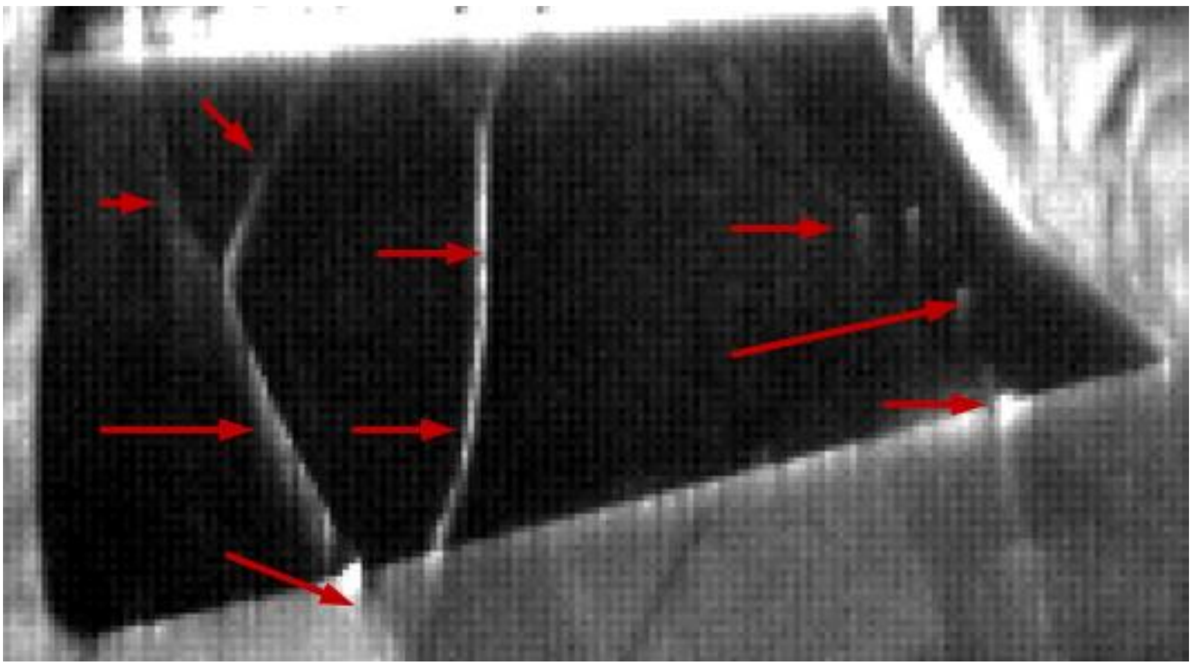

Fig. 4: Image 13.11.08 M (10 m), marked gully boarders

Figure 5 reflects the graph for the dynamic of erosion processes for the years 2006-2009. The results indicate a growth of the surface area of the gullies. The processes of water erosion of the soil under conditions of slight denudation are well-interpretable on images taken during the summer period. Here, directed alongside the denudation, an increase in the acuity of the image can be observed, which is accompanied by an increase in plant biomass resulting out of the fact that at those parcels, the humus proportion in soil is higher due to the soil being lacerated after the retreat of thaw water and a subsequent filling of the lower horizons with material from the humus-accumulative horizon.

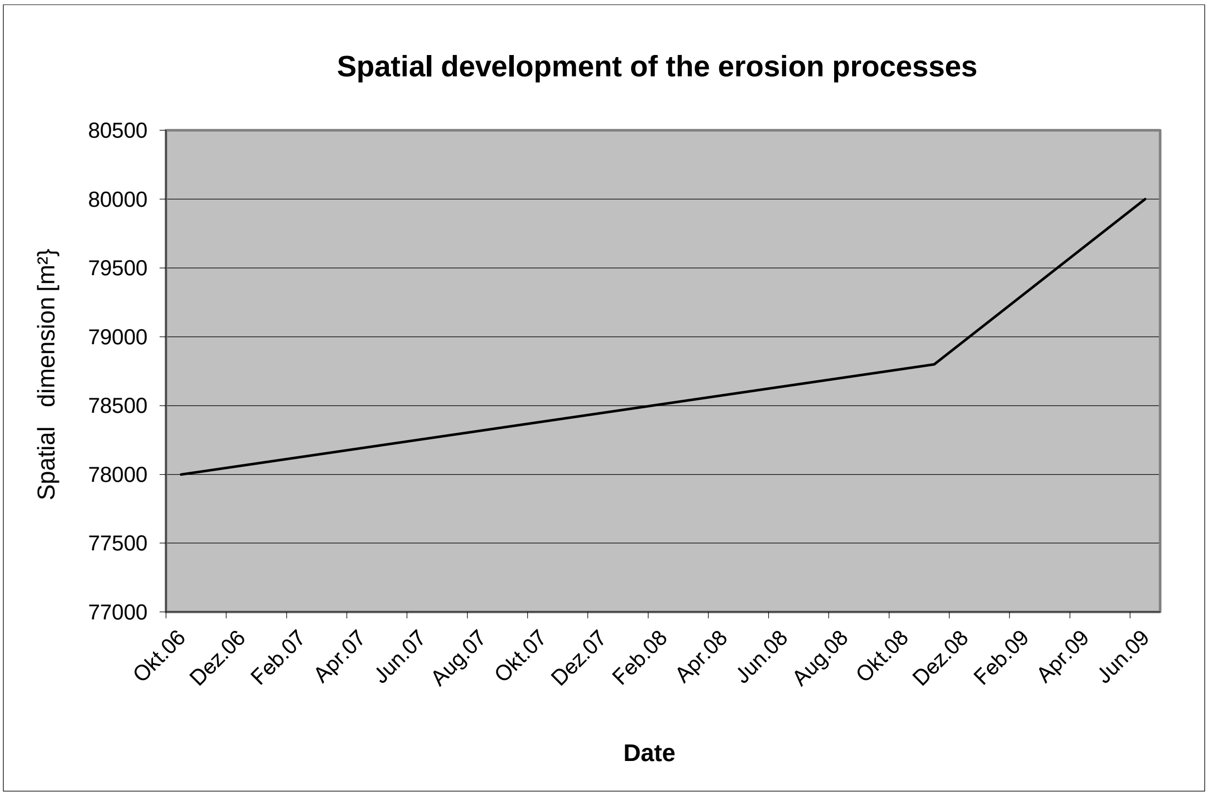

Fig. 5: Dynamic of erosion processes for the years 2006-2009

On images taken in spring, these parcels show lower acuity values due to over-humidification. During that period, strongly eroded soil - although eluviation reaching the lower, brighter horizons has not been observed -, as well as surface erosion are well-interpretable. Examples of linear and surface erosion visible on satellite images are presented in figures 3-4. On images taken in autumn, only gullies with soil ablated up to the parent rock can be distinguished.

For the identification of the starting point of the gully formation in the beginning of the crop season, an image taken by SPOT-4 on June 15, 2008 was used (figure 6)

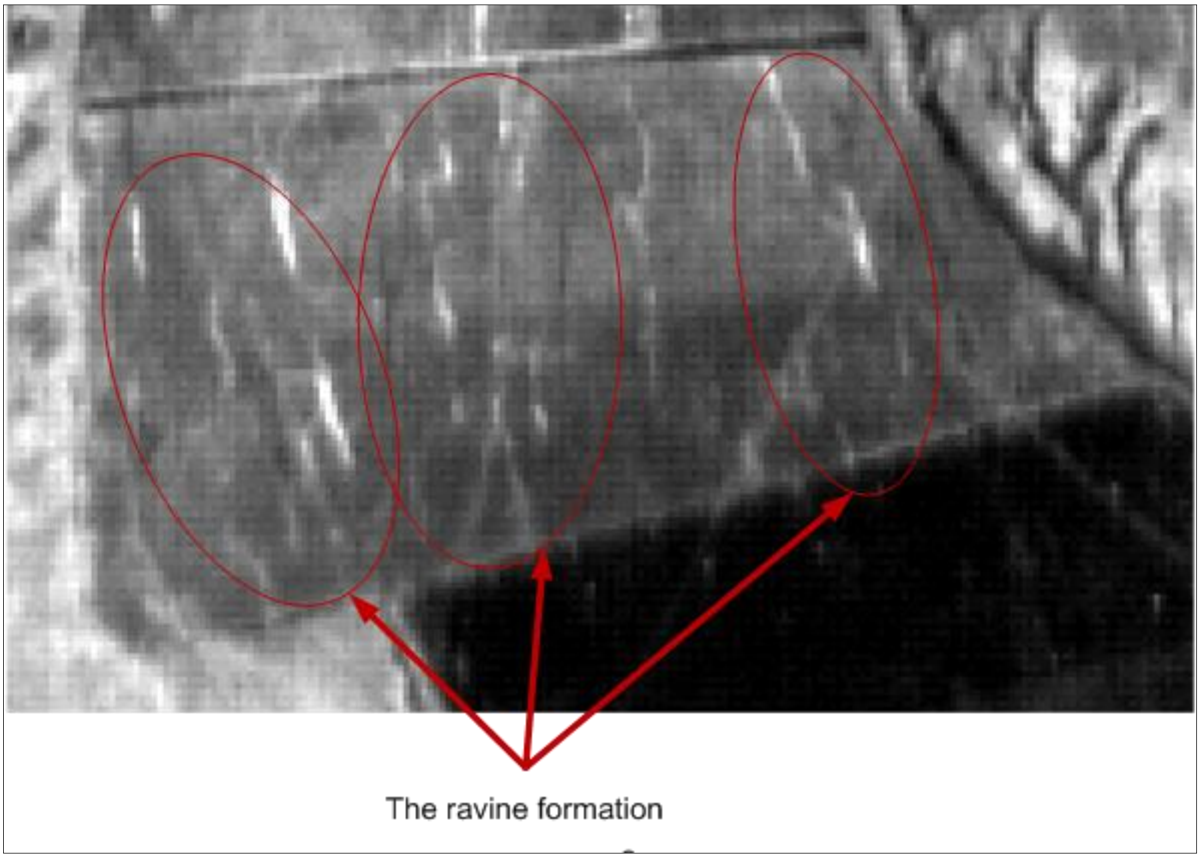

Fig. 6: Image 15.06.08 (resolution 10m)

Figure 7 reflects the informational technology of the retrospective satellite data processing, which is aimed at the identification of the transformational dynamic of land use. The method is based on the identification of the land use type on soils of the automatic classification of the conglomerate of spectral channels resulting out of the base hyper spectral image (NDVI).

The essence of the method of analysis of the plough lands` condition is the following: based on data from the spectral channels Red and NIR a composite NDVI map is formed, allowing characterizing objects of vegetation according to their chlorophyll content. Then, the NDVI image is being classified, i.e. several statistically homogeneous areas are being identified by means of the ISODATA algorithm. The classification`s main characteristic is the mean value NDVI determining the belonging of a spatial area to a “bunch” in the NDVI.

Classes, determined by means of the program ISODATA, are grouped into objects: forest, pastures, water, etc. on grounds of the assignment of threshold values of the NDVI in accordance with the regular procedure. The values of the threshold determining the belonging of ISODATA classes into objects of the agricultural infrastructure are being corrected on test parcels by means of previously created maps.

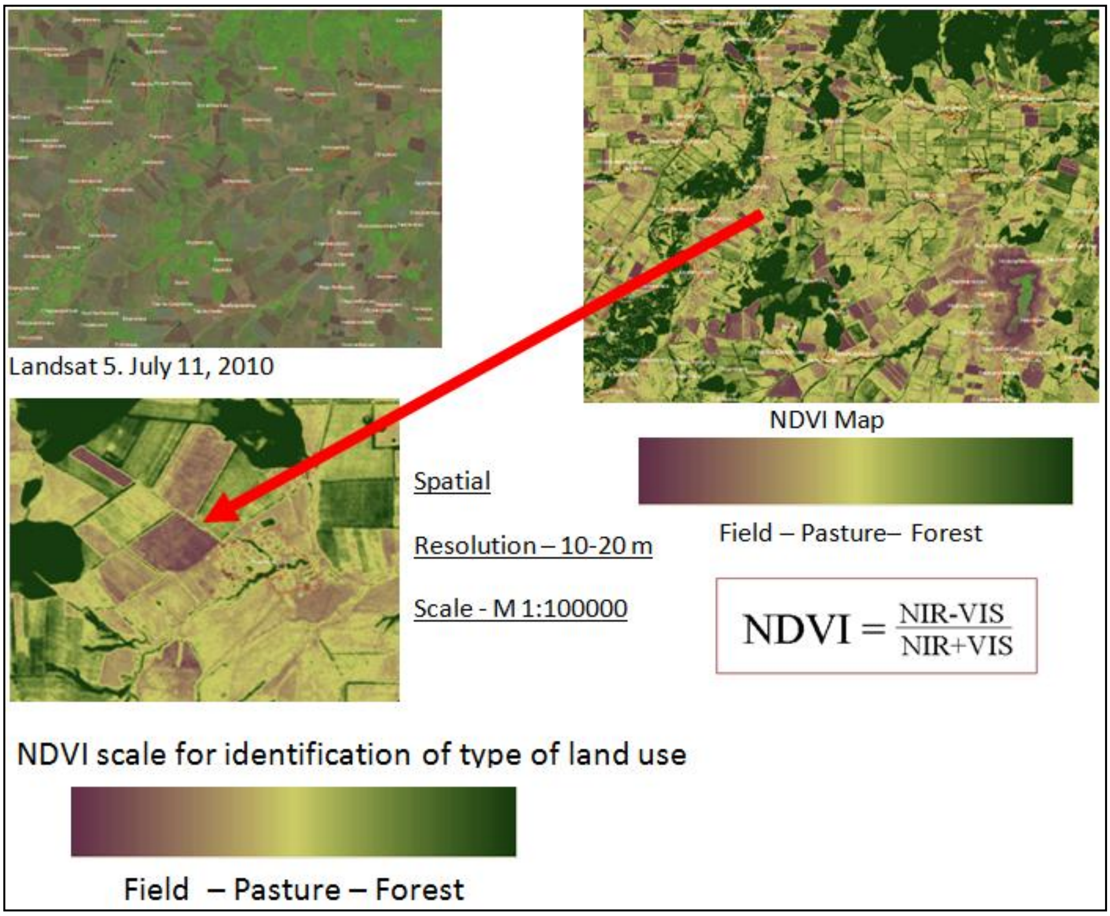

Fig. 7: Method of identification of land use types based on the NDVI

Based on the analysis of retrospective images during a period of 20 years, tendencies of a decrease of the total surface area of plough lands and an increase in the area of pastures have been identified. The results are presented in figure 8.

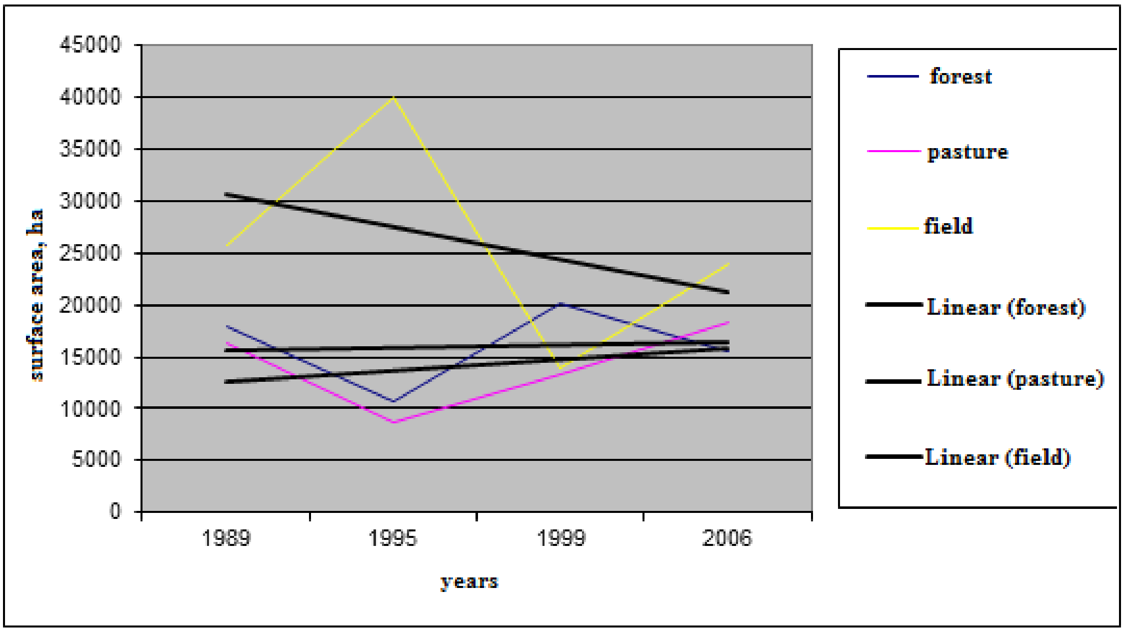

Fig. 8: Identification of the total area of agricultural objects

Conclusion

The analysis of the satellite image illustrated on picture 6 shows that in order to identify the starting point of gully formation, images having a resolution of not lower than 10 m and taken in the beginning of the crop season when there is no relief modification (April-May, November – beginning of the snow fall) can be used. On images taken during the beginning of the crop season, in the spectral channel 3 (near-infrared 780-890 nm) one can identify changes in the acuity of the vegetation cover along the structures of the gully line. So, the beginning of a new gully formation can be detected at the moment when relief modification did not yet occur. As a result of our study, an informational method of the analysis of the dynamic of land use in the forest-steppe zone of the Republic of Bashkortostan based on remote sensing has been developed, alongside with digital maps of the forest-steppe zone of the Republic of Bashkortostan, which were created with the purpose to analyze the different types of land use, and a detection of their dynamic.

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3 Topic: Indicators of climate change and their consequences for soil degradation

Indicators of the spatial and temporal change of precipitational conditions, their dynamic and the resulting consequences for the dynamic of soil moisture

Gareev A.M., Galimova R.G., Minnigaliev A.O.

Abstract

As a result of a change in the climate`s functional conditions, the natural-anthropogenic systems used by men begin to transform. This can be observed throughout practically every component of the natural environment. The transformation of the thermal and water regimes, as well as a change in those transformation`s speed, lead to a restructuring of the hydro-thermal properties of the territory, the surface and soil water runoff, the pedogenesis, to a displacement of plant species, etc.

Introduction

There is no commonly accepted point of view on the reasons for climate change on the planet. The most widespread ones out of the official versions are the following: the change in size and relative position of the continents and oceans, solar activity, Earth orbit parameters, atmospheric transparency and composition as a result of volcanic activity, the concentration of greenhouse gases (CO_2 and CH_4) in the atmosphere as a result of anthropogenic activity, reflectivity of the Earth surface (albedo) as a result of glacial melting, the amount of heat in the depth of the oceans.

At present, published academic literature is consistent on a number of core assumptions regarding modern climate change:

- The major causing factor is aqueous vapour. With increasing temperature, the amount of aqueous vapour in the atmosphere also increases. Hereby, aqueous vapour, like the greenhouse gas, induces further warming, which then leads to a further increase of the amount of aqueous vapour in the atmosphere. More aqueous vapour means more clouds, which affects the climate system in diverse ways.
- Clouds can both strengthen the global warming (by holding back the emanating radiation) and weaken it (by reflecting the incoming radiation back into the cosmos). The results of most models indicate a positive feedback (a strengthening of global warming).
- Due to atmospheric temperature increase, the surface temperature of the ocean also increases. Ice, which serves as an insulating cover, did not “allow” the ocean to emit the

absorbed heat back to the atmosphere before. Now, the surface of ice declines due to an increase in the air and ocean surface temperature. Glacial melting also means an inflow of sweet water into the Northern Atlantic and other regions of the World Ocean. Satellite observations in the second half of the XX century indicate a decline in the overall surface of the snow cover.

- The increase in atmospheric temperature induces the melting of permafrost and, as a consequence hereof, a change in the natural systems of these territories and a moving of their boundaries.
- “In the report of the intergovernmental group of climate change experts was annotated that given the current rate of the glacial melting in mountain systems and of the climate change, many Asian streams could become seasonal and dry out in between the rain seasons“ (Galimova 2011).

Research methods

To verify the ongoing changes, following methods were chosen by the authors: 1) the use of averages to calculate average long-term values, their variations and deviations, 2) moving three-years averages for the detection of regular cycles, 3) the identification of trends and the calculation of an equation for each indicator, 4) cumulative sums for the identification of the timely dehomogenization of data sets. Statistical calculations and graphical material were supplemented by cartographical editions.

Research results

The peculiarities of the annual distribution of the recurrences of cyclical processes are reflected in the dynamics of the long-term correlations between the zonal and the meridional components of the total atmospheric circulation. Currently, a substantial change in the meteorological parameters from year to year takes place. It was detected simultaneously on different levels and during different periods. These fluctuations of the atmospheric circulation were identified as circulatory epochs of a zonal or meridional character depending on the relative dominance of the different forms of circulation during the respective period (Yarapov I.M., Galimova R.G., 2009).

The investigated territory – the forest-steppe zone of the Bashkir Cis-Urals – undergoes a substantial change in its climatic conditions, which, in turn, will evoke changes and a re-construction of the natural-landscape properties, among them different kinds of soil processes (formation of humus and forest soil, erosion etc.).

The entire set of the regular annual and the anomalous fluctuations in the form of atmospheric circulations generally determine the predominance of the amounts of atmospheric precipitation during the warm period. Depending of the specific year, the cold period makes up for around 30-40% of the total annual sum of precipitation (figure 1).

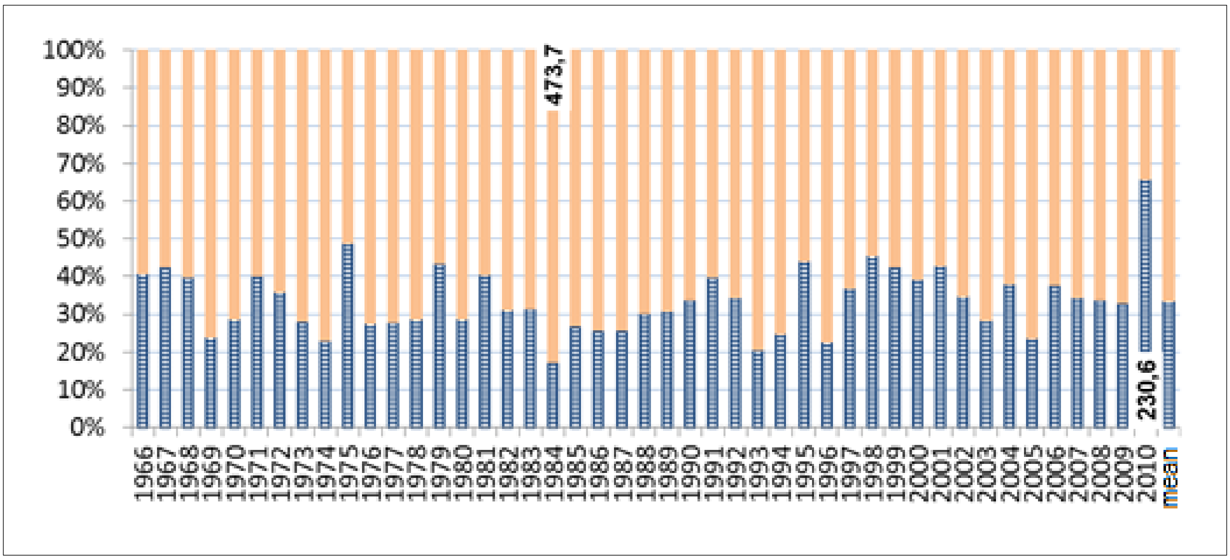

Fig.1: The correlation of precipitation sums for the cold (dark grey) and the warm (light grey) periods, meteo-station Kushnarenkovo *(data by BashUGMS)*

Notwithstanding its insubstantial portion, it is the precipitation of the cold period which affects the processes of erosion and its intensity during the spring period

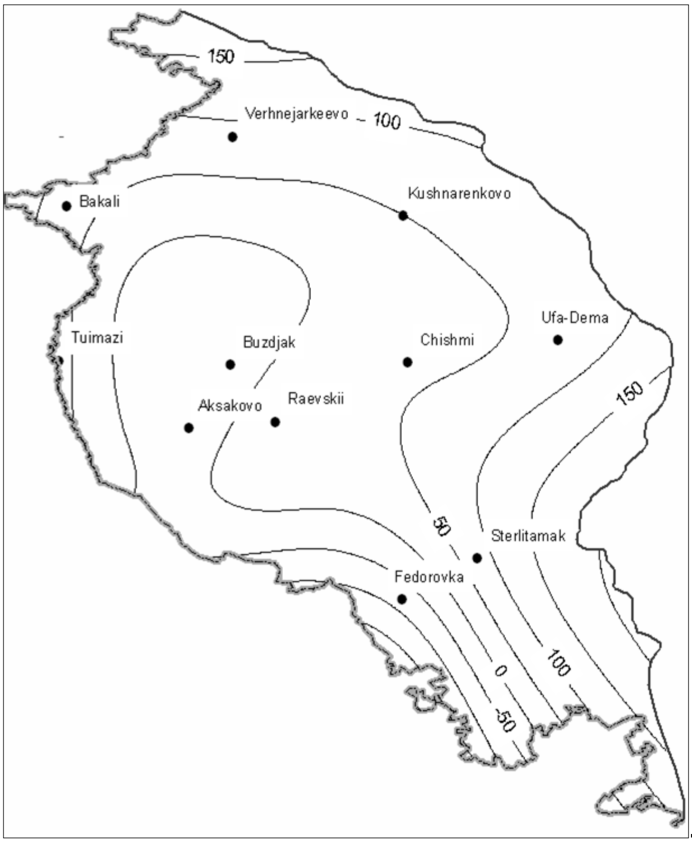

Fig. 2: Dynamic of the sums of annual precipitation

The sums of annual atmospheric precipitation vary relatively insignificantly when correlated (figure 2). So, while an **increasing tendency of the sums of annual precipitation** (up to 50 mm) was characteristic the north-western, northern and eastern peripheries of the forest-steppe, a slight decrease was detected for the southern regions of the forest-steppe.

As indicated in figure 2, the greatest increase in the annual sums of precipitation was detected on territories located near the forest zone, where the total amounts of precipitation were higher than in the forest-steppe. As follows from visual observations of the last decade, forest formations begin to dominate in the indicated regions. A slight decrease in the annual sums of precipitation was observed on territories adjacent to the steppe zone.

Parcels covered by forest are only minorly exploited in land use and less vulnerable to the processes of erosion. On the territory of the Bugulma-Belebey Upland with its developed agro-industrial complexes, the degree of the soil erosion will increase over years because of the flat washout formed under the influence of precipitation and snow cover.

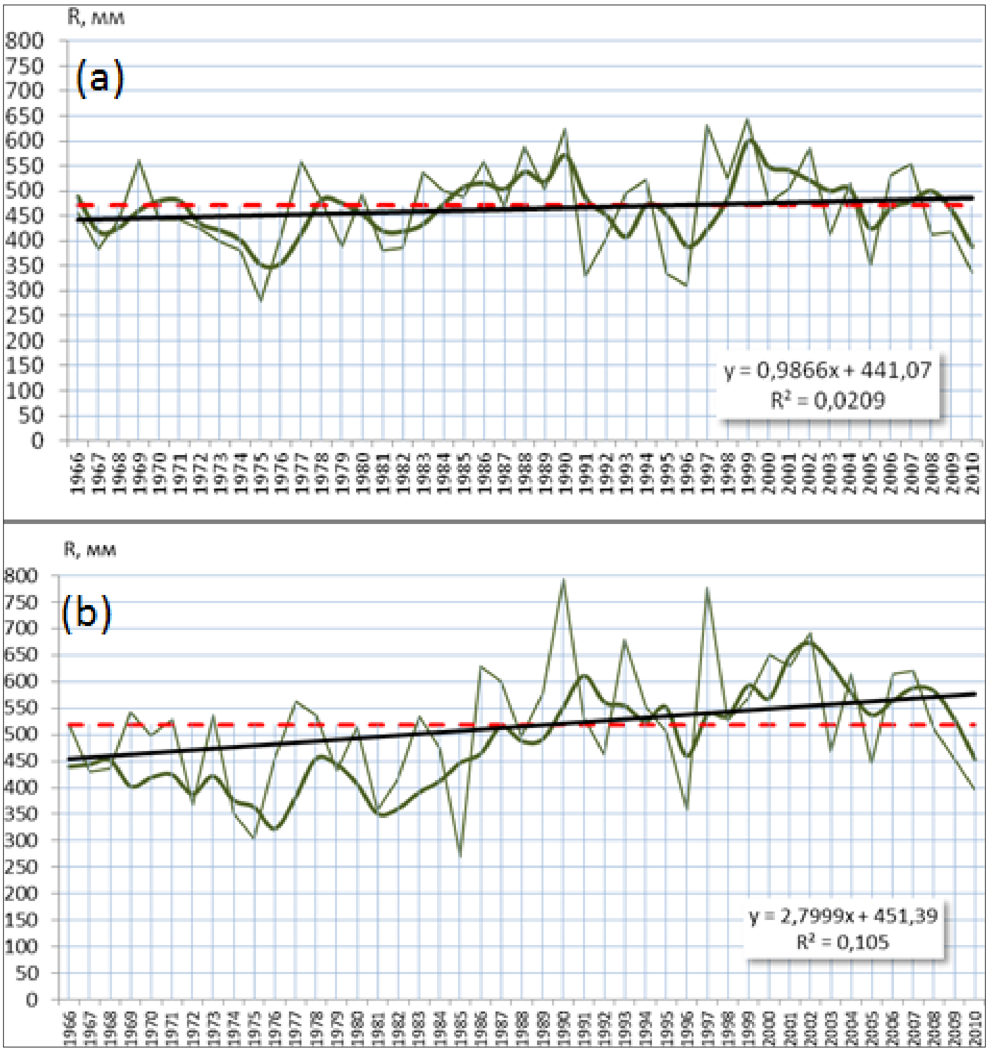

Fig. 3a/ 3b: Long-term development of the sums of annual precipitation, meteo-station Tchishmy (3a) and Sterlitamak (3b) *(data by BashUGMS)*

When analyzing the graphs of the long-term development of the annual atmospheric precipitation sums, analogous tendencies became apparent – the northern and eastern regions have a stronger tendency towards increase as compared to the southern ones (figures 3a/ b).

Distinct forms of circulation affect not only the annual amounts of precipitations, but also their allocation during the year.

The dynamic of the moisture regime during the cold period undergoes greater changes, than during the warm period (Gareev A.M., Galimova R.G., 2012). According to the climatic interpretation, the term `cold period` for the Republic of Bashkortostan refers to the five months (from November to March) with an average daily temperature below 0°C. Hereby, precipitations in millimeters, as well as the characteristics of snow cover (height and water storage), are accounted for.

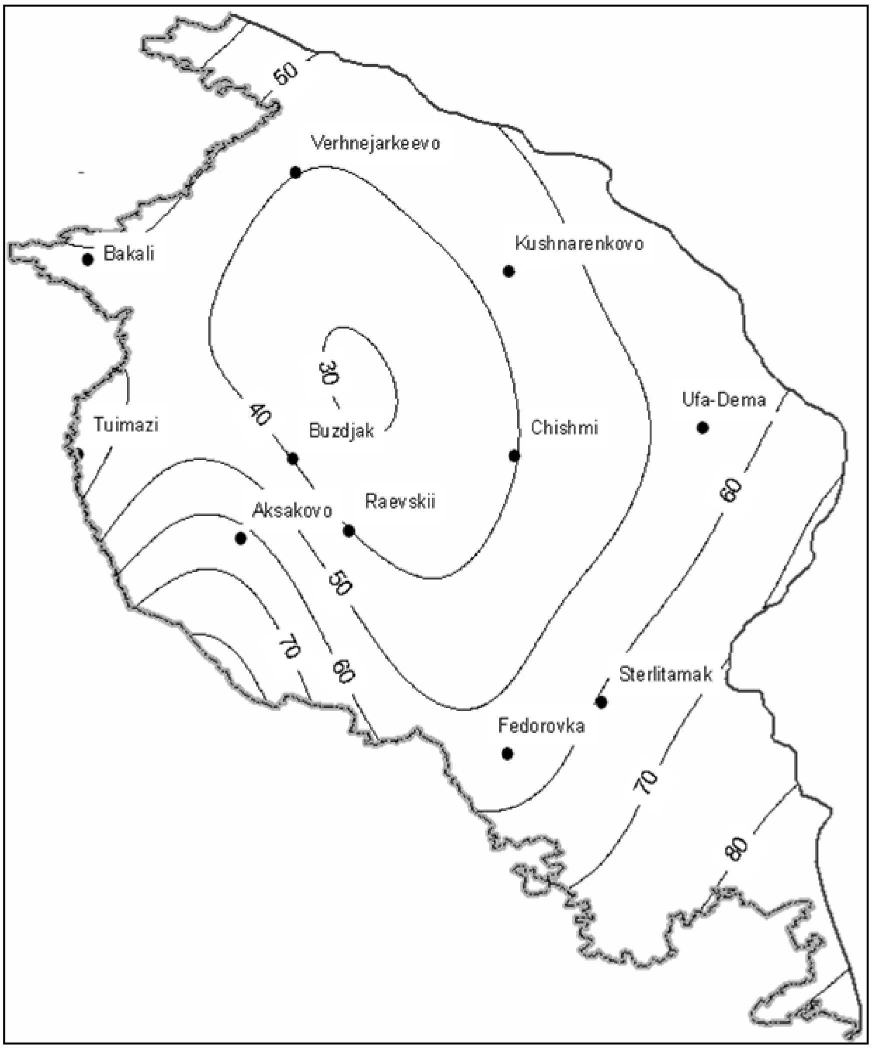

Fig. 4: Mean annual indicators of increase of the precipitation sum for the cold period, mm

The spatial variability of the indicators of the sums of atmospheric precipitation for the cold period is illustrated by figure 4. This schematic map visualizes a general increase of precipitation which amounts up to 40-80 mm. The smallest increase is typical for central regions, the greatest – for the eastern and the most elevated parts.

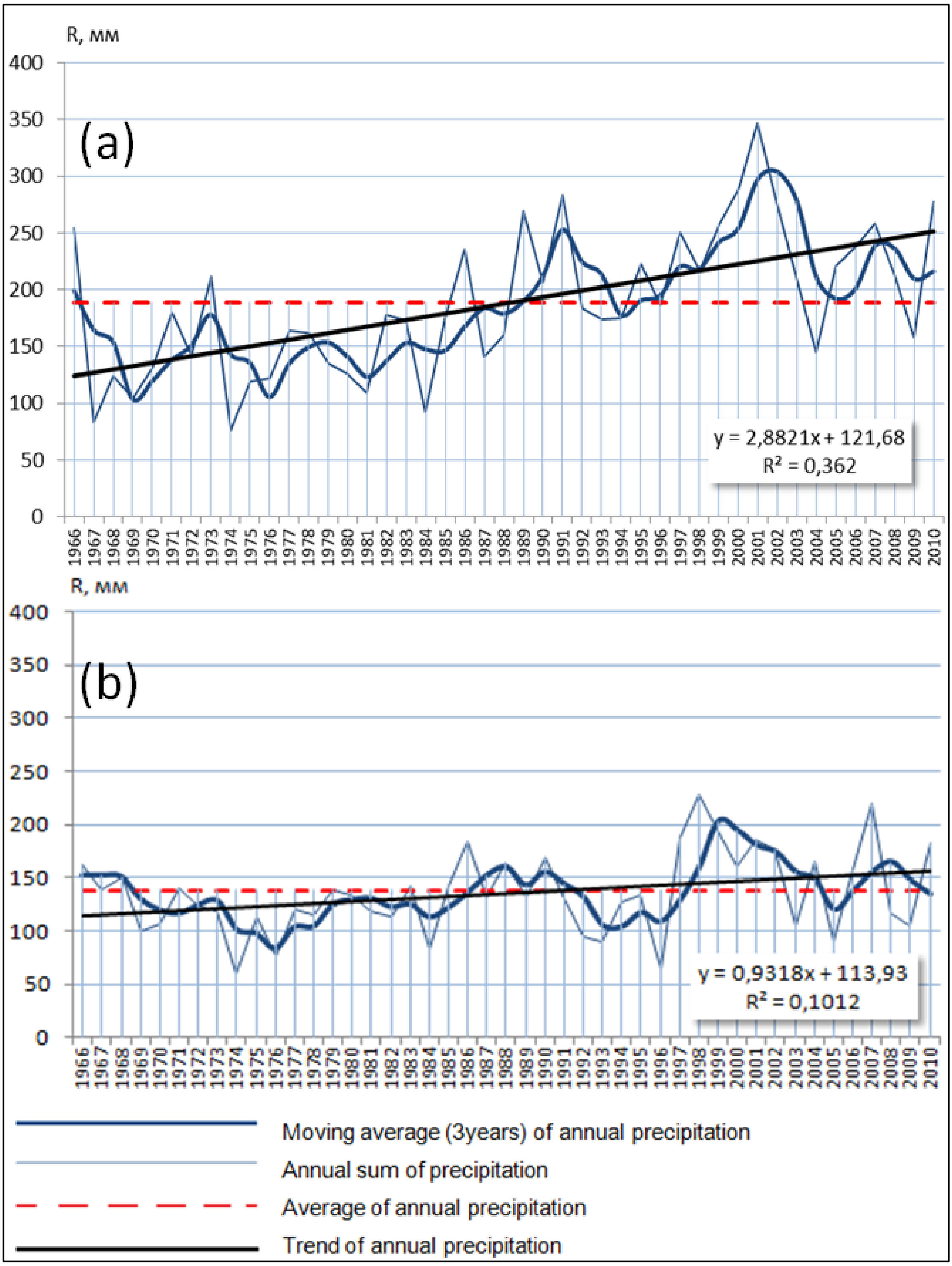

Fig. 5a/ b: Dynamic of total annual precipitation in winter period at meteo-station Kushnarenkovo (a) and meteo-station Sterlitamak (b) *(Daten BashUGMS)*

When analyzing the graphs of the moving averages of the long-term development of precipitation sums for the cold period, virtually all meteo-stations measured an analogous allocation – starting from 1990s, meaning that a water-rich phase has begun in which the total amount of precipitation transcends the “climatic norm”.

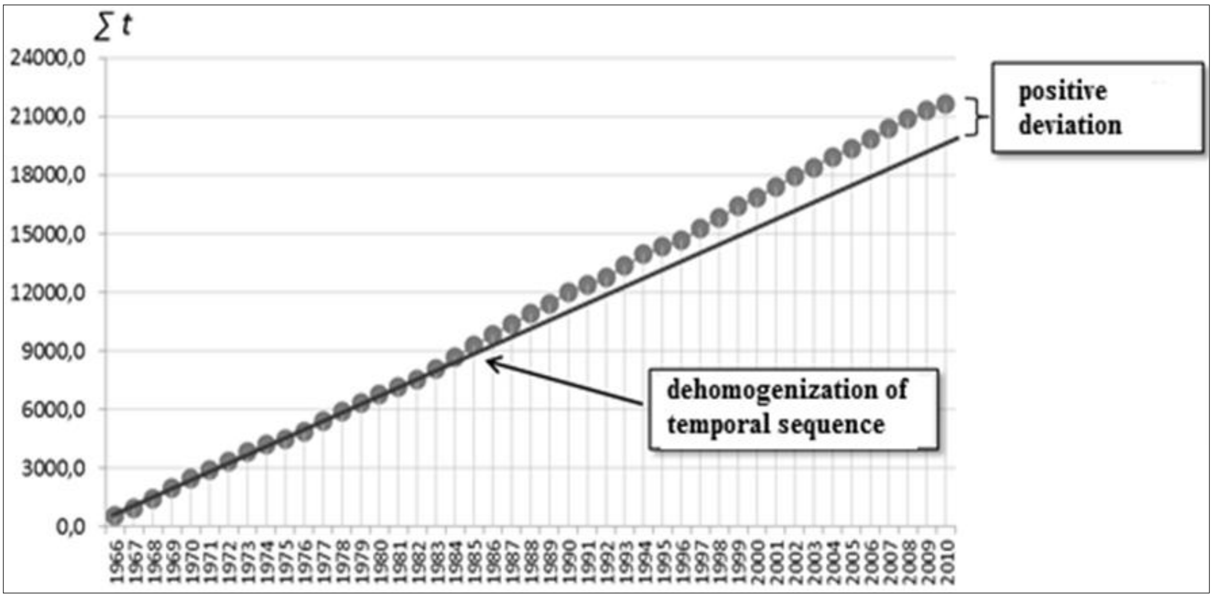

Fig. 6: Detection of dehomogenization of the temporal sequence of annual precipitation sums, meteo-station Kushnarenkovo (data by BashUGMS).

The cumulative sums method illustrates the disturbance in the temporal sequence (figure 6) which has taken place since the 1980s. From that period on, the frequency of the anomalies in the sums of atmospheric precipitation has increased (Yaparov I.M., Galimova R.G., 2009). Hereby, the anomalies were of both a positive and a negative character under conditions of an overall increase in precipitation sums.

The table below shows the values of the deviation and the variations of precipitation for the cold and the warm periods, as well as for the year. The data illustrates that the highest deviation values were detected at the meteo-stations Ufa-Dema, Sterlitamak and Raevsky.

When analyzing the allocation of the height of snow cover during the period of investigation by using the moving averages method, a number of regularities become apparent.

Cyclicity in snowy winters and those with little snow was verified. The maximum (extreme) thickness of the snow cover was detected during the periods 1970-1975 (5 years), 1978-1980 (3 years), 1987-1990 (4 years), 1998-2003 (5 years), and 2007-2009 (3 years).

The periods with maximum heights lasted for 3 to 5 years, in between those periods there were years with regular or minimal share of the snow cover`s thickness.

A minimal share was characteristic for the beginning of the 60-s, the middle of the 70-s, the beginning of the 90-s, as well as for the first half and the end of the 2000-decade.

It is worth mentioning that the periods with minimal thicknesses of the snow cover were less durable, than those with maximum values.

Table 1: Average quadratic deviation and coefficient of variation of the sums of atmospheric precipitation for the cold, warm and annual period within the forest-steppe zone of the Bashkir Cis-Urals

Meteo-station	***Average quadratic deviation***			***Coefficient of variation (%)***		
	$\sigma_{х.п.}$	$\sigma_{т.п.}$	$\sigma_{год}$	$c_{v\,х.п.}$	$c_{v\,т.п.}$	$c_{v\,год}$
Verkhneyarkeevo	34	68	79	24,3	20,5	16,9
Kushnarenkovo	35	60	73	21,4	18,7	**15,1**
Bakaly	39	66	88	27,5	23,0	**19,4**
Tujmazy	**29**	65	67	25,0	22,7	15,4
Ufa-Dema	44	62	**93**	**21,2**	**17,8**	16,7
Chishmy	30	61	75	21,8	18,8	16,1
Buzdyak	**29**	67	76	24,6	**24,9**	18,4
Aksakovo	43	**70**	83	21,9	23,8	**15,1**
Raevskij	30	**58**	**71**	22,4	20,2	16,7
Sterlitamak	**52**	**58**	87	**27,6**	19,3	16,8
Average σ и c_v	36	64	79	23,7	20,8	16,6

At the present time, a clear tendency towards an increase in the thickness of the snow cover can be detected, at some stations this tendency is quite significant (the trend lines are presented in figure 7). The greatest increase was detected in the southern regions of the forest-steppe zone (meteo-stations Sterlitamak, Raevsky,Aksakovo).

Table 2: Average decennial values of the snow cover height

MS	***Baka-li***	***Ufa-Dyema***	***Tuy-masy***	***Busdyak***	***Aksa-kovo***	***Sterli-tamak***	***Kushna-renkovo***	***Raevsky***	***Verhne-yarkeevo***	***Tchishmy***	***Fedo-rovka***
1960-70	34	46	34	31	**48**	36	41	24	n/d	36	n/d
1971-80	32	42	34	32	**54**	36	37	19	33	39	n/d
1981-90	35	50	32	33	**60**	49	40	30	34	49	67
1991-00	42	57	42	36	**59**	49	51	33	41	49	67
2001-10	34	51	39	41	**62**	49	45	34	40	46	79
Average	35	49	36	35	**57**	44	43	28	38	44	**72**

On grounds of the analysis of the parameters of the snow cover, one can conclude that the years 1990-2000 were characterized by winters with little snow. Extremely high values were measured from 1997 to 2001. At the present period, the exceedance amounts to 2-2,5 over the perennial norm. According to the trend lines, the increase of this parameter can be expected to continue. Based on the applied method of cumulative sums, years in which a refraction of the general line of the graph took place were identified. At all tested stations, those periods occurred during the following years – 1977-1980, 2000-2001.

Minor fluctuations were observed in 1968-1969 at the meteo-station „Busdyak“, in 1965-1966 at the meteo-station „Kushnarenkovo“, and in 1996-1997 - at the meteo-station „Fedorovka“.

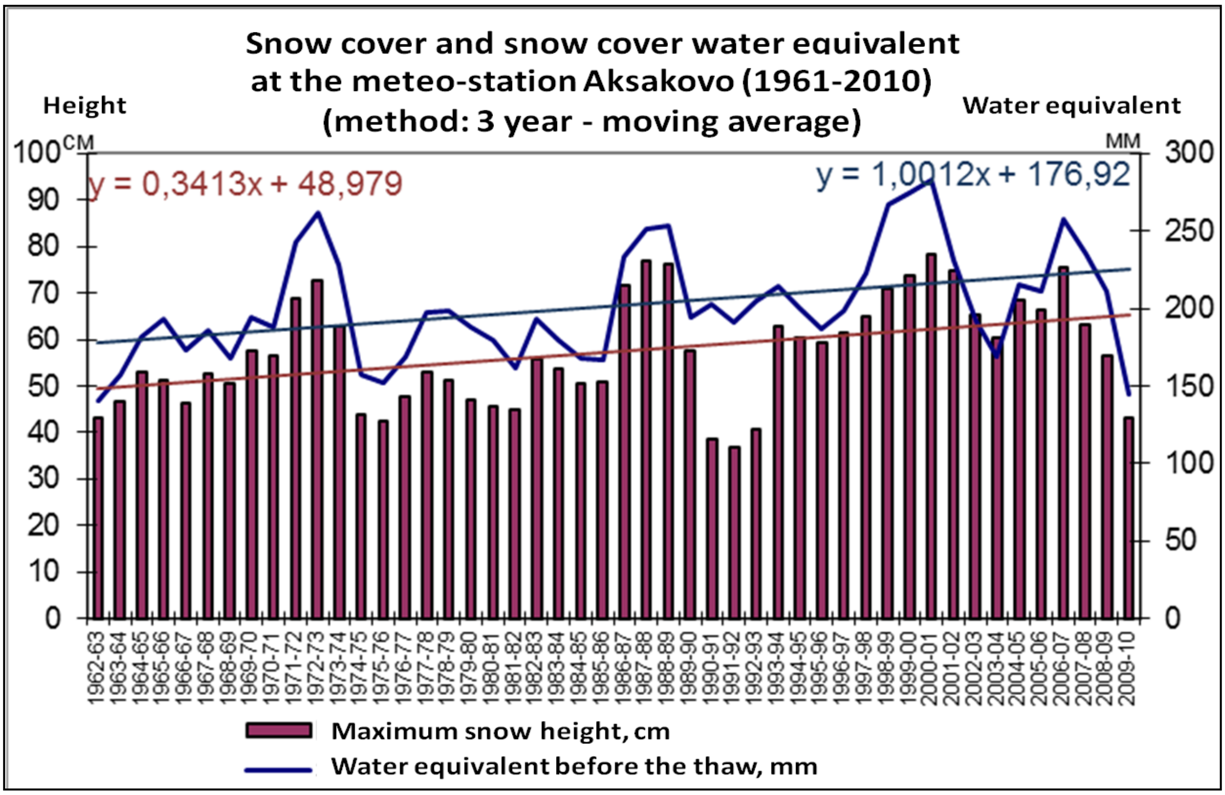

Fig. 7: Dynamic of snow cover and snow cover water equivalent (1961-2010) at meteo-station Aksakova

Following the graphs correlating the height of the snow cover and the water stored inside of this snow, a general regularity can be traced, namely, that water storage increases when the height of the snow cover increases. Yet, in the period between 2003 and 2005, a decrease in the amounts of stored water in presence of an increase in the height of the snow cover could be observed. When the trend lines of those two parameters were correlated, an overall increase was noted, except for the meteo-station “Verhneyarkeevo”. According to the data from that station, when the height of the snow cover slightly increased, the amounts of stored water decreased (Gareev A.M., Galimova R.G., 2013).

Remarkable is that this is reflected both in an increase of the snow cover height and of the amounts of water stored in snow before the beginning of the spring snowmelt. Consequently, the increase of the height of the snow cover affects the overall decrease in the depth of the soil frost penetration.

Using the calculated values of the tendencies of the snow cover`s height increase, a map of this indicator´s fluctuations was created (figure 8).

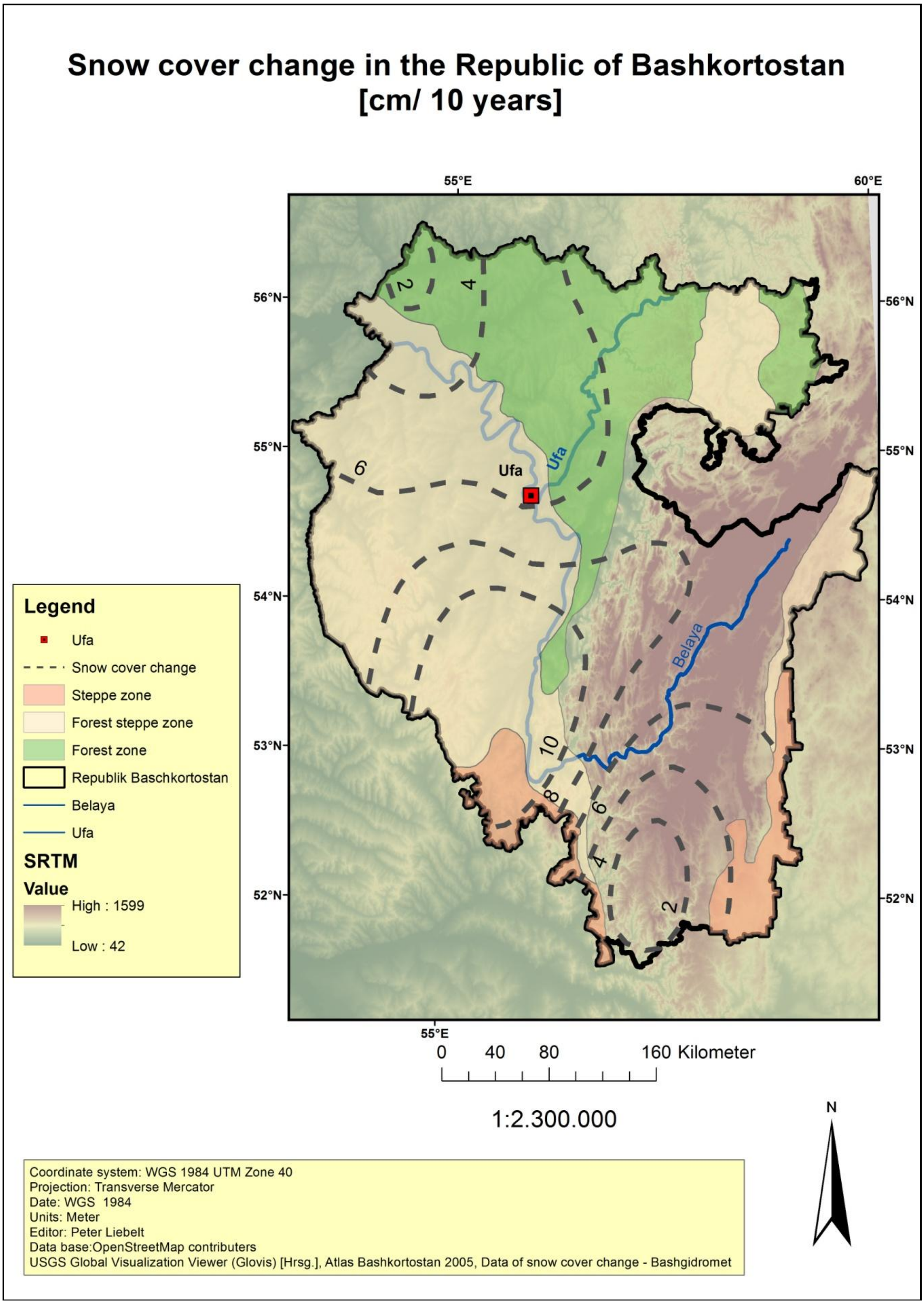

Fig. 8: Snow cover change *(Liebelt 2014)*

As can be observed in the schematic map, the greatest increase is characteristic for the southern part of the forest-steppe (the elevated part).

The lowest values are characteristic for the lower course of the river Belaya (the northern part).

Due to the topographical properties of the territory, the processes of snow accumulation and snow melt will have a different character at the indicated territories. Under the influence of spring thaw water, the intensity of the flat water erosion can increase for the elevated territories due to the slopes, as well as due to the growth of the snow cover´s thickness.

Conclusion

Based on the multi-factorial analysis of the calculations and evaluations we conducted, it can be established unequivocally that the ongoing global changes of the climatic conditions find a regional expression. This fact suggests for the necessity to account for the detected changes when approaching the practical problems in the different spheres of human economic activity.

Hereby, the following core results detected by the authors during the research should be taken into account:

1) The overall annual amount of precipitation has an increasing tendency, which is not spatially homogeneous. The more steppificated regions have a small increase (or none), while regions located near the forest zone experience substantial increases in the annual sums of precipitation which leads to an increase of the woodlot in the area (further triggered by a decline of farming).
2) The amount of precipitation during the cold period and, consequently, the height of the snow cover throughout the entire forest-steppe, increase. The greatest increase was characteristic for the elevated parcels of the Bugulma-Belebey Upland.

With a higher woodlot of the northern and eastern parts of the forest-steppe zone, soil properties and processes will experience a number of changes. Over time, soil horizons will become analogous to forest formations, and the processes of erosion will manifest themselves much weaker in comparison to those in the southern regions. In the latter ones, soil erosion will be determined by elevation differences and substantial slopes, while an increase in the thickness of the snow cover will affect the intensity of water erosion through thaw water.

The study of these processes, which might strengthen under conditions of the global climate change, can contribute to the creation of a full-scale evaluation of the ongoing changes in the natural complexes and transfer the results to analogous objects which might increase the effectiveness of land use.

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Effects of climate change on soil erosion with a special focus on the snowmelt period

Gareev A.M., Galimova R.G.

Abstract

This article illustrates the main tendencies of climate change characteristics on the example of the forest-steppe of the Cis-Ural region. Those tendencies have been identified by means of statistical, graphical and cartographical analyses of the material of long-term observations (from 1961 to 2011) at 12 observational stations. The received data is of considerable scientific and practical value for, among others, the study of the intensity of the development of erosion processes and the optimization of land use.

Introduction

The development of erosion on the Earth can historically be grouped into three main phases. The first was characteristic for the epoch of the formation of the Earth as a planet with active tectonic and volcanic processes taking place under conditions of no vegetation cover. The formation of the Earth`s rough surface took place during that epoch as a result of the highly active interplay between endogenous and exogenous processes, among others - a rapid development of erosion. As argued by scientific literature, the second phase took place from the end of the glacial period when the nowadays typical climate epoch was formed, which – due to global favorable parameters of heat and moisture supply, as well as the presence of a vegetation cover on the surface of the Earth - contributed to a sharp decrease in the intensity of the processes of erosion and the formation of the nowadays regular natural parameters.

The current epoch can be regarded as the third (accelerated) phase, which is largely shaped by the effects of anthropogenic activity on the soil-vegetation cover under conditions of an intense use of natural resources, among them – land use. If the indicated tendency manifests itself in a transformation of the surface runoff brought about by a sharp modification of the soil capacity of water-absorption and water-permeability, then the global climate change and its regional consequences will evoke further changes in the process. This constitutes a need for research in that area.

It should be pointed out that the problem of climate change is one of the nowadays rather frequently discussed topics approached on different levels. It should further be noted that regardless of the existing disagreements between scientists, some definite tendencies can be observed. Those reflect the direction and the absolute values of the changes of the different parameters detected by means of the analyses of long-term material. Among the published works (Antropogen…, 1987; Borisenkov, 2000; Global…, 1993; Galimova, 2011; Gareev A.M., Galimova R.G., 2012 a.o.), interesting regularities can be observed which take shape to reflect some trends in the climate change on the regional scale. This is a consequence of the fact that the regional feedback of global climate conditions reflects a clear presence of the processes characterizing an aggravation of the ecological and socio-economic conditions marked by the specifics and the levels of influence of human activity.

We shall pay a more detailed attention to the analysis of the material of long-term research we conducted within the territory of the mountain-forest and forest-steppe zones of the Republic of Bashkortostan. The research was dedicated to the analysis of the distinctive features of the formation and variation of the surface and river runoffs depending on the influence that time-varying natural and anthropogenic factors have on natural complexes with different geneses. The research material, including data received through the carrying out of long-term observations on natural observational stations, is reflected in several published academic works (Gareev, 1997, 2001, 2008; Gareev, Khabibulin, 2010 & co). The main findings generally indicate that in the mountain-forest and the forest-steppe zones, the degradation of natural complexes under conditions of excessive human activities evokes the formation of processes leading to a transformation of the surface runoff. It manifests itself in a decrease of the amounts of water which the soil can absorb, and of the soil water runoff accompanied by a corresponding increase of the surface runoff. This leads to a boost of the destructive ability of water streams and an activation of the processes of erosion.

Research methods

It should be noted that natural factors are characterized by a great alterability in time and space. Depending on the influence of the global changes of climate conditions in one or another region, processes start to form and manifest themselves either directly, or indirectly.

In the framework of the contract of creative cooperation between the Bashkir State University and the Martin-Luther University (Halle, Germany), research was conducted entailing the analysis of the material of long-term observations (from 1961 to 2011) on 12 observational stations located within the forest-steppe zone of the Cis-Urals. The study was carried out in respect of its 9 key factors (figure 1).

Hereby, the features of the variations of the studied variables were identified by means of the following indicators: 1) annual amount of atmospheric precipitation; 2) the sum of atmospheric precipitation during the cold period; 3) the sum of atmospheric precipitation during the warm period; 4) height of the snow cover; 5) water storage in snow cover; 6) average annual air temperature; 7) sum of negative temperatures; 8) depth of frost penetration of soil during the winter; 9) variation of extreme values of positive and negative temperatures.

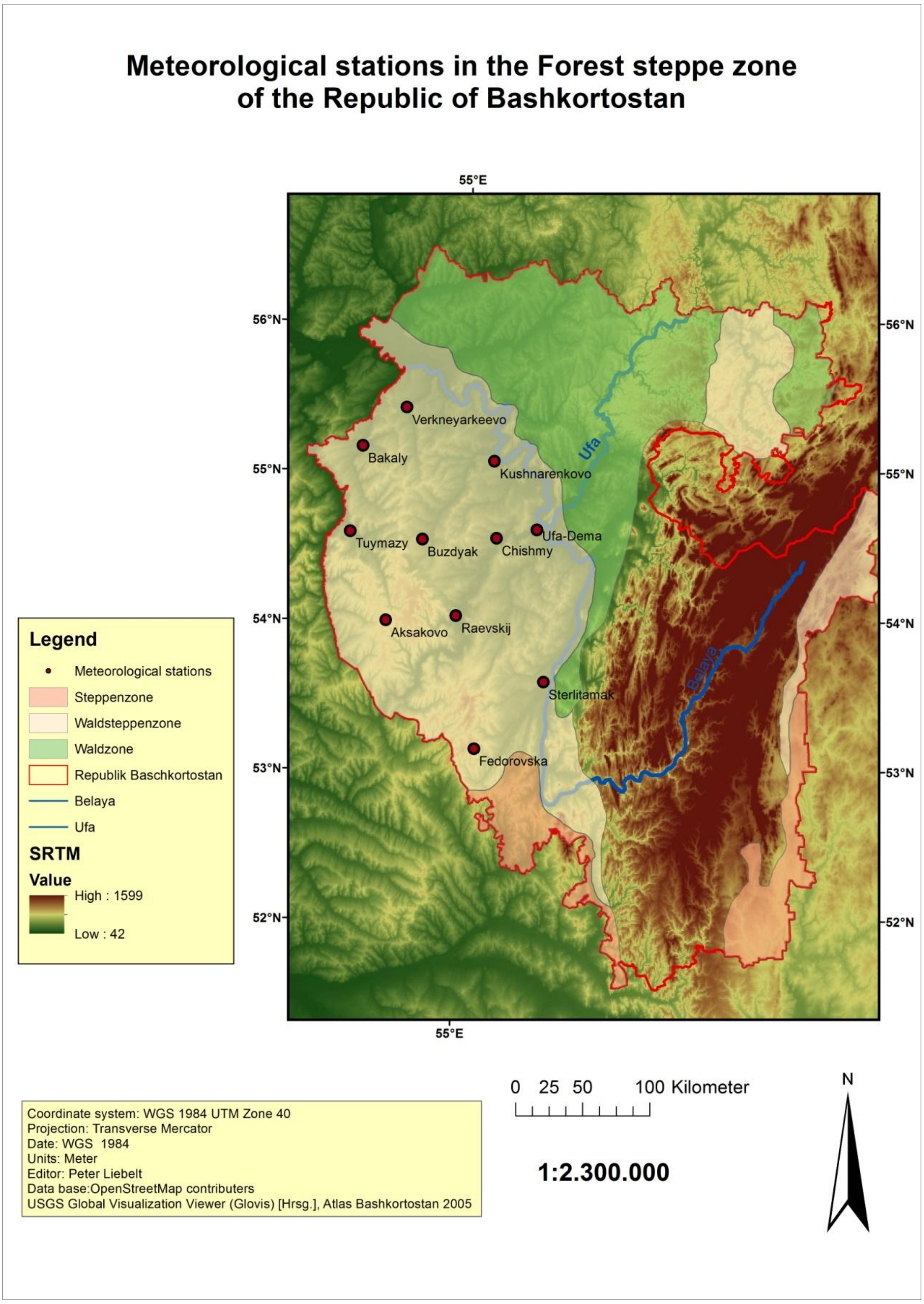

Fig. 1: Meteo-stations in the forest steppe zone of the Cis-Urals *(Liebelt 2014)*

Results of the research

It was verified on soils of a graphical analysis of the studied parameters of a long-term profile, that for all variables, cyclicality in changes is characteristic. At the same time, clear trends in those changes became visible. They can be summarized as follows. The values of annual sums of atmospheric precipitation measured at all meteorological stations during the entire period of observations differed only slightly. Hereby, clear tendencies become visible in the long-term profile reflecting their increase (during the cold period) and a minor decrease (during the warm period).

During the indicated years, a gradual increase in the average annual values of the snow cover, as well as the water storage in snow, were detected before the beginning of the spring snowmelt (figure 2). At the same time, starting from the year 2001, a fairly steep decrease of the indicated parameter alongside with the formation of abnormally low values during the winter 2009-2010 could be observed.

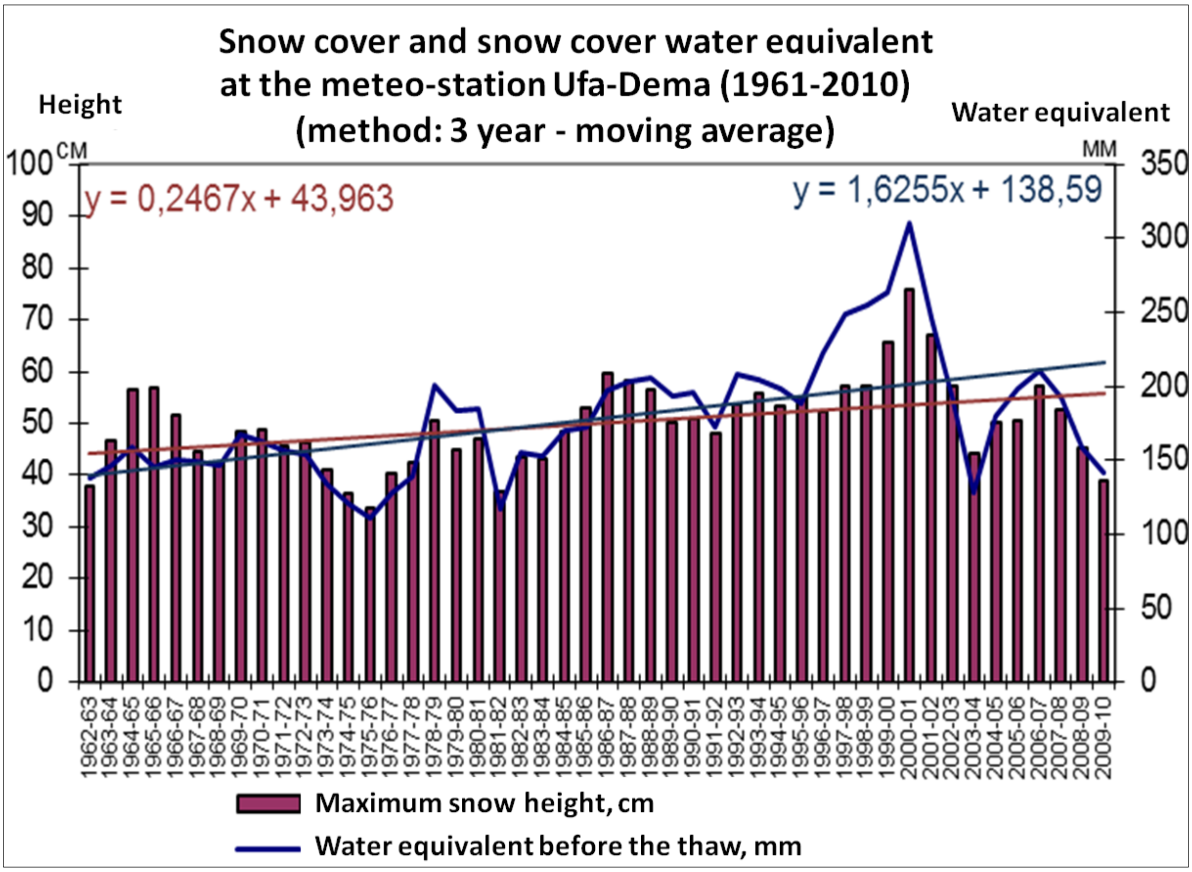

Fig. 2: Long-term development of the heights of the snow cover and snow cover water equivalent, meteorological station Ufa-Dema

During the research period, there has been an increase in the average annual air temperature by 0,5-0,8ºC within the investigated territory. Hereby, a decrease in the sums of negative temperatures during the winter per year (figure 3), as well as in the depths of frost penetration of soils was detected (Gareev A.M., Galimova R.G., 2013).

The graphs illustrating the change of extreme positive and negative air temperatures indicate that the highest, as well as the lowest values have begun to occur more frequently. This reflects a considerable growth of the volatility of climatic conditions which induces unfavorable ecological and economic effects.

The most striking tendencies of the alteration of natural factors affecting various events were verified by means of cumulative sums- graphs with the following equation:

$$\sum x_i = f(t),$$

where $\sum x_i$ – cumulative sums of measured variables, t - time (years).

The total number of graphs used for the calculation of the parameters amounted to 108. Based on their analysis, it could be verified that the dehomogenization of the meteorological long-term series took place since the second half of the 1970s - beginning of 1980s of the XX century.

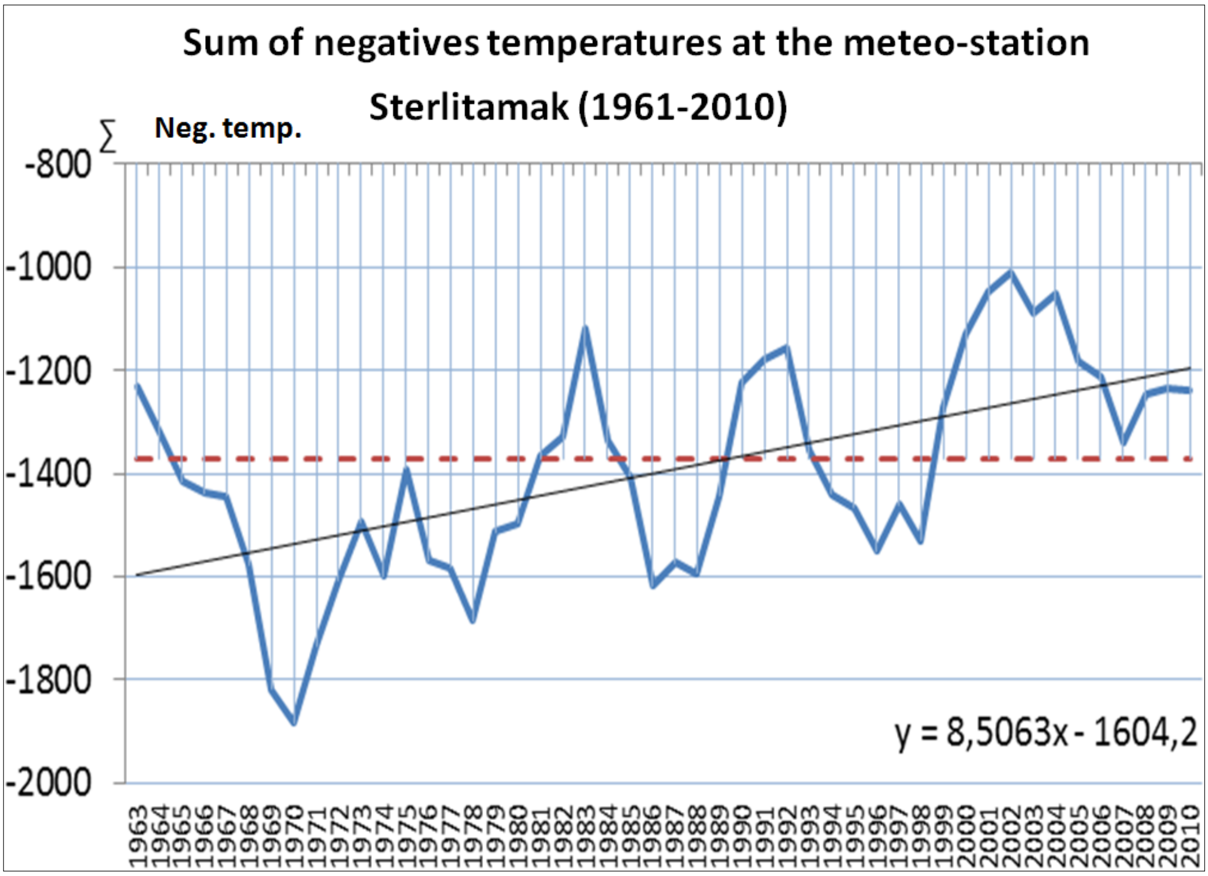

Fig. 3: Long-term development of the sums of negative temperatures, meteorological station Sterlitamak.

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The obtained data per measurement station was used for the creation of index maps reflecting the variability of parameters within the studied territory. Those are illustrated in figures 4-6.

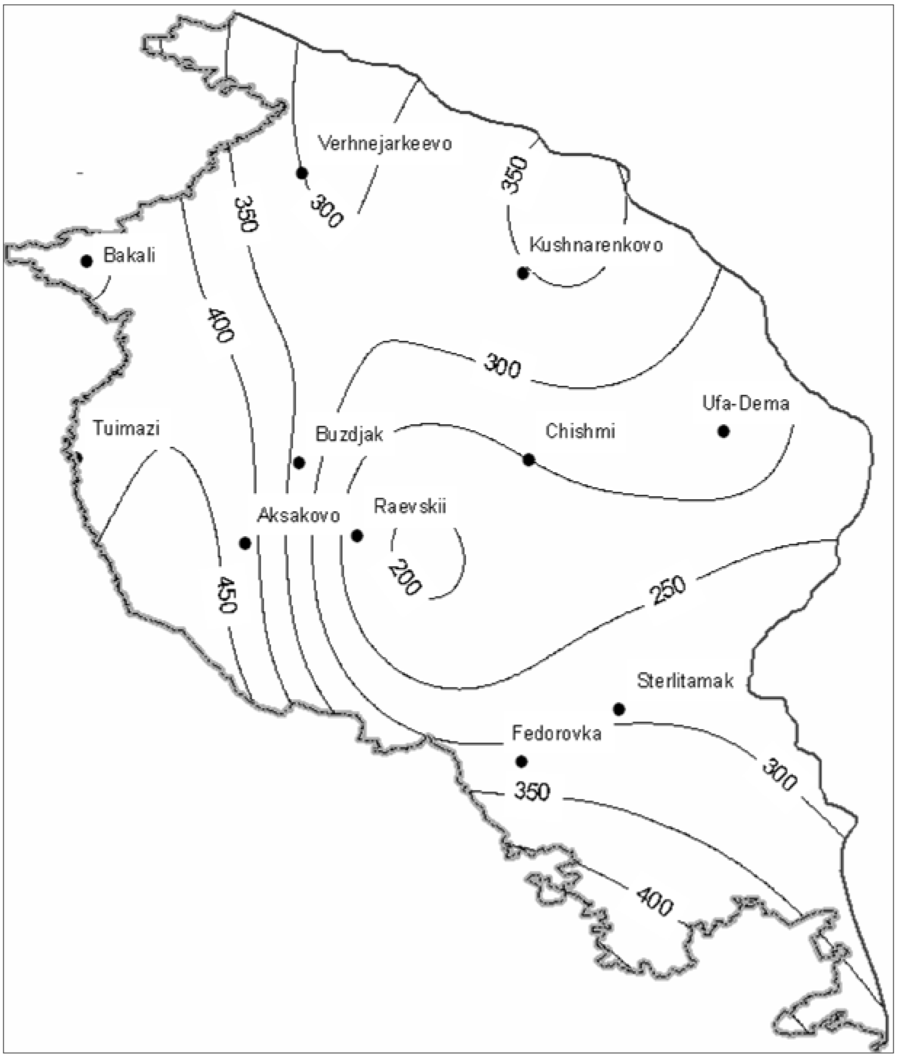

Fig. 4: Indicators of reduction of the sums of negative temperatures, °C.

As indicated by figure 4, the values (difference) reflecting a decrease in the sums of negative temperatures during the winters within the studied territory's boarders amounts to considerable values ranging from 250 to 450°C.

The annual sums of atmospheric precipitation change at an insignificant proportion (see figure 2, essay by Gareev, Galimova). So, while their increase (up to 150 mm) is characteristic for the north-western, northern and eastern peripheries of the Belebey-

Sterlibash Hills, a considerable decrease in precipitation (up to -50 mm) can be verified in the southern regions (Miyakinsky, Fedorovsky).

The territorial variability of the values of the sums of atmospheric precipitation during the cold period reflects their overall increase amounting to 40-80 mm (see figure 3, essay by Gareev, Galimova).

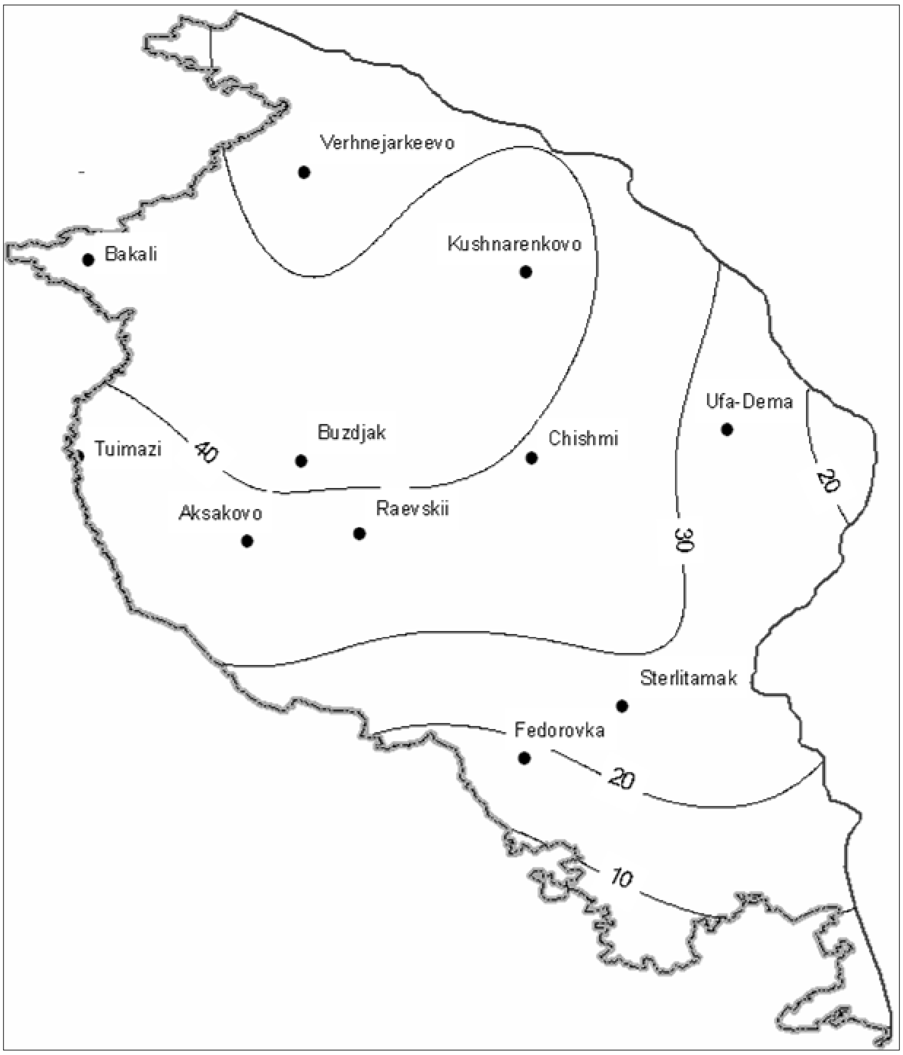

Fig. 5. Indicators of mean annual reduction of depths frost penetrations in soils, cm

The territorial variability of the values of the sums of atmospheric precipitation during the cold period reflects their overall increase amounting to 40-80 mm (see figure 3, essay by Gareev, Galimova). Revealing is that these trends are reflected in the height of the snow cover, as well as in the water storage in snow before the beginning of the spring snowmelt (figure 6).

Consequently, the overall decrease in the values of the depth of frost penetration of soils is correlated with an increase in the snow cover`s height (figure 5).

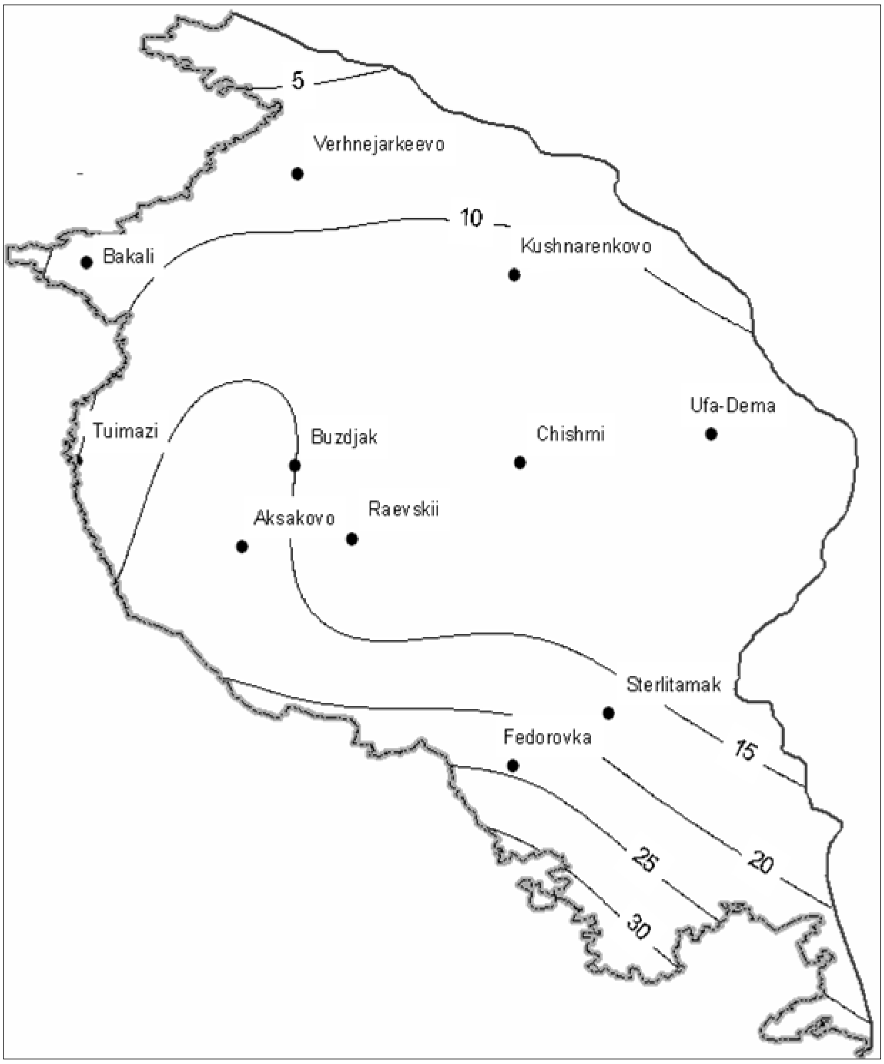

Figure 6. Illustration of the height increase of snow cover, cm

Research results (conclusions)

Based on the analysis of calculations and evaluations we conducted, one can fairly definitely state that the ongoing global climate change finds a reflection on the regional scale. This manifests itself, among others, in the rate and scale of the development of erosion depending on the influence of the respective changes.

In light of the above elaborations, the following major trends reflecting the tendencies of the on-going changes can be illustrated:

1. The currently established tendencies of climate change have been observed since the second half of the 1970s - beginning of the 1980s of the XX century;

2. The territorial variability of the natural factors affecting the conditions under which the natural-economic systems functions is not identical and mainly depends on regional natural conditions;

3. A substantial difference in the values of the annual sums of atmospheric precipitation could be detected, while the general trend was their considerable decrease along the transition from the northern to the southern regions;

4. The increase in the sum of winter atmospheric precipitation in the long-term series and, consequently, in the snow cover and the water storage in snow before the beginning of the spring snowmelt are factors determining the increase of the intensity of erosion on degraded pasturages, as well as on working fields;

5. The overall growth in average annual temperatures (especially during the summer time) indicates an increase in the aridness of the climate.

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4 Topic: The effects of the different types of tillage on soils and yield, as well as on soil protection measures

Temporal/spatial high resolution analyses of the influence of the different types of land use on on- and off-site effects of the water balance and the cycle of matter at the point of intersection between terrestrial and aquatic ecosystems conducted at the perimeter of a climate/lysimeter station

Komissarov M.A., Komissarov A.V., Suleymanov R.R., Liebelt P.

This study is dedicated to the study of the dependency of the runoff's intensity and fine grained soil withdrawal during the snowmelt on different natural-climatic factors. Further, the loss of soil during the spring snowmelt on plough land, stubble field and forest is going to be detected.

Introduction

Soil erosion is one of the major causes for the loss of land resources. Being one of the most wide-spread types of soil degradation, soil erosion causes great economic and ecological damage and constitutes a threat to the sheer existence of soil as a major means of agricultural production and an indispensable component of the biosphere. (Dobrovolsky, G.V., 1993). According to the data from the Food and Agriculture Organization of the United Nations (FAO), the total annual world losses of land productivity caused by erosion amount to ca. 6,7 mil. ha, the losses of the fertile soil layer - to 24 mil. tons (Lal R., 1991).

Modern water erosion is characterized by a combination of natural and anthropogenic factors. While the combination of certain natural factors creates preconditions for an acceleration of erosion, non-rational agricultural economic activity constitutes the main cause for its development (Kiryushin V.I., 1996).

In the Southern Cis-Urals, a considerable amount of plough land is located on slopes with a steepness of 1-3°, on which water erosion develops fairly quickly. One of the major natural causes of its development is the spring runoff. Among the anthropogenic factors, the following can be marked as erosion-provocative: ploughing along the slope with a furrow slice inversion plough, seeding of cultivated crops and the neglect of the sprinkling irrigation regime.

Objects and methods

The research was carried out during the years 2008-2011 on the territory of the water balance station (WBS) run in the framework of the monitoring of meliorated lands by the Federal Public Administration (FPA) “Bashmeliovodhos”, which is located in the Southern Cis-Urals (Republic of Bashkortostan, Ufimsky district - - 54°50', 55°44'). The objects of research have been the soils on gentle slopes of three drainage basins located on unprotected (fall tillage) and protected plough lands (stubble perennial grass field), as well as forest. The main characteristics of the drainage basins, obtained by means of a topographic survey, are illustrated in table 1.

Table 1:

Indicator	Catchment area 1	Catchment area 2	Catchment area 3
Land use	Tillaged land Ploughed field	Tillaged land stubble field	Forest
Area, ha	0,15	0,15	0,04
Average inclination, mm/m	41	43	33
Exposition	Southern		

To characterize the soil, soil profiles were cut on each drainage basin. The soils of field drainage basins are represented by clayey-illuvial, medially leached, slightly clayey, weakly eroded agro-chernozem. Those soils are characterized by a medial thickness of the accumulative humus horizons (A+ AB=60 cm), a medial content of humus (8,7 %) and a sub-acid reaction of the medium. They have an impeccable aggregate phase (structure coefficient - 1,6) and a high water resistability of the structure (82,4), a satisfactory porosity of the plough layer (52,5 %), as well as an optimum water permeability – 2,27 mm/min during 6 hours on the ploughed parcel and 2,05 mm/min on a stubble field (during the medially moisty summer period).

The soils of the forest drainage basin are represented by clayey-illuvial, strongly leached, slightly clayey, not eroded chernozem. Those soils are characterized by a great thickness (78 см) and a high humus content (10,4 %), the reaction of the medium is close to neutral. They also dispose of an excellent aggregate phase (structure coefficient – 8,2), an inordinately high water resistability (87,2), an - in the upper layer - excellent porosity (65,5 %), and an inordinately high water permeability (4,21 mm/min for 6 hours).

The data obtained from the drainage basin was used to calculate the autumn and spring water storages in the soil (Vadynina A.F., Kochargina S.L., 1986). During the period of a stable snow cover, its height and density were measured in the field and in the forest. The height of the snow cover was measured by means of a portable snow stake every 10-20 m, and its density – with a snow-densitometer every 100-200 m. Route surveys were carried out every 10 days during the period of a stable snow cover and every 5 days during the period of active snowmelt. The depth of frost penetration of the soil was verified by using the cryopedometer “Danilin”; the water permeability of the soil – using the cylinder method. The soil temperature was measured by means of the electronic soil thermometer “Keytag”. The soil resistance to water penetration using the penetrometer “Field Scout CS-900”. The basic meteorological data (air temperature and humidity, precipitation, air pressure, solar radiation, speed and direction of wind) were obtained by means of an automatized weather station. For the calculations, further data of the regular (daily at 8:00 and 20:00) meteorological observations of the average daily air temperature and precipitation was used (meteo-station “Dmitrievsky”).

The water discharge in the lower sections of the slope at the drainage basin was measured using the stationary triangular weir “Thomson”. Along the perimeter of the studied drainage basins, contour bunds with drainage ditches were constructed.

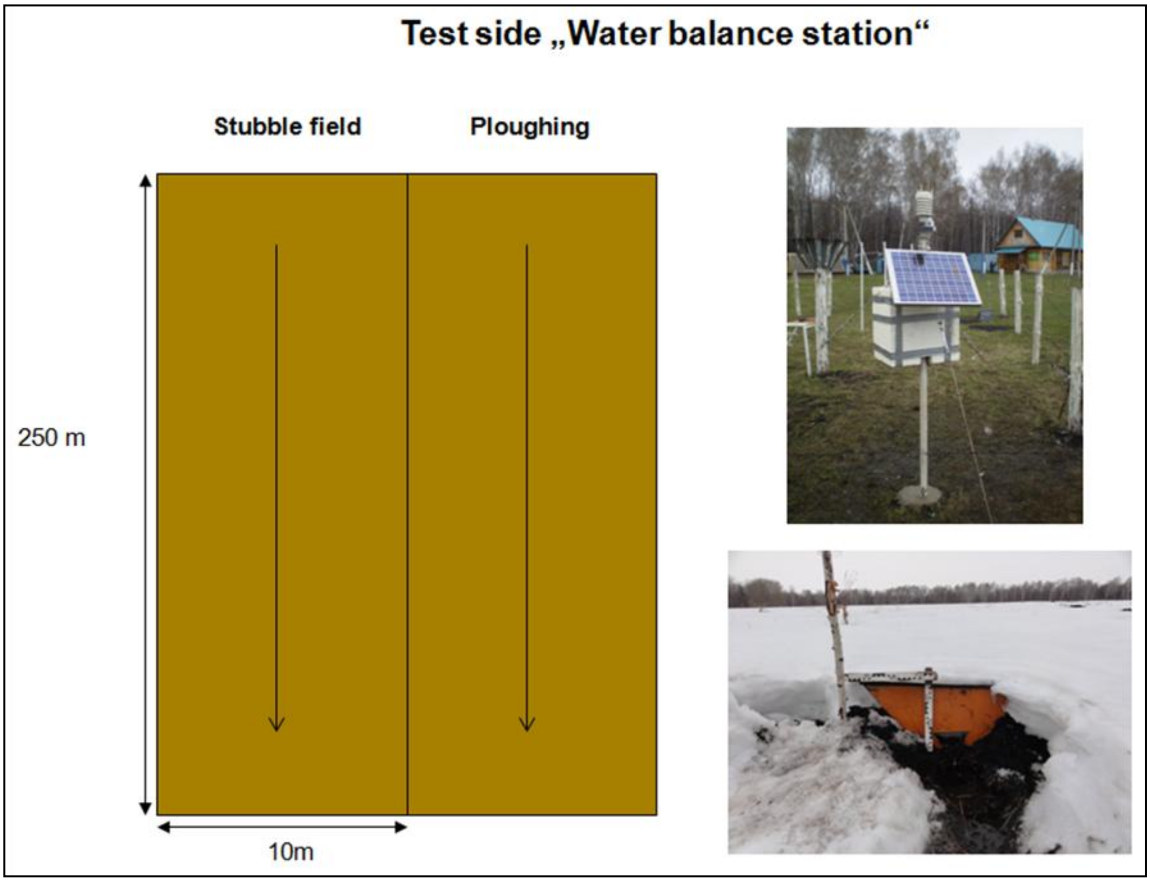

Fig. 1: Test side: Water balance station (Dmitrievka) (on the left: test plots, on the right on top: meteo-station, on the right below: stationary triangular weir “Thomson” during snow melting

Soil loss (containing suspended sediment) was identified by the turbidity of water (Sumratch G.P., 1976). The measurements of water discharge and the taking of probes to identify water turbidity were carried out during the entire period of the runoff every 3 hours from 9:00 to 21:00. At night, surveillance did not take place, because during that time the air temperature was predominantly negative and there was no runoff. The probes were taken along the entire depth of the stream. The probes have been allowed to settled, were filtered; the filters were dried until a constant mass has been received, and weighted.

The hydro-physical properties of the soil and the sediment were identified by means of well-established methods (Arinushkina E.V., 1970; Vadynina A.F., Kotshargina S.L., 1986).

Results and discussion

The winters of the research years were diverse: the winter of 2008-2009 had little snow and was mild; the one of 2009-2010 was medially snowy and harsh, and in 2010-2011 – snowy and mild.

In autumn 2008, the first snow fell on November, 7 (figure 2a) and a stable snow cover developed only by December, 12. Due to an unfriendly spring with precipitation in form of snow, two cases of exposed soil without a snow cover were registered in April: the first recession of snow was on April, 3, and the second – on April, 26. The snow cover reached its maximum height on March, 25, when it amounted to 51cm. In 2009, the first snow and the formation of a stable snow cover occurred on November, 10, the snow melt on April, 12, and for the year 2010 – on November, 22 and April, 16, respectively. In 2010, the ultimate height of the snow cover amounting to 65 cm was registered on March, 22, while in 2011 it reached 83 cm on March, 17. It should be noted that in all the years of the testing, it has been just before snowmelt in the end of March when the thickness of and the stored water in the snow reached their maximums, while the soil was heavily frozen at that moment. This fact indicates an increased risk of erosion of the soils on gentle slopes of the region.

The height of the snow cover in the forest for all years of the experiment was 15-20 cm greater, than at the field drainage basin. This trend manifested itself more distinctly during the winter 2008-2009 with little snowfall.

Water storage in snow was determined not only by the height of the snow cover, but also by the snow`s density. The results we obtained have revealed that the density of snow varies in time as well as space. For both the tested drainage basins, the density of snow changed following the same pattern: it grew with increasing air temperature, time span of soil compression and closeness of the snowmelt period. Minimal density was detected in November (0,13 g/cm^3 in field soils and 0, 11 g/cm^3 in the forest), the maximum – by the end of March (0,34 and 0,32 g/cm^3, respectively). It should be noted that with an increase in the height of snow cover, its density grew while steadily remaining lower in the forest than at the open drainage basin. In a winter with little snowfall, the density of snow was higher than during a snowy winter. After the snow cover has reached its ultimate height by the end of March, following processes began to take place: compression, caking, short-term minor melting and a partial or full soaking with water.

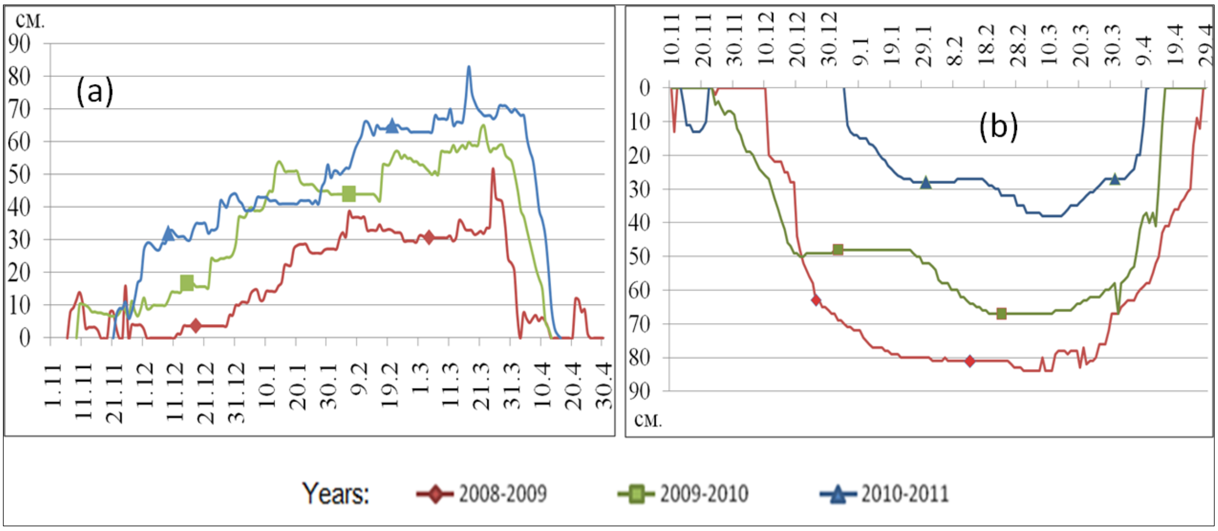

Fig. 2: Dynamic of the snow cover height (a) and dynamic of the depth of frost penetration on the field catchment areas (b)

When studying the changes in the density of snow on a gentle slope, its decrease directed from the drainage divide towards the lowest section of the slope, especially distinct by the end of March, was detected. On higher sections, the snow normally hardened under the influence of wind and thaws, and its thickness decreased. In turn, the density of snow along with the air temperature and the height of the snow cover had a great effect on one of the core agro-climatic indicators - the freezing and thawing of soil. As commonly known, loose snow with little density has a low thermal conductivity, which contributes to the soil protection from freezing. Compacted snow, on the contrary, has a higher thermal conductivity and a lower ability to protect the soil from frost. Consequently, a high snow density on elevated elements of the relief constitutes one of the factors increasing the risk of the development of water erosion during the snowmelt period.

Being a function of the thickness and the density of snow cover, water storage in snow varies according to the regularities verified for those parameters. As illustrated by figure 2a, in 2009 maximum values of water stored in snow on plough land before snowmelt were measured on March, 25 and amounted to 68,2 mm, in the year 2010 – on March, 31 to 104,9 mm, and in 2011 – on March, 25 making out 154,9 mm. In the forest (figure 3b), the maximum water storage in snow for the year 2009 was detected on March, 25 and amounted to 93,8 mm, and in 2010 – on April, 5 to 124,5 mm, while in year 2011– on April, 10 they had a value of 147,6 mm. Hence, for all years of the investigation, the amounts of water stored in snow were higher in the forest than on the open drainage basin, their maximum values were measured in the beginning of the snowmelt period (end of March/beginning of April).

The depth of frost penetration of the soil by year (figure 2b) varied considerably: in the winter 2008-2009, which had little snow, it was at its maximum in the middle of March and amounted to 84 cm at the open drainage basin (field), while in the medially- and snowy winters – to 67 and 38 cm, respectively.

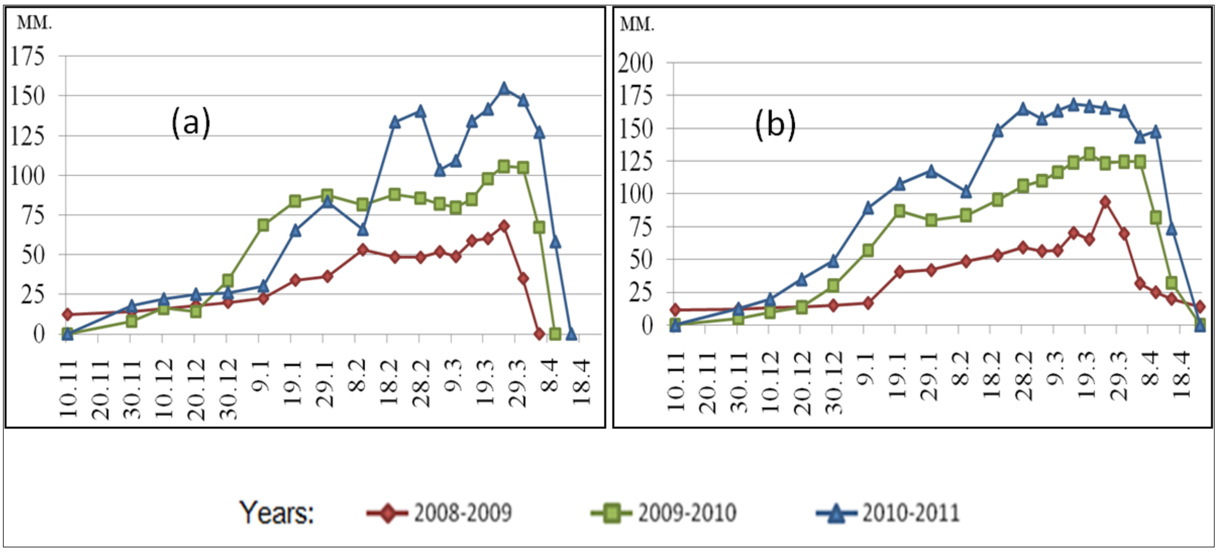

Fig. 3: Water storage in snow on a field (a) and a forest drainage basin (a)

Frost penetration of forest soils was weaker. So, in 2011 the maximum depth of soil penetration amounting to 16,5 cm could be observed from the 4th to the 9th of February. Overall, the frost penetration of forest soils was 2,2 times weaker than that of field soils and the freezing of forest soils began later, while the thaw – earlier.

Our investigations revealed a close correlational dependency of the depth of soil penetration (y, cm) and the height of the snow cover (x, cm) on plough land which is expressed by the following equation: $y=0,01x^2 - 2,64x + 105,33$ (R=98, P=95 %). The influence of other factors (air temperature, soil moisture) turned out to be statistically unreliable, while it was obvious that they do play a certain role in the process.

Soil temperature differed according to the soil protection with vegetation. Those differences were more pronounced in the soil upper layers, while with growing depth, the variations in temperature became irrelevant. The lowest average soil temperature for the entire period of observations was detected in a depth of 5 cm on plough land (when ploughed) (table 2). Soils protected by stubbles or located in the forest had an average temperature above zero, whereby in the upper layer of the forest soil it was lower than that of field soils, and in a depth of 15 cm - higher. The statistical analysis revealed that the verified data of the variations was reliable. Lower temperature of the upper soil layer in the forest was most likely related to the fact that the snow cover had been formed in the forest 5-10 days later than in the field, and its recession had lagged behind with 15-20 days.

Table 2: Soil temperature under diverse agro-ecological conditions, °C (average values during the period from 3.11.2010 to 24.04.2011, n=2301, P=99%)

Depth, cm	Ploughed field	Stubble field	Forest
5	-0,16±0,04	+0,43±0,04	+0,009±0,026
15	+0,57±0,04	+1,02±0,03	+1,18±0,024

An intense water supply from snow begins when the average daily temperature transcends the freezing point and the runoff starts to frame when the average daily temperature exceeds +1°C (+4°C when the soil is strongly frozen) (Litvin L.F. & co., 1997).

In accordance with the meteorological conditions of the three years of research, in 2009 the transcendence of the average daily temperature over 0 °C took place on March, 27, in 2010 – on March, 31, and in 2011 – on April, 3. The runoff at the field drainage basin during the first 2 years began 6 days after the average daily temperature grew to 7,5 °C, and in 2011 – the runoff was formed 3 days after the temperature increased to 4,7 °C.

The continuity of the runoff at the field drainage basin differed from year to year and lasted for, respectively, 16, 12 and 6 days. The longest runoff period, which appeared to be in 2009, was a consequence of a renewed formation of the snow cover coupled with a revertive transition of the average daily temperature over 0 °C, which could be observed after April, 7. The shortest runoff period of the snowy year 2011 was a result of a prolonged spring, a high insolation and a sharp increase in temperature in the middle of April.

In the forest, the runoff started to form almost a week after that at the field, and was of short duration (2-3 days). This is because the major part of the thaw water seeped into the soil already while being under the snow cover as a result of the soil good water permeability (figure 4). In 2010, when the frost penetration of soil was greater, water permeability was not higher than 0,11 mm/min, while in 2011 it amounted to 3,13 mm/min.

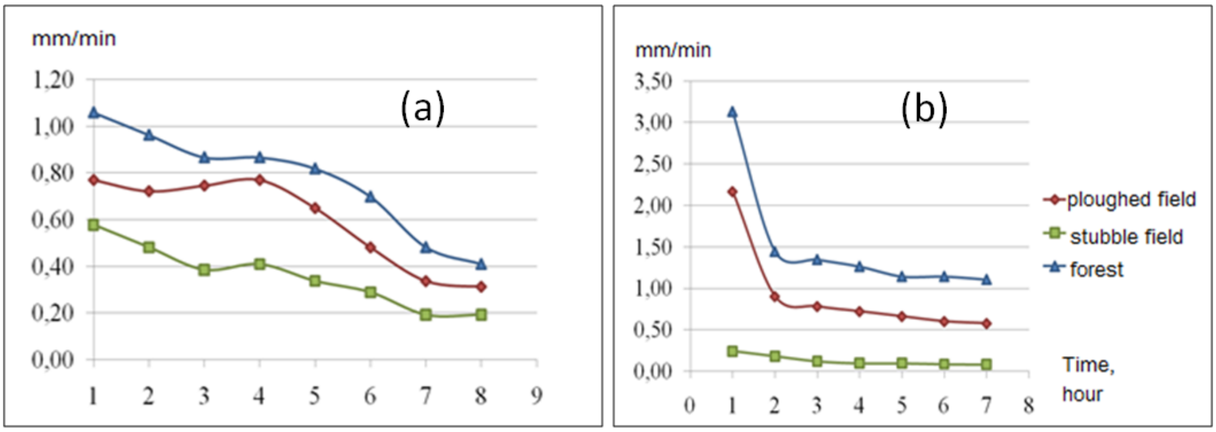

Fig. 4: Water permeability of soil during snowmelt: a) 2010, b) 2011

At the field drainage basin, water permeability of soil was lower than when measured in the forest. Hereby, it was 1,5-2 times lower at the stubble field than at the ploughed field during the medially snowy winter (2009-2010) and 6-9 times lower after the snowy, mild winter (2010-2011).

The volume of the daily runoff at the drainage basins was diverse and inconsistent over time. The most intense runoff was usually observed during the first three days after its start, after which it gradually declined. In certain cases, for example in 2009 at the field drainage basin, it completely stopped during a temperature decrease and restarted only 3 days later. In should be noted that while the volume of the surface runoff doubled in 2010 in relation to that of 2009, the mass of the transported sediment remained almost identical. That means that the amount of rinsed material mainly depends on the intensity of the runoff and not upon its volume.

The first and most intense sediment runoff was detected in spring 2009 (table 3). This was caused by a combination of a snow cover with a relatively small thickness, a high level of soil freezing (up to 81 cm) and a sharp increase in the average daily air temperature (up to + 10°C) during the first days of April. Under such conditions, the volume of sediment runoff on a ploughed field amounted to 110 kg/ha, while the presence of stubbles on the field contributed to its decrease by almost 4 times, in the forest – by 22 times. In the next year, the runoff was twice as high as in the previous year which was a result of considerably higher amounts of storage water in snow before snowmelt (37 mm more), while the volume of sediment runoff was slightly lower for all the three parcels. This was related to a reduced background temperature during the period of snowmelt and this period`s longer durability under conditions of a little depth of frost penetration.

By the third year of the investigation, notwithstanding the very high amounts of water stored in snow, liquid as well as sediment runoff were practically absent. This phenomenon was affected by a number of factors: very low autumn moisture stored in soil, little depth of frost penetration (38 cm) caused by a thick snow cover (83 cm), a gradual snow thawing under conditions of moderate temperatures, as well as a high water permeability of the soil during the period of snowmelt.

Sediment runoff leaches out humus and nutrients, whereby the respective amounts depend on the runoff's intensity and the presence of vegetation, and differ according to the type of soil in the drainage basin. In 2010 the total runoff was more uniform than in 2009, and the total mass of the transported fine grained soil contained slightly more humus, nitrogen and phosphorus. In the sediment runoff of the plough land protected by stubbles, the loss was substantially lower, which is mainly because of lower contents of the silt fraction in the composition of soil (table 4). It should further be noted that the daily variations of the runoff also affect the amounts of rinsed humus and nutrients (results from 12th and 13th of April, 2011) depending on the runoff´s intensity.

Table 3: Factors and indicators of a water erosion during snowmelt

Indicator	Year	Catchment 1 (Tillaged land - Ploughed field)	Catchment 2 (Tillaged land - stubble field)	Catchment 3 (Forest)
Autumn soil moisture (0-50 см), mm	2008	143.4	144.7	156.3
	2009	148.8	149.7	158.2
	2010	122.4	123.5	132.4
Maximum water equivalent of snow cover before snow melt, mm	2009	68	70	94
	2010	105	106	125
	2011	155	157	168
Maximum frost penetration, cm	2009	81	81	37
	2010	67	67	31
	2011	38	38	16.5
Depth of runoff, мм	2009	19	39	31
	2010	41	47	46
	2011	0	3	0
Sediment runoff, kg/ha	2009	110	28	5
	2010	104	25	4
	2011	0	0,89	0
Coefficient of runoff	2009	0.28	0.37	0.25
	2010	0.39	0.45	0.37
	2011	0	0.02	0

The analysis of the rinsing dynamic of fine grained soil revealed that the major mass of fertile soil is being transported away during the final days of the snowmelt, when the increase in air temperature creates thawed patches and thaws the upper soil layer. So, the unprotected plough land lost 3,9; 66,5; 25,1 kg/ha of soil on the 9th, 10th, and 11th of April 2010, respectively, containing 6,5; 7,4; 8,7 % humus.

Table 4: Particle size composition of solid matter flow

Place of sample captur	Specific density, g/cm^3	Hygrosc. moisture, %	Particle size composition, mm/ %						Sum of the particle	
			1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	>0,01	<0,01
Ploughed field 2010	2,42	5,19	0,76	3,50	31,92	13,85	28,20	21,77	36,18	63,82
Stubble field 12.04.2011	2,48	4,45	2,08	15,77	27,94	16,68	18,43	19,10	45,79	54,21
Stubble field 13.04.2011	2,45	4,60	0,65	8,18	34,13	10,83	26,31	19,90	42,96	57,04

After the end of the snowmelt, the available water capacity in the soils of the different sections of the drainage basins (table 5), as well as the resistance to penetration

characterizing the soil density, were measured.

After the snowmelt, the available water in the soil of the lower section and the center of the slope on field drainage basins was 1,5-2,0 times higher than at the drainage divide. This was, most likely, due to the fact that the drainage divide freed itself from snow faster and thaw water flew to the lower sections of the slope while still being inside of the soil layer. One should also account for the fact that the amounts of stored water in snow on a drainage divide are always smaller than those on the slope. In the forest, the differences in the available water in the soil depending on the relief are insignificant.

Table 5: Available water capacity in the soil (0-50 cm) after the snowmelt at drainage basins, mm (n=9)

Slope section	Ploughed field	Stubble field	Forest
Drainage divide	132±2,8	125±1,6	210±3,2
Center of slope	206±2,6	204±2,8	213±4,0
Lower section	213±0,8	198±1,5	215±0,3

Spring moisture stored in soil is one of the key parameters of agricultural production. It mainly consists of thaw water, therefore, it is necessary to minimize the surface runoff to the greatest possible extent, preferably by means of an increase of the soil water permeability though the use of special agro-technical methods.

Resistance to penetration is the extent to which the soil can be infiltrated by agro-technical devices and plant roots. This indicator strongly differs according to the land type and increases in the following sequence: plough land (when ploughed) – forest – plough land (stubble field). It should be noted that a weak resistance of the soil on plough land, while stimulating a favorable development of the root system of plants, makes the soil to be more inclined to densification as a result of the use of agricultural machinery. This should be accounted for when seeding or completing other agro-technical tasks.

Conclusion

During the snowmelt the fine grained soil content in the runoff primarily depends on the extent of frost cementation of the soil and on air temperature, as well as on the existence and character of vegetation, while the water storage in snow and the total runoff are not of a substantial importance in that process. In the presence of spring runoff in ploughed drainage basins with gentle slopes, one cubic meter thaw water rinses up to 0,6 kg fine grained soil.

Hereby, each hectare loses around 100 kg of fertile soil, which is being rinsed of up to 12 kg humus.

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The impacts of the different strategies of soil tillage on the soil moisture dynamic with regard to the specific climatic conditions and climate change (at the "Artemida" test side)

Liebelt, P. & Frühauf, M.

Introduction

Soil water is of fundamental importance to the development of vegetation in areas of limited water supply, such as the forest-steppe zone of Bashkortostan. Consequently, it also constitutes a core factor in agriculture of the research area *(Gao et al. 2011)*.

Soil water balance is mainly determined by the climatic and pedological conditions, as well as anthropogenic influences, such as agrarian land use *(Wohlrab 1992, Gao et al. 2011)*.

Out of the modified hydrological base equation: N = Au + Ao + V *(Hölting 1996)* follows that climate influences water supply to the soil through precipitation, which is the only input factor into the soil water balance, as well as through the loss of soil water caused by evapotranspiration. The interactions of soil and climate are, therefore, of a great importance to the soil water dynamic. Especially in continental regions, climate plays an important role constituting a control quantity for the soil water balance, vegetation period and crop *(Alcamo et al. 2007)*.

The analyses carried out in the framework of the work package: „Characterization of climate, with a special focus on climate change" by means of data provided by the institution „Baschgidromet" allow for high-resolution statements on the climate conditions of the research area and indicate changes leading to the establishment of new natural framework conditions of the soil water balance, on the consequences for soil water dynamic as well as – resulting thereout – the crop yield *(Own analyses, data: Bashgidromet 2011)*. Throughout the research, precipitation dynamic is deemed to play a special role, because it is regarded as the core natural risk factor determining the crop yield in the research area (Chanyshev 2008), which gains even more importance in the face of increasing drought periods in the southern parts of the forest-steppe zone (*Own analyses, data: Bashgidromet 2011*).

Apart from climate conditions, soil properties also play a big role in the soil water balance. They determine, among others, the size of the portion of precipitation water which infiltrates the soil (infiltration rate) and which can be accumulated (field capacity) *(Khaziev 2007, Max-Eyth-Association Agrarian Technology at VDI 2007, Wohlrab 1992)*. The agrarian land use determines to a great deal those soil properties important for the soil water content *(Haghigi et al. 2010, Wohlrab 1992, Zimmerling 2003)* and is considered to be one of the core control quantities determining the soil water dynamic *(Qiu et al. 2001, Pan and Wang 2010)*.

In the light of the post-soviet agrarian land use change - which can be observed in the forest-steppe zone and which has stipulated, apart from large-scale abandonment of agricultural land or its conversion into other more extensive land use types (hay meadows and pastures), a diversification of the soil cultivation quality and intensity - an understanding of the interactions between the soil water dynamic and land use is of great importance for the optimization of the agrarian land use in the research area.

With regard to the diversification of the applied tillage methods it can be observed that the conservation soil cultivation gains on importance in the research area *(Liebelt 2010 [unpublished])*.
The results of long-term field tests carried out by the Bashkir State University, as well as measurements recorded in the framework of the project, indicate that the establishment of this trend in soil cultivation lead to changes in the quality (agrochemical and physical soil properties) of agriculturally used soils in the Republic of Bashkortostan and, by this, also constitutes a factor relevant for the soil water dynamic *(Khaziev 2007)*. Usage-induced changes in the content of organic soil substance, as well as transformations of the soil structure, should be pointed out *(Gabbasova 2004, Khaziev 2007, own research)* due to these soil properties` great influence on processes relevant for the soil water, such as infiltration and field capacity *(Wohlrab 1992, Zimmerling 2004).*

The various factors of influence and their changes (climate change, land use change, change in soil quality) lead to a high degree of spatial and temporal variability of the soil water content in the upper soil layer (*Famiglietti 1998)* which is, despite the existing long-term studies conducted by regional scientific institutions, such as the Bashkir Agrarian University Ufa, barely known.

Field tests on the farming level, which were carried out in the framework of the project in cooperation with the agrarian enterprise "Artemida", were intended to generate high temporal resolution data on the dynamic of the soil water content depending on soil cultivation quality and intensity and, by doing so, to contribute to the understanding of the interactions between the different forms of post-soviet agrarian land use change in the context of climate change.

Methods

Choosing location

The selected test enterprise „Artemida" is located in the agriculturally intensively used eastern part of the forest-steppe zone (fig. 1) *(Atlas Bashkortostan 2005, Rosreestreet 2012)*. Due to its climatic and pedological properties, the region is one of the agriculturally favourable areas of Bashkortostan. The average precipitation ranges between 450-500mm (see fig. 1) and leads to balanced up to slightly negative moisture conditions – interpreted using the aridity index „Hydrothermal coefficient“ developed by Seljaninov, which lies between 1,0 and 1,15 *(YAPAROV 2005)*.

Under these climate conditions, chernozem soils mainly dominate. At the research location Artemida, Leached Chernozem/ rus. Vyshelochennye Chernozemy/ by FAO: Luvic Chernozem, is widespread. The typical profile sequence of *Leached Chernozems* in the research area is: *A1-A1B-Bt-Bca-Cca.*

Active bioturbation in the soil makes possible the development of an approximately 50-60cm deep dark-grey up to black dyed *A1-Horizon*, which, due to its high humus content of 6-9% and a stable soil structure (crumby and subpolyhedronic structure), is especially from the agricultural point of view highly valuable.

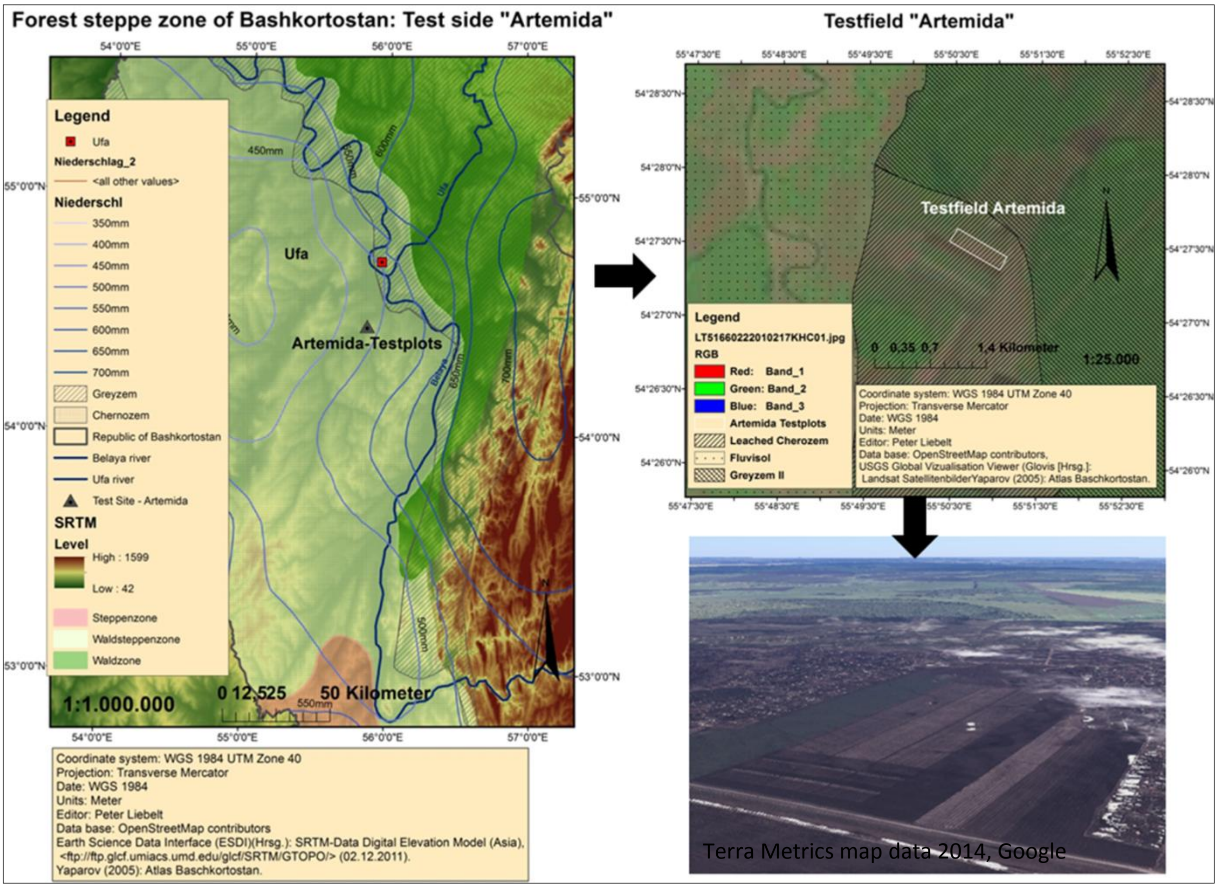


Fig. 1: Geographic location of research area *(Liebelt 2014)*

<u>Setup of the research location</u>

At the research location „Artemida“, field tests consisting of 4 plots with diverse tillage intensities were carried out (see fig. 3). Each test parcel (test plot) had a width of 30m and a

length of 700m. The surface area of one plot amounted to, correspondingly, around 0,03km² or 3 ha. The tillage intensity was gradually increased from plot A1 up to plot A4.
The crop culture used since the beginning of research in 2010 has been spring grain.

Test plot A1 is managed by the direct seeding method (No-Till method). Due to operational reasons, though, plot A1 was cultivated with the same method as plot A2 - that means with near-surface primary cultivation - until the beginning of year 2012.

On plot A2, primary soil cultivation by means of a compact disc harrow (for ex. „Catros“), which loosens the soil up to a soil depth of around 6-8cm, is applied.

On plot A3, soil cultivation is carried out by means of a tillage aggregate, which consists of a combination of a disc harrow and a cultivator (for ex. „Cenius”). Its working depth is around 14-16cm. The primary soil cultivation at plot 3 can be located between plot 2 and plot 4 according to its intensity.

The most intensive primary soil cultivation is carried out on plot A4. The plough aggregate cultivates the soil up to a depth of 28-30cm. Contrary to the other cultivated plots, the soil on plot A4 is turned around to get loosened.

Test plot A5 was setup as a reference plot to simulate natural conditions. The soil on that plot has not been tilled for more than 10 years, so, due to natural succession, by this time it is covered by a rampant herb and shrub layer.

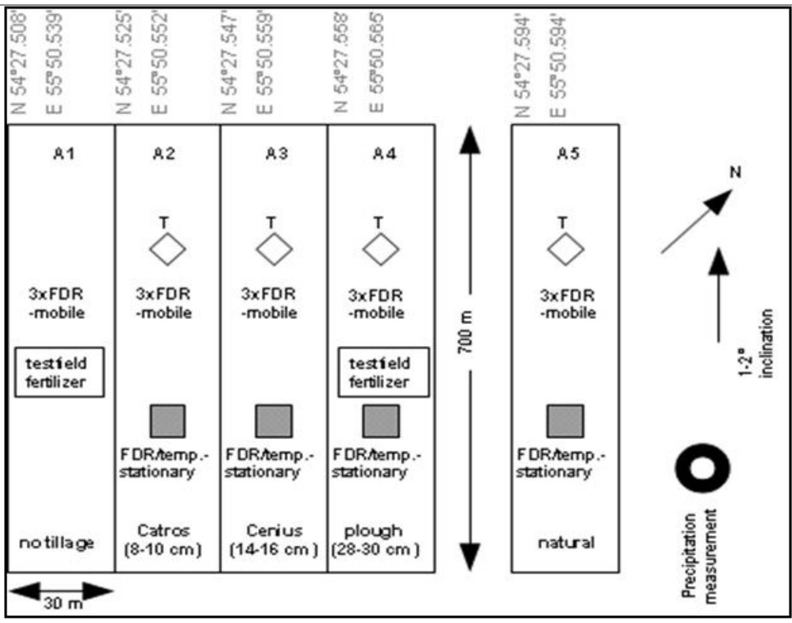
On the test plots, regular measurements of the physical and chemical soil parameters were carried out.

Soil water content and soil temperature were measured on the test plots with a high temporal resolution by means of stationery FDR-probes and soil thermometers. In order to measure precipitation, a Hellmann rain gauge was installed (fig. 2).

The FDR-measuring probes were installed in the depths of 20cm, 40cm, 60cm, 80cm and 100cm. Additionally, mobile FDR-measuring probes were applied to measure the profile cut with a depth of 0-50cm. These measurements were carried out on test plots A2-A5 with an interval of 10 days with a two-fold repetition. The applied stationary hydra-probes measure, apart from the relative volumetric soil water content, also the soil temperature. In addition, stationary soil thermometers were installed on test plots A2-A5 in a depth of 5 and 15 cm.

Fig. 2: Soil moisture measurement *(Liebelt 2011)*

Research design



Plot	A1	A2	A3	A4
Method of soil tillage	No-tillage	Minimum	Minimum	Conventional
Depth of soil tillage	-	4-6cm	14-16cm	28-30cm
Operation	-	Disking	Cultivating and Disking	Ploughing

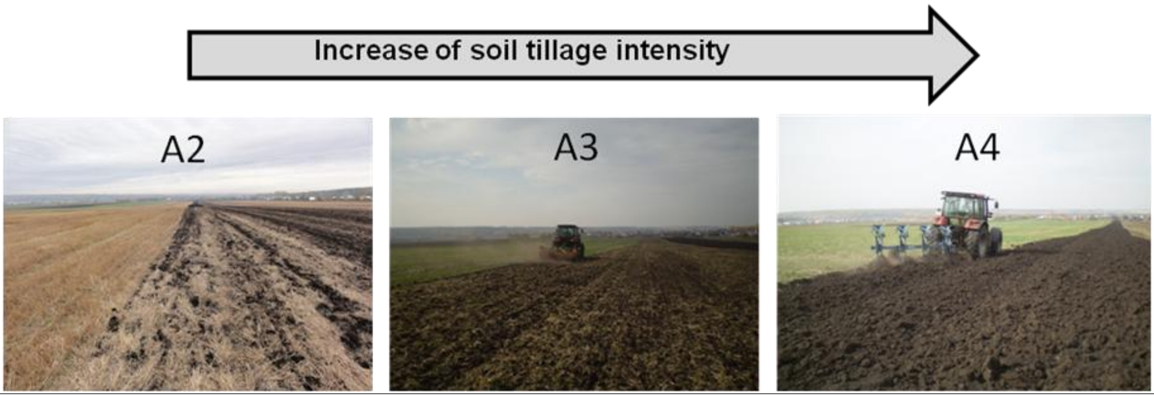


Fig. 3: Research complex *„Artemida“ (Liebelt 2014)*

Results

The analysis based on descriptive statistics of the measurements of the soil water content carried out by means of the FDR-probe (measurement interval: October 2010 – October 2012, number of measurements per test plot: 84) shows that the samples` value distribution varies according to test plot. It should be pointed out that the method of descriptive statistics does not allow to draw conclusions on the total unit.

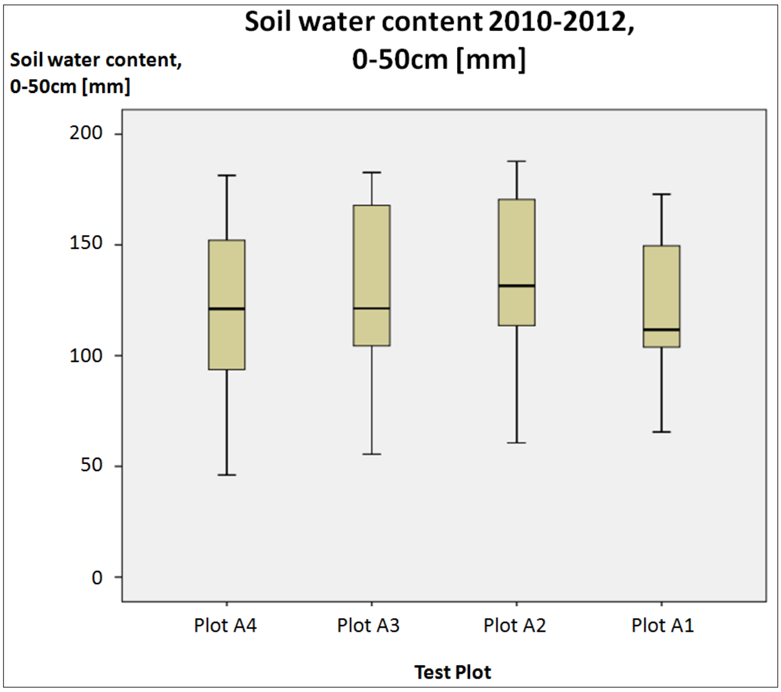


Fig.4: Value distribution of the soil water content at the different test plots, depth: 0-50cm, 2010-2012 (*Liebelt 2014)*

Relevant statistical measurements of the central tendencies of frequency distribution of the studied variable reflecting the soil water content were compared. The focus of the data analysis has been on the lower part of the value distribution, because, due to spatial proximity of the research area to the agronomic drought determined limit, water shortage is an important factor of limitation for agricultural production in the research area.

The upper Boxplot-diagram illustrates the distribution of the measurements of the absolute soil water content in the A-Horizon in a depth of 0- 50cm.

It becomes clear that all relevant central tendencies of the frequency distribution of the values of the absolute soil water content show a rising gradient from plot A4 over plot A3 to plot A2, thus, with a decreasing intensity of tillage. The median value, for example, rises from 121,2mm on plot A4 (conventional tillage) to 131,6mm on plot A2 (minimum tillage), which is equivalent to an increase of 10,4mm/ 8,6%. The 25%-percentile as well as the lower limit of the range of values also increases with decreasing tillage intensity. The 25%-percentile on plot A2 amounts to 113,3mm and, with this, constitutes good 19,6mm / 20,9% higher values than on plot A4.

This gradient can also be found in the studied near-surface layers: - 0-10cm, 10-20cm and 20-30cm – of the A – horizon and is most clearly pronounced in a soil depth of 10-20cm (see fig. 5).

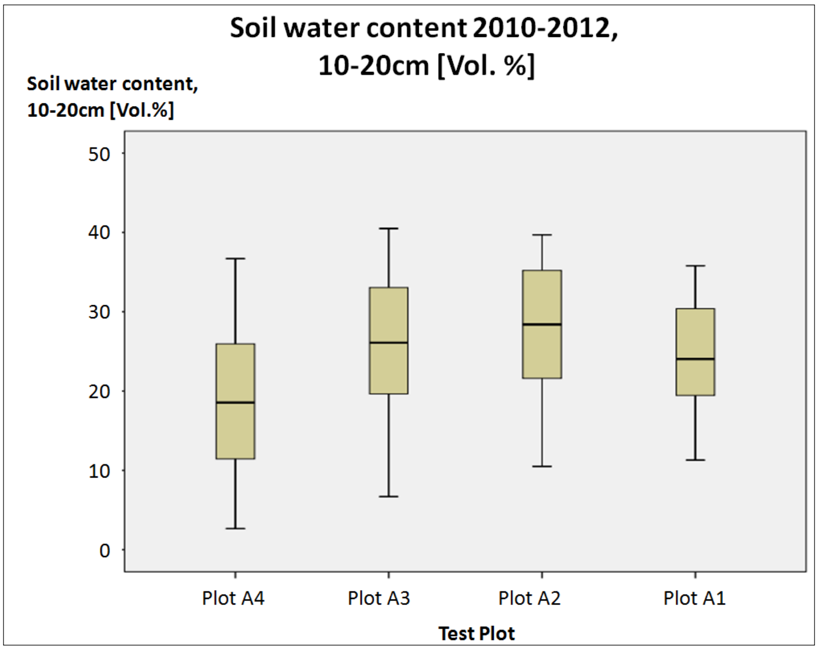


Fig. 5: Value distribution, range: 10-20cm, 2010-2012 *(Liebelt 2014)*

The median value increases in this depth from 18,6 Vol. % (plot A4) by 9,8 Vol. % to 28,4 Vol. % (plot A2). Even more striking is the increase of the 25% percentile. Under conventional tillage (plot A4), the 25% percentile of the measurements amounts to 11,4 Vol. %, and under minimum tillage (plot A2) - distinctively higher to 21,5 Vol. %. This means that 75% of the measured values on plot A4 are located above the measurement value of 11,4 Vol. %, and on plot A2 – above the measurement value of 21,5 Vol.%.

The trimmed arithmetic men value rises from 19,1 Vol. % under conventional tillage (plot A4) by 8,7 Vol. % to 27,8 Vol. % when near-surface tillage with the Catros harrow has been applied (plot A2).

The next two diagrams reflect the change in the central tendencies in dependence on the soil depth (fig. 6/ 7). The gradient of the central parameters ranging from 10 to 20 cm becomes clearly visible on the median and the 25% percentile.

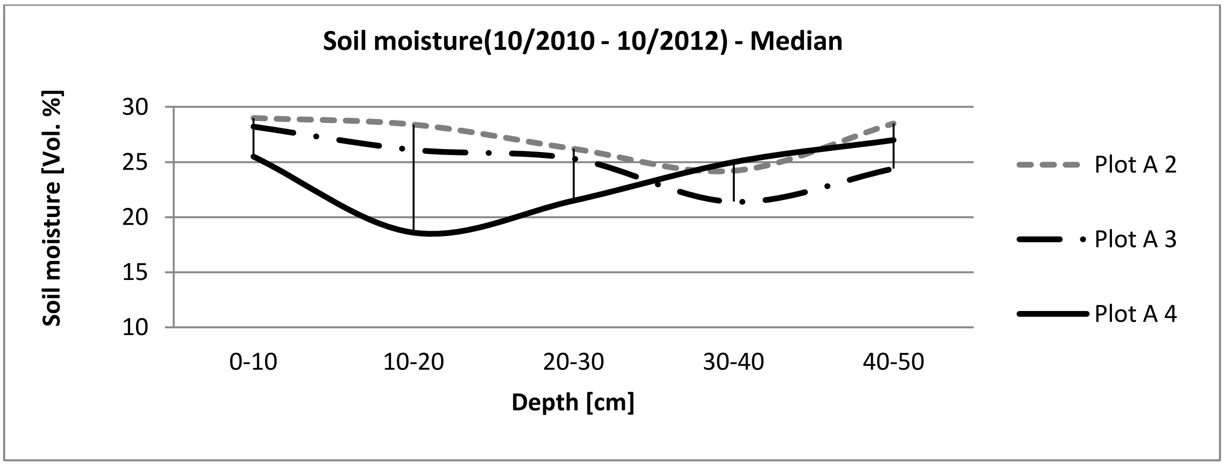


Fig. 6: Depth dynamic of the medians of the soil water content *(Liebelt 2014)*

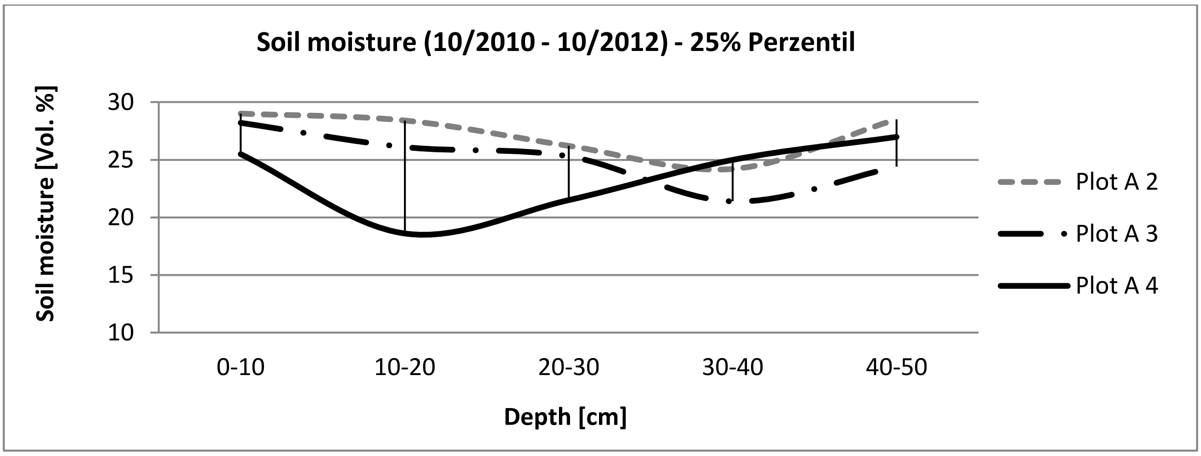


Fig. 7: Depth dynamic of the medians of the soil water content *(Liebelt 2014)*

When comparing the soil water content throughout the growing seasons 2011 and 2012, it becomes apparent that the soil moisture gradient, which has been present in the upper 30cm of the soil throughout the entire period 2010-2012, has also been very apparent during the growing season 2012. During the growing season 2011, the decrease of different central parameters with decreasing tillage intensity was less striking up to not given as far as the lower limit of the rage was concerned.

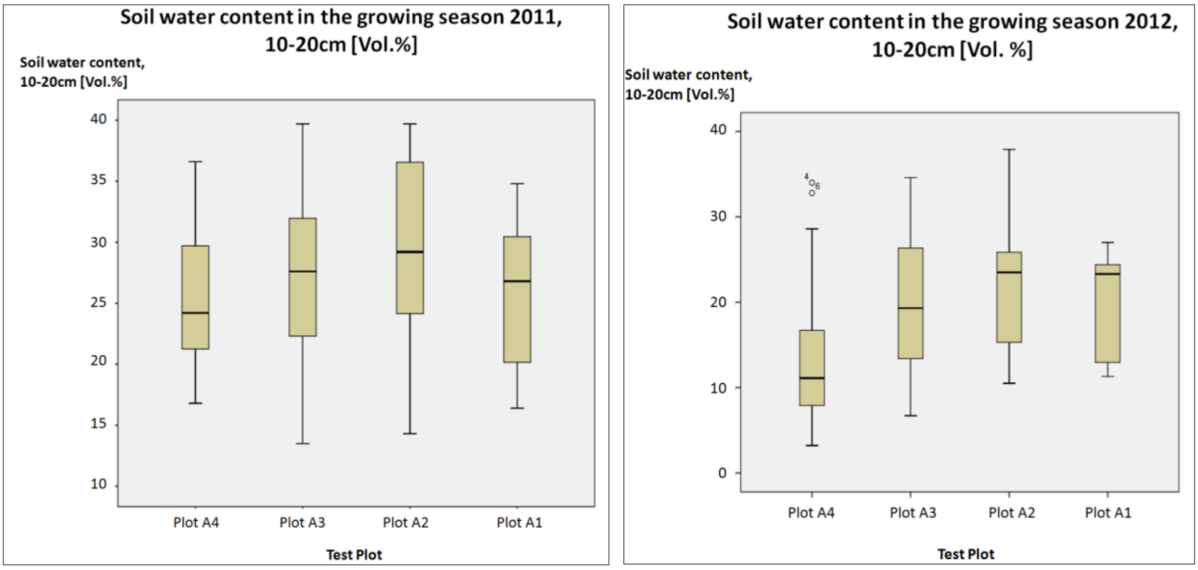


Fig. 8: Soil water content (10-20cm soil depth), growing season 2011(on the left) und growing season 2012 (on the right) *(Liebelt 2014)*

The different value distributions of the soil water content are also reflected in the temporal dynamic of the soil water content. The next diagram reflects the course of the relative volumetric soil water content on test plots: reference plot (green), Cenius-plot (blue) and plough (grey) for the growing season 2012 (fig 9).

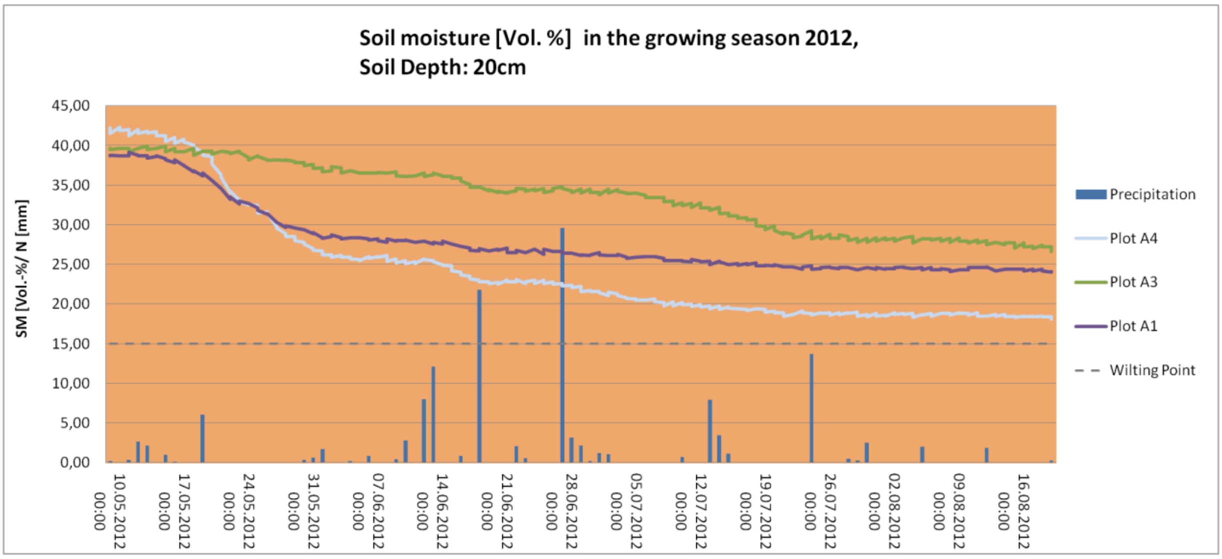


Fig. 9: Soil water dynamic during the growing season 2012 (Liebelt 2014)

At the beginning of the growing season, up to around the middle of May, the soils of the test plots in a depth of 20cm show a similarly high soil water content of around 40 Vol. %, which lies slightly above the maximum field capacity (37 - 39 Vol. %) of the soils. The high amount of soil water has been caused by the ending of the snowmelt period in April, which allowed great amounts of water to infiltrate the soil. The equivalent of the snow cover in water before the beginning of snowmelt amounted to approximately 90mm.

During the course of May, a drying of the soil occurred as a result of relatively dry weather conditions and increasing air temperatures. From then on, diverse courses of the development of soil moisture began. While the soil water content on the preservatively cultivated plot A3 decreased only moderately, it drastically fell on the conventionally tilled plot A4. On June, 6th, the soil water content on plot A3 was already 11 Vol. % higher than on plot A4. This difference between the plots remained until the end of the growing season. By September, the soil water content on plot A4 was only slightly above the permanent wilting point, which constitutes around 14 Vol., while the soil moisture content on plot A3 at that time was clearly above this value amounting to 27,8 Vol. %. In order to identify the reasons for these clear differences it is necessary to examine the factors influencing the soil water content in more detail.

<u>Climatic factors of influence</u>

One of the reasons for the unequal value distribution of the soil water content, as well as differences in its temporal dynamic between the growing seasons (April-September) 2011 and 2012, is provided by differences in the climate conditions during the research.

These differences are reflected in the verified balance between the measured sums of precipitation and the height of potential evaporation (both values were summarized in decades). It can be concluded from the balance that due to climate conditions the water input into the total soil water content in 2011 was higher than in 2012.

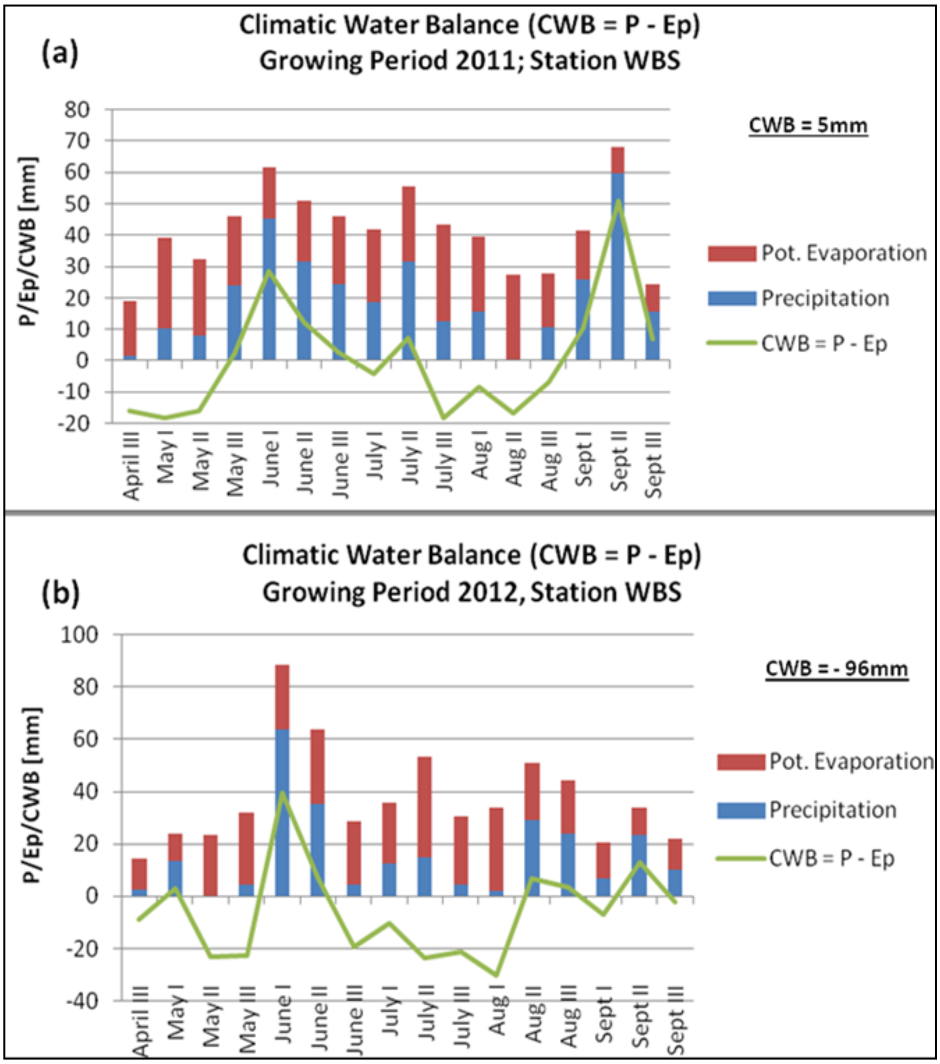


Fig. 10a/ 10b: Climatic Water Balance *(Liebelt 2014)*

In spring as well as during the entire growing season of 2011, the water input into the total soil water content through melt-water and precipitation was considerably higher than in 2012. The year 2012 was an unusually dry year. Apart from a considerably smaller snow cover in spring (water equivalent 2012: 90mm; vs. water equivalent 2011: 155mm), distinctively less precipitation fell during the growing season (N during growing season 2012: 265mm; vs. N during growing season 2011: 315mm). Precipitation occurred mostly in form of short heavy rain and did not lead to a discernable reaction or – increase – in soil water content in soil layers below 20 cm. This can be explained by interception and evaporation losses as well as surface runoff on slightly sloped test areas.

The impact of evaporation losses, especially under dry climate conditions, on the total soil water content can be concluded from a negative correlation between soil temperature and

the soil water content during the growing season 2012, as soil temperature has a strong influence on evaporation *(Schlichting et al. 1995)*. As follows from the correlational table, with increasing soil temperature soil moisture decreases (table 1).
The correlation is stronger on the conventionally tilled plot (A4) than on the conservationally plot A3. This can be interpreted as a stronger sensibility of the soil moisture towards soil temperature and, by this, towards evaporation, on the ploughed field than on the conservationally tilled test plot A3.

Table 1: Correlation between soil moisture and soil temperature (Plot A4 und Plot A3) following Pearson *(Liebelt 2014)*

Soil Moisture	**Soil temp. Plot A4 (20cm)**	**Soil temp. Plot A4 (40cm)**	**Soil temp. Plot A4 (60cm)**
SM Plot A4 (20cm)	-0,79	-0,94	-0,97
SM Plot A4 (40cm)	-0,66	-0,84	-0,91
SM Plot A3 (20cm)	-0,56	-0,74	-0,84
SM Plot A3 (40cm)	-0,46	-0,65	-0,75

The comparison between the climatic conditions and the soil water dynamic as well as the value distribution of the soil water content leads to the conclusion that dry climatic phases and periods of drought intensify the positive effects conservation soil cultivation has on the total soil water content.

This finding is of great relevance for the research area of the forest-steppe zone, because the forest-steppe zone, being the transitional zone between the forest zone in the north and the steppe zone in the south, is regularly hit by drought. In the context of global climate change, the Bashkir forest-steppe zone in also subjected to climate change. The analyses of climate data by the institute „Bashgidromet" carried out by the working group BSU indicate different climate trends, such as an increase of the average air temperature and a decrease in the sum of precipitation, which take place during the growing season in southern near-steppe regions of the forest-steppe. This gives rise to increasing aridity, which could – according to our project results – best be countered by conservation tillage, due to its more favourable soil water dynamic.

Pedological factors of influence resulting out of tillage

Apart from climate, tillage, as well as the resulting changes of the soil properties, constitutes a control quantity influencing the soil water content. Physical and chemical soil properties, as well as the thereout resulting factors relevant for the soil water content such as the rate of infiltration and evaporation, have been examined.

Of a special relevance for infiltration are the physical parameters of soil: type of soil and soil structure, because these factors determine the development of the soil pore system, which is responsible for water transport (*Gieska 2003, Max-Eyth-Association Agrarian Technology at VDI 2007, Scheffer & Schachtschabel 2002, Zimmerling 2004)*. Depending on the size of the pores, different forces act influencing the transport of soil water and, hence, infiltration. Through coarse pores, for example, water can infiltrate the soil very quickly. The core function of fine and median pores, on the contrary, is it to rise and accumulate water in soil (Zimmerling 2004).

While the granulometric properties of the soil barely differ among the test plots, differences with regard to the soil structure become visible (fig. 11).

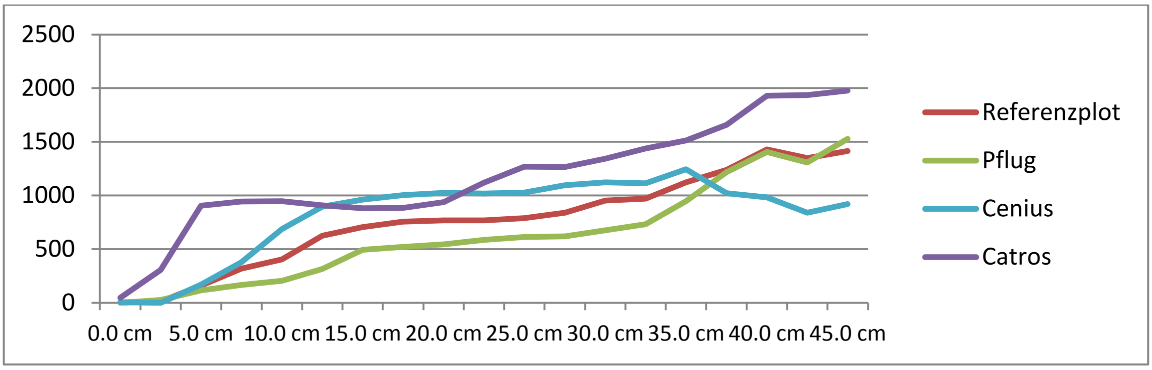


Fig. 11 Penetrometer measurement (Growing season 2012) *(Liebelt 2014)*

Penetrometer measurements in year 2012 indicate that the bulk density in the upper 30 cm soil layer under classic tillage (plot A4) is lower than when preserving tillage is applied (plot A3/A2). This accounts for the fact that under intensive mechanical soil loosening pores and hollow spaces between the aggregates are created, which can result in an increase of infiltration. According to *Ehlers* (1996), the increase of the infiltration coefficient is determined by a number of factors. On the one hand, increased surface roughness, which can be achieved through soil loosening, leads to an increase in infiltration. On the other hand, a great number of coarse probes between the aggregates have the same effect.

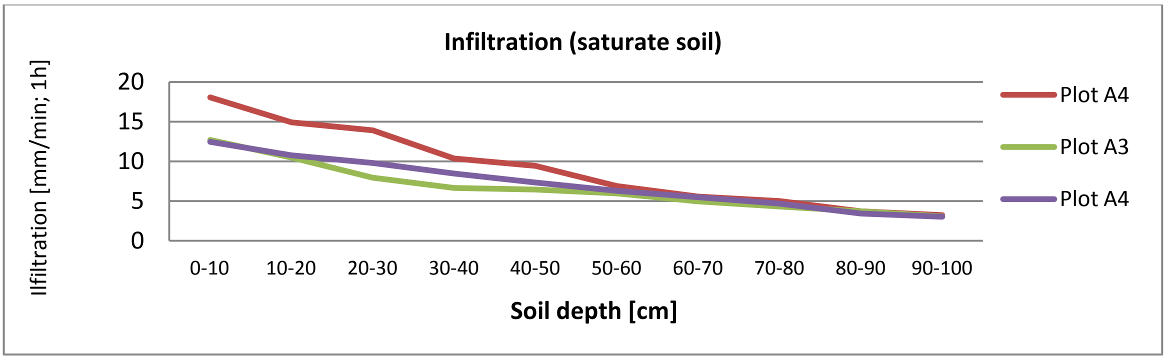


Fig. 12: Infiltration (saturated soil) *(Liebelt 2014)*

Analyses of infiltration show that the water in the upper layer on the plough variant has the highest rate of infiltration (fig. 12). Thus, it can be concluded that ploughing has had a positive effect on infiltration of the upper soil layer. Nevertheless, conventionally tilled soil is exposed to a higher risk of disaggregation, which entails a decrease in infiltration (*Ehlers 1996,Gieska 2003, Tebrügge 2003*). Experiments on the aggregate stability on the test plots have revealed that when ploughing has been applied, aggregate stability has been the lowest in comparison to the rest of the plots. Nonetheless, aggregate stability on the plough variant was still on a high level.

Infiltration is especially important in spring during the snowmelt, because it determines the amounts of melt water which can be absorbed by the soil and which portion runs off the surface and, by this, can evoke erosion. How strong the impact of the infiltration rate on the soil water content is became visible during the snow melt period 2011 (fig. 13). In spring 2011, the soil water content increased more rapidly and at a higher rate on the conventionally tilled plot A4 as a result of a higher rate of infiltration, than it did on the Cenius-plot A3.

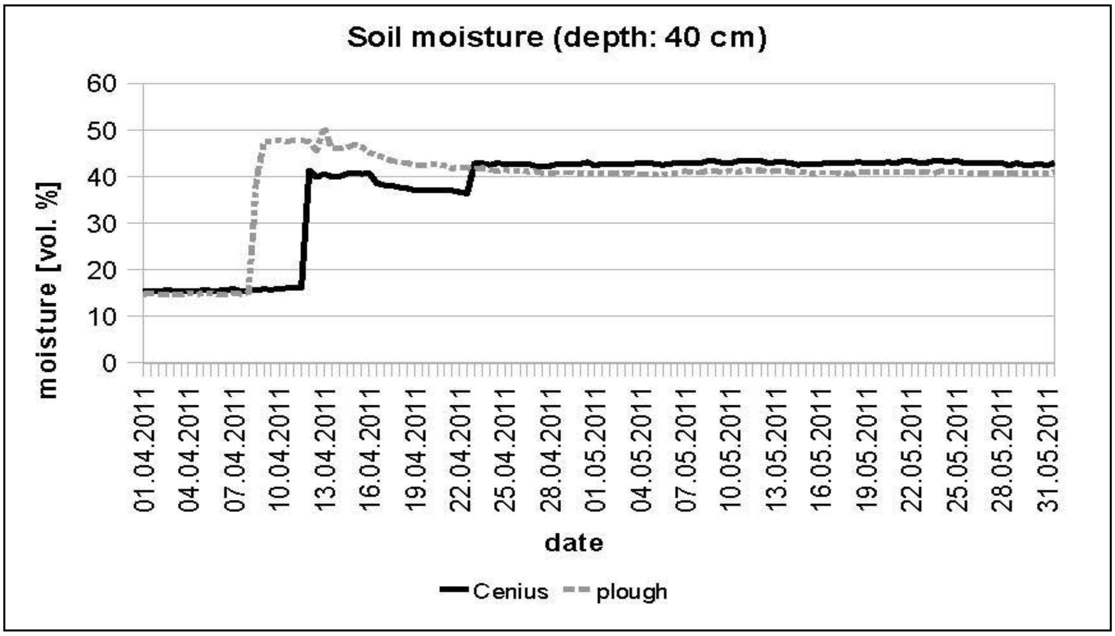


Fig. 13: Soil moisture content (in percent by volume) at different test plots, depth: 40cm *(Liebelt 2014)*

A further factor of influence on the soil water content, which results out of tillage, is the diverging evaporation.

As already illustrated in the paragraph on climatic factors of influence, research during the growing season 2012 indicated a clear negative correlation between soil temperature and the soil water content.

A comparison between the soil temperature on the test plots A4 and A2 after sowing summer grain shows that the topsoil managed by ploughs is warmed up heavier than the topsoil with plant residue managed by minimum soil cultivation (test plot A4) (fig. 14).

In their research, Köller & Linke (2001) confirm this observation. The warming of the soil surface with plant residue, like that on test plot A2, is lower; therefore, a smaller evaporation is to be expected. Besides, the straw layer works as a steam barrier. Consequently, more water gets lost on fields with a conventional soil tillage using the plough in comparison to fields with a cover of mulch, because of higher evaporation *(Köller & Linke 2001, Ehlers 1996)*.

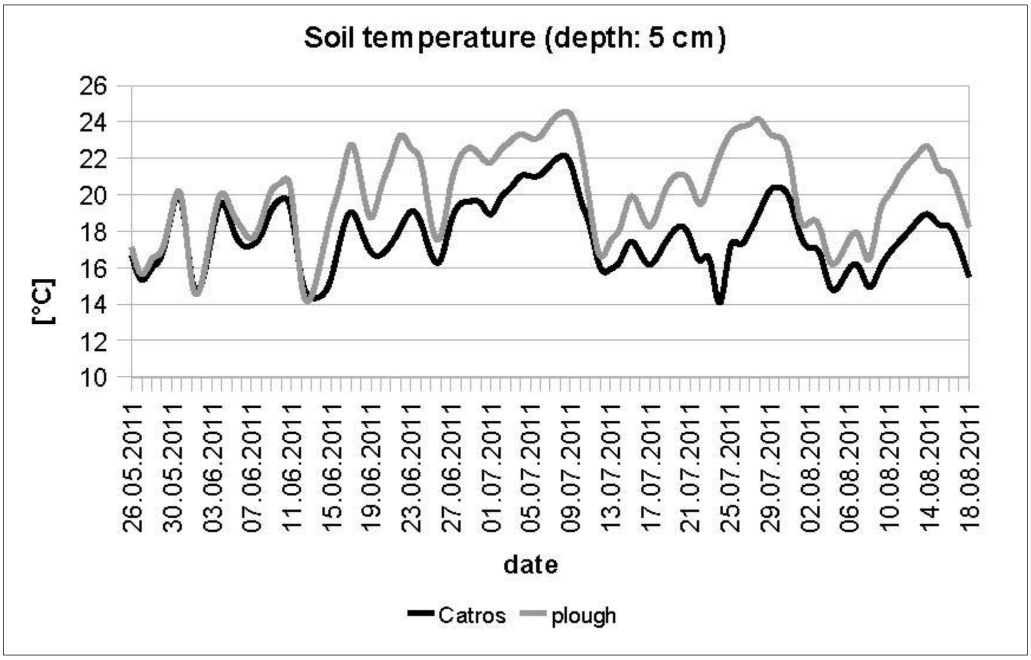


Figure 14: Soil temperature (soil depth: 5cm) *(Liebelt 2014)*

The investigation has revealed that the soil water dynamic can be differentiated according to the method of tillage and climatic conditions which brings along consequences for agricultural production.

In year 2011, there has been a sufficient water input due to weather conditions (climate conditions), so that the positive effect of minimal tillage has not become visible to its full extent. Under these conditions, the highest yield has been achieved on the conventionally tilled plot A4, which can be explained by a number of factors of ploughing, such as the high rate of mineralization, low bulk density as well as a favourable seed-bed ensilage (Khaziev 2007).

Under the very dry climate of year 2012, an opposing image of the yield situation arises (table 2). The low climatic water input and the ability of the preservatively tilled plots (A3 and A2) to better accumulate water have led to the outcome of a higher yield on conservationally tilled plots than on the conventionally tilled plot.

Table 2: Yield 2011-2012 *(Liebelt 2014)*

Soil cultivation	**Spring wheat (2011)**	**Spring barley (2012)**
	Yield dt/ha	Yield dt/ha
Plough (Plot A4)	40,7	13,2
Cenius (Plot A3)	33,3	17,8
Catros (Plot A2)	28,3	21,8

Summary

Research results shows that both the increasing differentiation of the tillage intensity and quality taking place in the framework of the post-soviet agrarian land use change and the climatic conditions, especially the ongoing climate change, affect the total soil water content and the soil water dynamic in the research area. This corresponds to the results of other research projects in this problem area (for instance GAO et al. 2011)

The high temporally resolution measurements of the soil water content allow to conclude that a minimization of tillage in light of the increasing aridity of the climate (Data by BASHGIDROMET 2011) in the southern regions of the forest-steppe zone can lead to an increase in the soil water content and, thus, to a stabilization of crop yield. Therefore, conservation tillage in the near-steppe forest-steppe regions constitutes a suitable measure to adapt the agriculture to the ongoing climate change.

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The change of the chemical and physical soil properties depending on the different intensities of tillage (at the "Artemida" test side)

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Introduction

The soil cover of the Southern forest-steppe zone consists mainly of chernozem (around 70% of the crop area), which natural fertility is very high. Soil erosion in this region is triggered by intense agricultural use (up to 74% of the area, while being sparsely populated 16-30%) and its disposition on a gentle slopes. In this zone, joint effects of water and wind erosion can be observed (Khasiev, 1995).

According to generalized data, the shortfall in production on slightly eroded chernozem soils amounts to 10-20%, on medial-eroded – to 30-50% and on strongly eroded soils – to 60-80% (Fokin, 1986). Soil erosion has a particularly harsh effect on wheat, sugar beet and helianthus – core agrarian cultures of that region. Next to erosion, moisture deficit has a strong negative impact on the level of crop yield. In recent years, droughts have occurred more frequently, which increased the wind erosion of the dried-out soils on slopes with sparse vegetation. Among the most accessible and effective means of the prevention of water and wind erosion are agro-technological methods, such as soil-protective and moisture-saving tillage techniques. In face of the above elaborations, the aim of this work has been the study of the impact of moisture-saving and soil-protective tillage techniques on the hydro-physical and agrochemical soil properties, as well as on crop yield on slightly eroded, leached chernozem of the Southern forest-steppe of the Republic of Bashkortostan.

Methods

The research was carried out at LLC „Artemida“, Karmalinsky district, Republic of Bashkortostan. During the autumn 2010 and the springs 2011 and 2012, the following types of tillage were applied on the test field: classic ploughing using a furrow slice inversion plough reaching 28-30 cm depths, cultivation with the Cenius cultivator working in a depth of 14-16 cm and with the Catros compact disc cultivator operating in a depth of 8-10 cm, as well as direct seeding without tillage (working depth 5-6 cm). The parcel area amounted to 2100m^2, the soil was seeded according to the framework of crop rotation adopted for the agricultural sector: in 2011 – spring wheat, in 2012 – barley, in 2013 - sugar beet.

The parcel is located on a gently westward slope covered by leached chernozem. The long-term agricultural use contributed to the development of erosion on this slope and at the present time, these soils can be classified as slightly eroded. To characterize those soils, soil profile cuts were set up on plough land and set-aside land. The corresponding morphological properties can be examined on the respective soil profiles listed below.

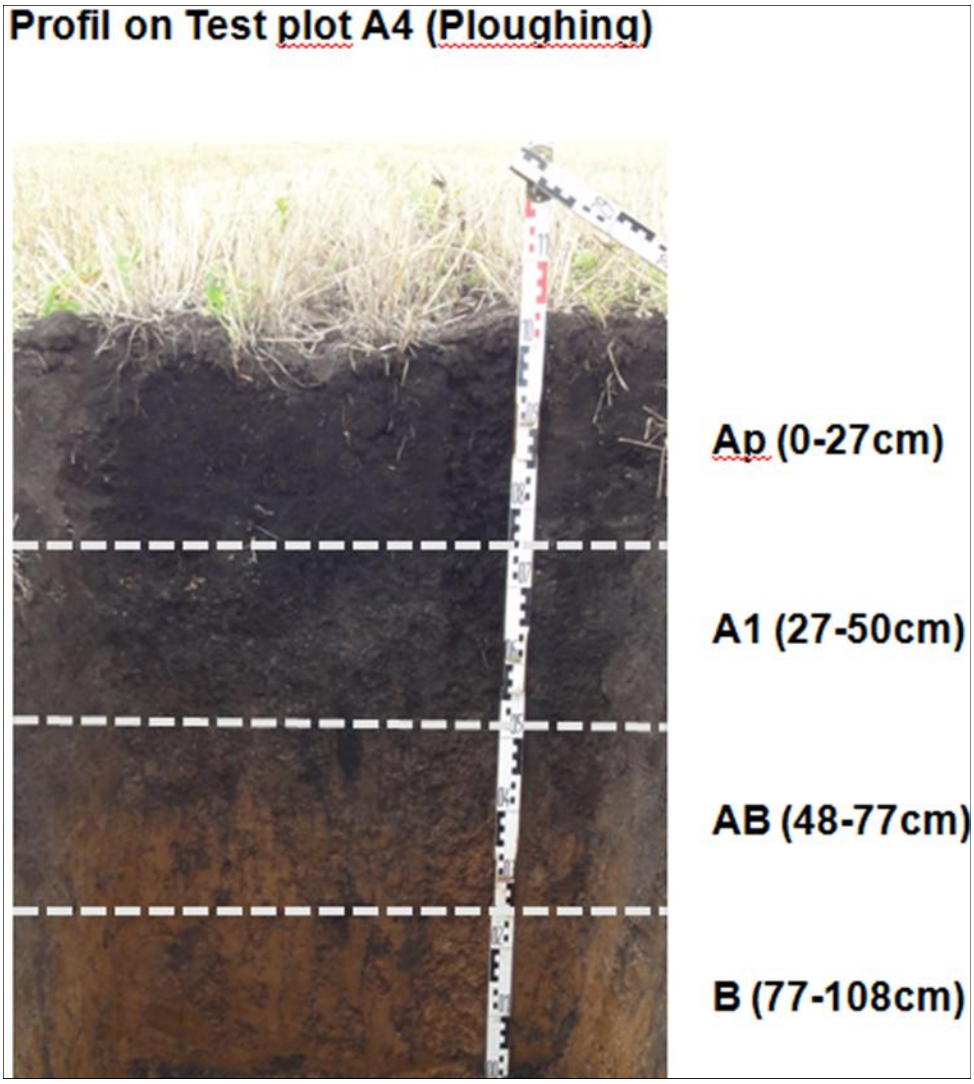

Fig. 1: Profile – Test plot A4 *(Liebelt 2012)*

Soil profile 1-2010, Plough land (fig 1)

Surface soil 0-27 cm. Dark-grey, dry, cloddy, crumby structure, heavily clayey, transition detectable along the ploughing line.

A1 27-50 cm. Dark-grey, dry, fine-medial crumby-granular structure, heavily clayey, transition detectable through change in colour, structure and mechanical composition.

AB 50-77 cm. Dark-grey with a reddish tint, streaks of humus, dry, granulated, gravel inclusion, heavily clayey, gradual transition.

B 77-108 cm. Brown-reddish, slightly moisty, coarse granular, lacquering along the bounds of the structural cleavages, scattered streaks of humus, heavy clayey, highly dense, transition detected along the soil effervescence boundary.

BCк 108-120 cm. Brown-reddish, slightly moisty, highly dense, columnar-prismatic, clayey, carbonates in form of pseudomycelium, violent effervescence from 10% HCl.

C 120-150 cm. Yellow-brownish, moisty, structureless calcareous glacial clay.

Soil: Leached, medial-thick, slightly clayey, slightly eroded black chernozem.

Soil profile 3-2010, natural land (Reference Plot).

A1 0-88 cm. Dark-grey, dry, crumby structure, heavy clayey, mellow, penetrated by roots, gradual transition.

AB 88-106 cm. Dark-grey with a reddish tint, dry, granulated, heavy clayey, streaks of humus, dense, gravel inclusion, gradual transition.

B 106-126 cm. Brown-reddish, slightly moisty, coarse granular, lacquering along the bounds of the structural cleavages, scattered streaks of humus, heavy clayey, highly dense, transition detected along the soil effervescence boundary.

BCк 126-143 cm. Brown-reddish, slightly moisty, highly dense, columnar-prismatic, clayey, carbonates in form of pseudomycelium, violent effervescence from 10% HCl.

C 143-160 cm. Yellow-brownish, moisty, structureless calcareous glacial clay.

Soil: Leached, thick, slightly clayey, black chernozem.

The laboratory-analytical research of the soil samples was carried out in accordance with the classical methods of pedology. The agrochemical parameters and the physicochemical properties of the soils were identified according to the generally applied methodology (Arinushkina, 1970; Agrochemical, 1975). The total humus content was determined according to the Tyrin method; alkali-based hydrolyzable nitrogen − according to the Kjeldal method; total phosphorus – through wet combustion with potassium perchlorate; loose phosphorus – by using the Chirikov method; exchangeable potassium – by using the Maslova method; pH of aqueous and salt suspension – potentiometric, exchangeable Ca^{2+} и Mg^{2+} – complexometrically.

The structural-aggregate composition was determined according to the Savvinova method, which has been modified by Bashkeev ; the granulometric composition was detected by using the Kachinsky method; the soil moisture, as well as the maximum, capillary and the total moisture capacity, evaporability, and density of soil – by using the classic methods (by Vadynina, Kochargin, 1986). The detection of moisture and temperature in the soil dynamic was carried out with sensors using the data logger function.

The received data was analyzed statistically by means of the programme Microsoft Office Excel 2003 (Dospehov, 1979; Dmitriev, 1995).

Results

The analysis of the morphological properties has revealed that the thickness of the accumulative humus horizon (A+AB) on the plough land changes over the range from 55 to 77 cm, which is in average 29 cm less than on set-aside land. The horizon is characterized by a dark-grey colour, a cloddy, yet unstable structure and a high density of the plough layer. When under field conditions, the granulometric composition of all types of soils was characterized as heavily clayey, but the analytical investigation has revealed that the content of physical clay makes out 57 to 64% with a prevalence of coarse silty (25-29%) and fine silty (18-24%) fractions of clay and sludge (26-37%) (table 1). Soil profiles 1 and 3 were classified as coarse, silty, sludgy, light clay, while profile 2 revealed fine and coarse, silty, light clay. That means that the allocation of mechanical elements in plough lands slightly differs from that in set-aside lands. The granulometric composition was quite congeneric in all profiles. The tested soils reflected a well-marked microstructure.

The number of micro-aggregates of a size bigger than 0,01mm amounted from 84 to 90%. It is further important to note that in plough land soils, the rate of the decay of micro-aggregates in water (dispersity factor by Kachinsky) is higher than in set-aside lands, while its soils potential fertility is high.

The data of the structural-aggregate composition of leached chernozem indicates that the soils are well-structured, and that the proportion of agronomically valuable fractions (0,25-10 mm) is above 60% when using the dry seeding method (table 2). Plough lands differ from set-aside lands in so far as they contain a higher amount of cloddy fractions and have a considerably smaller structure coefficient.

Table1: Granulometric composition of leached chernozem

Horizon depth, cm	Hydroscopic moisture, %	Content of fractions, %						Sum of particles		K-dispersity	P-structure
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	< 0,001	<0,01	>0,01		
		Size of fractions, mm									
Profile 1-2010. Plough land											
Ap 0-27	4,08	1,81	7,16	28,80	11,10	17,69	33,44	62,23	37,77	14,56	128,1
		4,50	43,97	39,76	3,25	3,65	4,87				
A1 27-50	3,95	3,46	12,08	23,64	8,97	20,39	31,46	60,82	39,18	15,67	159,0
		8,34	53,04	25,88	2,47	5,34	4,93				
AB 50-77	3,38	3,38	8,77	23,52	6,83	20,23	37,27	64,33	35,67	21,68	189,5
		6,34	45,76	24,48	3,63	11,71	8,08				
B 77-108	3,29	3,84	14,15	24,52	8,04	12,46	36,99	57,49	42,51	15,52	151,8
		6,35	35,45	33,61	5,33	13,52	5,74				
Profile 2-2010. Cenius											
Ap 0-15	3,99	2,18	12,10	26,51	13,87	24,06	21,28	59,21	40,79	15,37	112,3
		2,38	51,77	34,80	5,73	2,05	3,27				
A1 15-55	4,31	3,14	8,32	28,51	15,28	23,55	21,20	60,03	39,97	14,86	102,2
		5,37	62,95	23,04	2,47	3,02	3,15				
AB 55-71	3,44	4,78	12,68	25,55	10,30	19,78	26,91	56,99	43,01	16,61	130,2
		9,02	48,30	24,39	6,91	6,91	4,47				
B 71-105	3,32	3,33	8,46	30,46	7,82	14,41	35,52	57,75	42,25	21,85	130,4
		5,19	38,86	31,44	5,72	11,03	7,76				
Profile 3-2010. Set-aside land											
A1 0-28	4,21	3,49	9,43	24,62	16,41	19,69	26,36	62,46	37,54	12,44	112,2
		4,97	44,26	34,80	5,73	6,96	3,28				
A1 28-88	4,09	2,37	11,53	27,15	10,70	22,63	25,62	58,95	41,05	14,36	127,5
		4,46	56,28	28,22	3,68	3,68	3,68				
AB 88-106	3,64	3,28	12,35	21,18	10,50	17,92	34,69	63,11	36,89	16,43	166,1
		5,91	44,82	27,69	7,33	8,55	5,70				
B 106-116	3,28	2,86	9,29	26,13	8,57	19,59	33,56	61,72	38,28	19,40	153,2
		4,45	40,66	30,09	5,69	12,60	6,51				
Numerator – mechanical composition. denominator – micro-aggregate composition. K – dispersity factor by N.A. Kachinsky. P – structure index by A.F. Vadynina											

The content of water resistant aggregates in plough layers amounts to 60,3-61,4, which determines these soils' balanced water resistability, while in the higher layer of set-aside lands, the soil resistance to water is excessively high – an observation also confirmed by high values of the water resistability coefficient.

Table 2: Structural-aggregate composition of leached chernozem

Horizon depth, cm	Content of fractions, %									water resistability coefficient
	> 10	10-7	7-5	5-3	3-1	1-0,5	0,5-0,25	< 0,25	> 0,25	
	Size of fraction, mm									
Profile 1-2010. Plough land										
Ap 0-27	27,4	13,6	13,0	16,4	15,5	8,8	2,4	2,9	97,1	2,3
	-	3,76	3,50	5,04	19,64	19,88	20,22	27,96	72,04	74
A1 27-50	15,8	16,4	17,0	21,8	20,2	7,2	0,8	0,8	99,2	5,0
	-	-	2,48	11,60	38,98	18,36	12,64	15,94	84,06	85
AB 50-77	35,0	19,4	9,5	14,0	16,6	4,7	0,4	0,4	99,6	1,8
	-	-	3,96	15,92	46,42	12,74	7,74	13,22	86,78	87
B 77-108	57,6	9,1	6,3	7,5	9,6	57	1,6	2,6	97,4	0,7
	-	-	1,64	5,12	43,80	16,36	11,80	21,28	78,72	81
Profile 2-2010. Cenius										
Ap 0-15	33,1	10,6	9,6	11,9	11,6	11,2	6,2	5,8	94,2	1,6
	-	-	1,26	2,44	11,28	18,68	27,76	38,58	61,42	65
A1 15-55	13,4	12,0	14,3	21,1	25,7	10,7	1,4	1,4	98,6	5,8
	-	1,10	1,22	9,34	38,74	20,64	11,64	17,32	82,68	84
AB 55-71	32,3	20,8	14,3	14,1	13,3	4,4	0,4	0,4	99,6	2,1
	-	-	3,24	11,32	41,72	17,38	12,66	13,68	86,32	87
B 71-105	67,7	10,4	4,8	4,5	8,0	3,6	0,4	0,6	99,4	0,5
	-	-	1,96	7,12	44,74	18,42	12,20	15,56	84,44	85
Profile 3-2010. Set-aside land										
A1 0-28	5,0	8,8	16,7	30,4	22,4	12,3	2,8	1,6	98,4	14,2
	-	3,80	3,06	16,9	30,2	14,78	12,9	18,36	81,64	83
A1 28-88	15,2	8,2	8,2	13,6	16,7	16,8	9,9	11,4	88,6	0,9
	-	-	0,78	2,66	18,94	23,24	21,84	32,54	67,46	76
AB 88-106	40,1	15,3	10,8	11,1	14,2	6,3	1,1	1,1	98,9	1,4
	-	-	1,02	7,50	45,64	18,02	11,14	16,68	83,32	84
B 106-116	48,0	13,2	6,9	7,9	12,2	7,2	2,2	2,4	97,6	1,0
	-	-	0,44	3,66	32,22	23,64	16,58	23,46	76,54	78

The density of the solid phase of the plough layers varies between 2,55 and 2,65 g/cm^3, in a higher depth it increases to 2,82 g/cm^3 (table 3). The well-build structure of these soils contributes to the creation of an optimally structured plough layer. The density of the plough layer varies from 0,98 to 1,13, which can be characterized as optimal for all agrarian cultures; on set-aside lands, the humus-accumulative layer has a density of 0,88-1,02 g/cm^3. The porousness of all tested soils was good. Leached chernozem has a water-absorbing ability typical for slightly clayey soils of a granulometric composition with high humus content (table 3).

Table 3: Agro-physical properties of leached chernozem

Horizon depth, cm	Density, g/cm^3		Porosity, % of the total mass of soil	Moisture, % of the total mass of soil				Moisture capacity, % of the total volume of soil			
	specific	absolute		HM	MH	WP	Field moisture	MC	KC	AC	RAM
Profile 1-2010. Plough land											
Aп 0-10	2,65	1,02	61,5	3,9	10,7	14,3	17,55	37,6	56,1	62,8	23,3
Aп 10-20	2,67	1,13	57,8	4,3	11,1	14,8	19,86	37,2	53,9	61,6	22,4
A1 35-45	2,69	1,19	55,8	4,0	10,9	14,6	17,87	36,3	47,3	48,8	21,7
AB 60-70	2,74	1,44	47,4	3,4	10,6	14,2	15,52	27,1	34,2	36,3	12,9
B 80-90	2,75	1,45	47,3	3,3	10,6	14,2	16,67	26,2	34,4	35,2	12,0
B 95-105	2,78	1,45	47,8	3,3	10,4	14,0	13,94	25,4	33,8	35,3	14,0
C 108-118	2,82	1,62	42,6	3,1	9,9	13,2	14,92	22,9	27,0	28,8	9,7
Profile 2-2010. Cenius											
Aп 0-15	2,55	0,98	61,6	4,0	10,9	14,6	25,51	38,0	56,2	64,0	23,4
A1 35-45	2,61	1,22	53,3	4,3	11,5	15,4	23,66	34,8	53,2	50,6	19,4
Profile 3-2010. Set-aside land											
A1 0-10	2,54	0,88	65,4	4,2	11,2	15,1	27,82	39,7	56,4	65,5	24,6
A1 10-20	2,62	1,02	61,1	4,1	11,5	15,5	25,48	38,9	56,3	62,6	23,4
HM – hydroscopic moisture, MH – maximal hydroscopicity , WP – wilting point, MC – minimal moisture capacity, KC – capillary moisture capacity, AC – absolute moisture capacity, RAM – range of active moisture											

All soils can be characterized by a sub-acid reaction of the medium in the upper soil horizons which gradually transforms into a neutral up to a faintly alkaline reaction in the lower horizons. The soils are sated with roots predominantly holding absorbed calcium. They also contain high amounts of humus, easy hydrolyzable nitrogen and total phosphorus, while are weakly fitted with loose phosphorus (table 4). In plough lands, the humus and nutrient content of the soil is slightly lower than in the soil of set-aside lands.

Table 4: Chemical properties of leached chernozem

Horizon, depth, cm	Humus %	pH		Ca^{2+}	Mg^{2+}	Ca^{2+}+ Mg^{2+}	Phosphorus		Nitrogen
		H_2O	KCl	mg-eq/100 g of soil			loose	total	alkali-based hydrolyzable
							mg/100 g of soil		mg/kg of soil
Profile 1. Plough land									
Surface soil 0-27	7,67	5,9	5,1	40	6	46	3,33	156,74	231
A1 27-50	6,56	6,9	5,1	38	4	42	1,67	141,07	168
AB 50-77	4,31	7,0	5,8	35	5	40	1,38	109,72	70
B 77-108	2,56	7,4	6,2	22	5	27	4,52	125,39	28
Profile 2. Cenius									
Surface soil 0-15	7,89	6,4	6,0	40	5	45	4,52	188,09	217
A1 15-55	7,86	6,2	5,2	36	5	41	1,55	203,76	238
AB 55-71	5,12	6,8	5,4	33	6	39	0,67	125,39	112
B 71-105	2,93	7,4	6,2	22	4	26	2,00	97,18	56
Profile 3. Set-aside land									
A1 0-28	8,01	6,2	5,4	41	4	48	5,38	191,22	210
A1 28-88	7,29	6,5	5,3	41	4	48	2,38	188,09	175
AB 88-106	3,13	6,8	5,8	38	4	42	3,10	156,74	70
B 106-130	1,52	7,5	6,2	27	5	32	4,88	115,99	56

The analysis of the dynamic of soil moisture in the layer 0-30 cm has revealed (figure 2) that already by the first year (2011), it varied in accordance with the different variants of tillage. In the beginning of the cropping season, the soil moisture was rather constant showing only minor fluctuations (27-35%). By the end of May, it slightly rose on set-aside land and when applying cultivation. By the middle of June, the maximal moisture was detected on the test area for direct seeding without tillage and remained the highest until the end of the cropping season. 3-5% less moisture was verified when cultivation was applied. A more substantial difference was revealed in classic ploughing, while the lowest moisture was detected in the soil of set-aside lands.

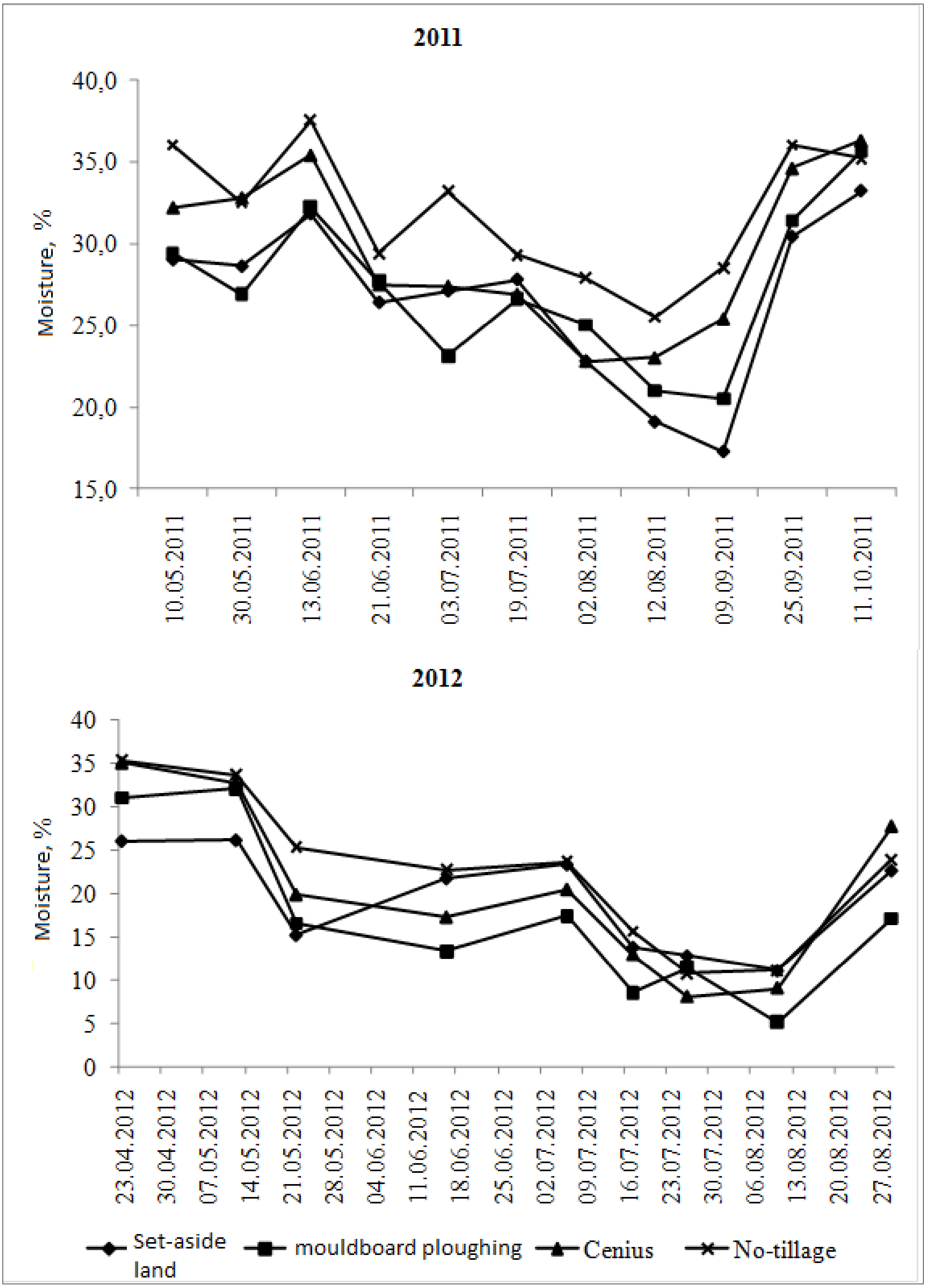

Fig. 2: Change of field moisture during the test process (layer 0-30 cm)

In spring of the following year (2012), the soil moisture under minimal tillage (direct seeding or cultivation) was comparably high (around 30-35%), while when using mouldboard ploughing and on set-aside lands it amounted to 16-23%. During the summer, soil moisture in all the tested variants gradually decreased up to 7-15% by the end of July, i.e. it practically approached the maximal hydroscopic moisture capacity.

The general trend of the preceding year, i.e. a decrease in soil moisture according to the tillage method retained in the following sequence: direct seeding (no tillage), cultivation, mouldboard ploughing, set-aside land. Such a variation in soil moisture has a number of causes: climatic conditions, structure of the soil, soil density, biomass of vegetation. Temperature variations in a depth of 15 cm generally corresponded with the air temperature variations, while differed according to the tillage method (fig. 3).

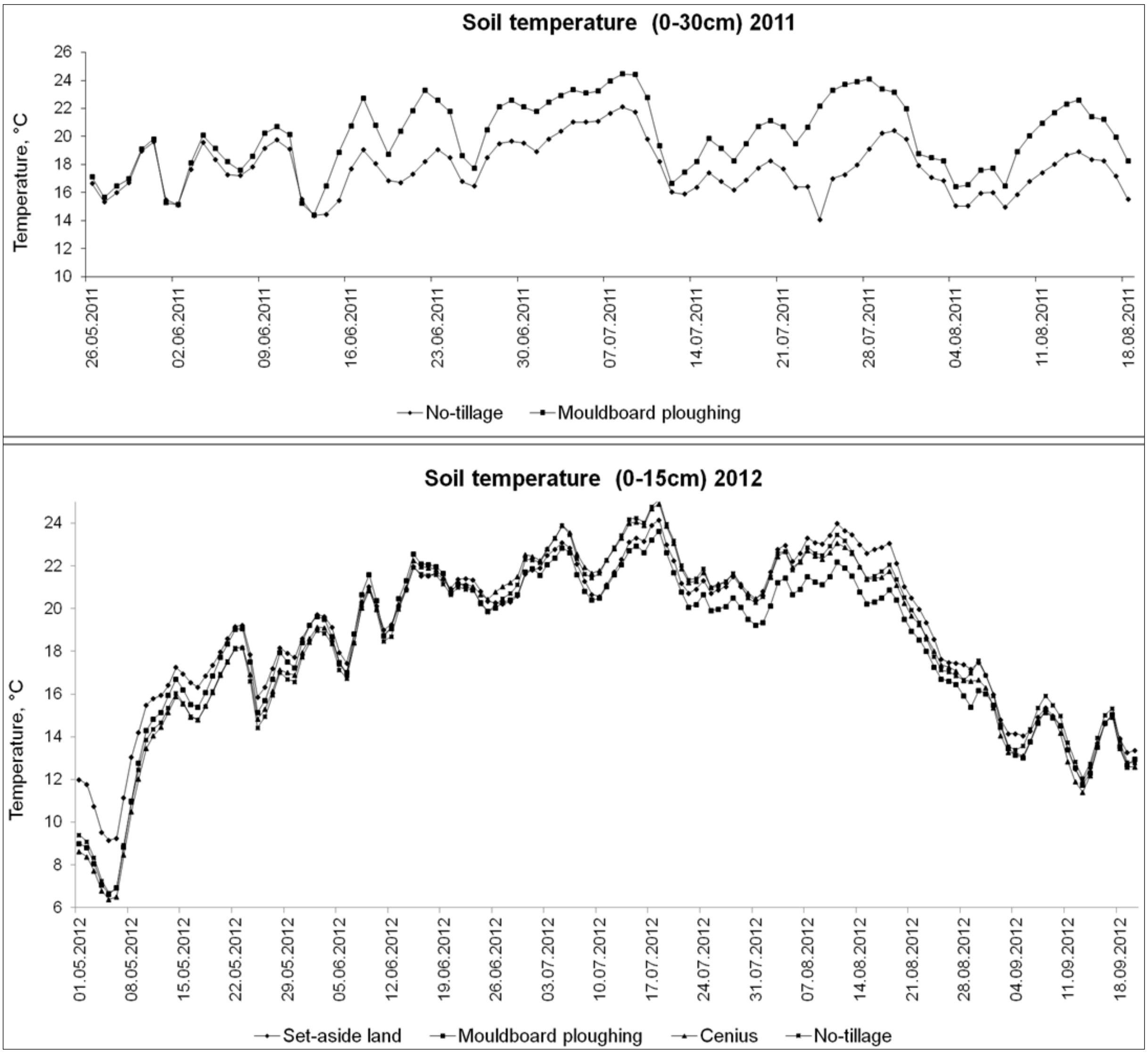

Fig. 3: Variations of the average daily temperature during testing (layer 0-15 cm/ 0-30cm) 2011/ 2012

As may be seen on figure 2, when using mouldboard ploughing, soil moisture was in average 2-3 degrees higher than when applying minimal tillage during the entire cropping season of the 2 years of testing. This finding agrees well with the fact of a better provision of soil with moisture when using minimal tillage. Those results were further confirmed by the verified speed of soil moisture evaporation (figure 4).

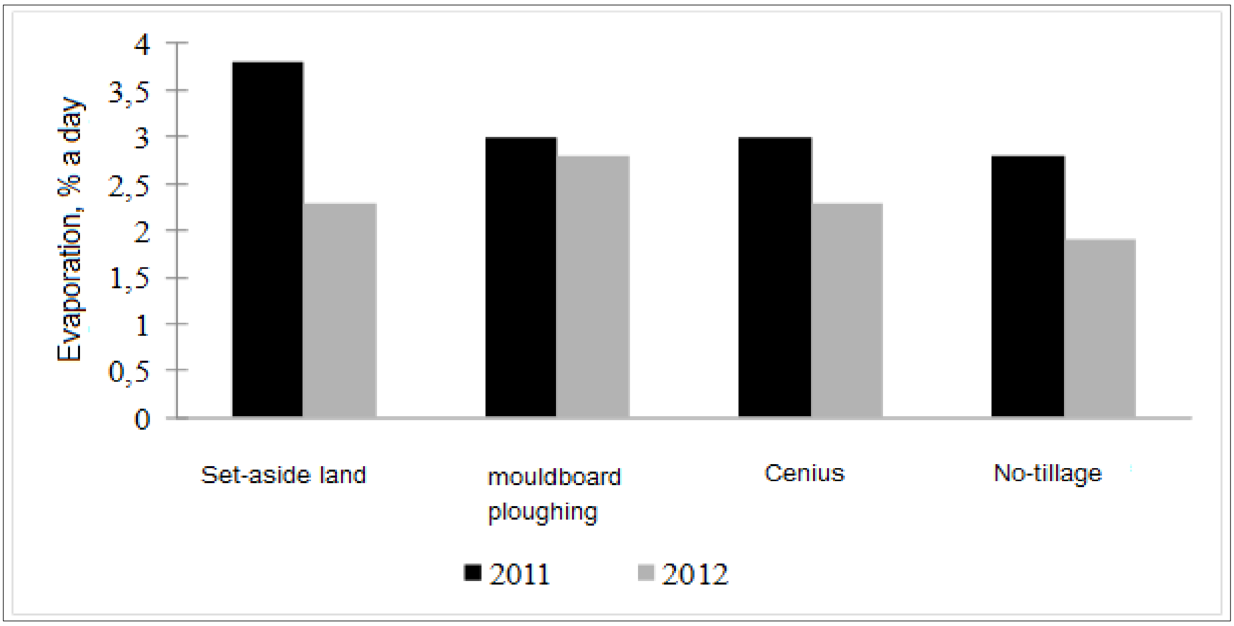

Fig. 4: The effect of the different tillage methods on evaporation in the 0-30 cm layer (average for 5 days)

The range of evaporation variations was not wide (1,9-3,75 % moisture a day), but the differences according to the tillage variant turned out to be more substantial. Its total increase for all types of soil cultivation: direct seeding, cultivation, mouldboard ploughing and set-aside land, manifested itself during the entire period of the two years of research. In should further be noted that in year 2, evaporation parameters were lower on test areas with minimal tillage, while remaining steady when using mouldboard ploughing. This was mainly caused by an increase in the density of the higher soil layers under conditions of minimal tillage (table 5).

In the autumn of the first year of testing (2011), the consistence of the soils where mouldboard ploughing was applied has been characterized as friable in the 0-10 cm layer; and, on average, was optimal in the ploughed layer for a majority of agrarian cultures when direct seeding or cultivation has been applied.

This trend remained for the following year, albeit the total mass values for minimal tillage grew slightly.

Table 5: The effect of the different methods of soil cultivation on the hydro-physical properties of soil

Method of soil cultivation	Depth	Volume weight, g/cm^3		Moisture capacity, %					
		2011	2012	MC		KC		AC	
				2011	2012	2011	2012	2011	2012
Set-aside land	0-10	0.86	0,93	41,2	39,2	56,6	56,5	64,1	64,1
	10-20	1.06	1,10	39,4	38,7	56,4	56,0	61,3	60,4
	20-30	1.12	1,11	39,1	38,3	47,7	46,3	51,7	51,8
	30-40	1.18	1,14	37,5	36,8	44,7	43,2	47,7	48,5
	40-50	1.20	1,17	36,6	35,9	42,1	42,6	46,9	47,8
	50-60	no res.	1,18	no res.	35,7	no res.	43,1	no res.	46,9
	60-70	no res..	1,19	no res.	33,4	no res.	40,4	no res.	44,1
	70-80	no res.	1,20	no res.	29,5	no res.	36,9	no res.	39,6
	80-90	no res.	1,30	no res.	28,4	no res.	31,7	no res.	34,0
	90-100	no res.	1,41	no res.	27,5	no res.	29,6	no res.	31,4
Mouldboard ploughing, depth 28-30 cm	0-10	0.94	1,01	38,5	38,2	56,7	56,8	61,2	62,2
	10-20	1.13	1,03	37,1	38,6	55,4	55,5	57,1	59,3
	20-30	1.22	1,06	37,5	37,5	43,7	43,4	52,9	52,3
	30-40	1.26	1,22	34,4	36,4	37,4	38,4	39,1	41,3
	40-50	1.39	1,33	29,3	28,1	30,1	32,4	38,1	39,9
	50-60	no res.	1,43	no res.	26,3	no res.	30,0	no res.	37,5
	60-70	no res.	1,45	no res.	25,3	no res.	29,3	no res.	36,1
	70-80	no res.	1,42	no res.	24,8	no res.	29,2	no res.	33,7
	80-90	no res.	1,43	no res.	25,9	no res.	28,7	no res.	30,1
	90-100	no res.	1,43	no res.	25,7	no res.	29,3	no res.	30,2
Cenius cultivation, depth 14-16 cm	0-10	1.01	1,13	39,2	39,1	56,4	56,2	63,5	64,8
	10-20	1.15	1,16	39,1	38,3	52,9	53,1	61,6	62,4
	20-30	1.20	1,25	38,7	36,1	41,3	40,2	56,9	51,8
	30-40	1.25	1,24	35,2	34,1	36,3	38,0	38,1	49,2
	40-50	1.32	1,25	34,1	32,5	34,9	36,9	37,6	39,2
	50-60	no res.	1,32	no res.	30,1	no res.	34,8	no res.	38,3
	60-70	no res.	1,36	no res.	28,5	no res.	34,3	no res.	37,5
	70-80	no res.	1,43	no res.	26,9	no res.	31,2	no res.	31,9
	80-90	no res.	1,43	no res.	24,6	no res.	29,0	no res.	30,7
	90-100	no res.	1,35	no res.	25,4	no res.	29,0	no res.	30,8
No-tillage	0-10	1.08	1,17	36,1	37,7	55,8	55,4	63,2	62,5
	10-20	1.10	1,18	36,0	36,9	52,5	50,5	60,0	62,3
	20-30	1.17	1,13	39,5	39,5	47,3	49,4	57,8	59,5
	30-40	1.20	1,14	38,4	35,1	41,2	40,1	53,2	53,3
	40-50	1.22	1,21	36,5	32,1	37,3	39,5	40,6	50,4
	50-60	no res.	1,29	no res.	30,2	no res.	36,1	no res.	41,2
	60-70	no res.	1,26	no res.	28,8	no res.	34,3	no res.	39,4
	70-80	no res.	1,34	no res.	26,3	no res.	31,0	no res.	34,8
	80-90	no res.	1,43	no res.	25,8	no res.	29,2	no res.	32,0
	90-100	no res.	1,35	no res.	25,0	no res.	29,0	no res.	30,7

For an estimation of soil moisture accessible to plants, hydrological constants for soil were identified (table 5). As has been noted in the collective monograph „Theories and methods of soil physics“ (2007), these constants change in accordance with the conditions of soil and their variations may amount to several percent, i.e. they can be regarded as conditional, yet sufficiently precise indicators characterizing the water state in the soil.
As indicated in table 5, all categories of moisture capacity are slightly lower on plough land, than on set-aside land. This is most likely caused by a lower concentration of organic substances in set-aside land, as the granulometric composition of all tested soils was fairly homogeneous. During the two years of diverse tillage, the indicators of minimal, capillary and absolute moisture capacity remained at the starting value level.

The structural-aggregate composition of the soil was almost identical for all types of soil cultivation by the autumn of the first year of the experiment (table 6), the coefficient of the structural make up changed from 3,6 to 6,0, the water resistability of aggregates also remained rather steady (77,5-81,0). By the second year, though, the structural-aggregate composition changes considerably: for all the tested variants of tillage, the proportion of coarse fractions of 7-10 mm and bigger (>10mm) grew, while the proportion of small fractions – mostly of a size of 0,25-0,5 and 0,5-1,0 mm - decreased. On the one hand, this was a result of lower soil moisture caused by a droughty cropping season of the year 2012 which led to an increase of the cloddiness of set-aside land soil. On the other hand, the tillage method played a role. So, when direct seeding was applied, the amount of cloddy fractions increased by a factor of 11, when cultivating – by a factor of 5 to 6, when using classic ploughing – 4-fold, and on set-aside land – by a factor of 2 to 8. Hereby, water resistability of aggregates also grew to considerably high levels.

The soil structure and density in light of its heavy granulometric composition predefined its water permeability in many respects. The analysis of the dependence of water permeability (x) on the soil total mass (y), which was carried out using the data collected during the second year of testing, revealed the existence of a reliable linear interdependency between the two indicators (R^2=0,76-0,92; P=95), whereby the dependency equation turned out to be almost identical for all types of tillage: y=1,5-0,03x.

A satisfactory water permeability during the first year of testing was detected only in the soils of set-aside land (120 cm/day) and when using classic ploughing (84 cm/day) (figure 5). When applying cultivation and dry seeding, it amounted to 65 and 50 cm/day, respectively, and was consequently rated as unsatisfactory. By the autumn of the second year, due to a worsening of the structural make up and consistency of the soil, the speed of filtration decreased for all tested soils. The absorption coefficient amounted to 65; 37,5; 29 and 26 cm/day (respectively for: set-aside land, mouldboard ploughing, cultivation and direct seeding).

Table 6: The effects of the different tillage methods on the structural-aggregate composition of leached chernozem (2012)

Horizon and layer of soil, cm	Fractions, %; Size, mm.								Coefficient of structure	Coefficient of water resistability
	>10	10-7	7-5	5-3	3-1	1-0,5	0,5-0,25	<0,25		
Virgin land (set-aside land)										
A1 0-30	12,13 / 0,00	13,26 / 1,70	16,18 / 6,07	25,73 / 12,96	17,08 / 26,78	9,78 / 24,23	3,26 / 22,22	2,58 / 6,04	5,79	96,45
A1 30-90	32,81 / 0,00	11,26 / 0,17	8,74 / 1,69	15,32 / 4,07	12,03 / 34,21	9,52 / 31,90	4,59 / 16,90	5,71 / 10,07	1,60	94,34
AB 90-102	34,48 / 0,00	13,40 / 0,00	11,53 / 1,39	14,95 / 6,92	11,63 / 36,60	8,20 / 29,68	3,12 / 16,82	2,70 / 7,61	1,69	93,93
B 102-130	59,09 / 0,00	13,96 / 0,00	7,90 / 0,00	8,55 / 5,55	4,87 / 37,00	3,14 / 40,08	1,19 / 11,10	1,30 / 6,29	0,66	94,96
Tillage in 28-30 cm depth										
A1 0-15	25,45 / 0,00	7,80 / 0,30	6,19 / 0,44	10,43 / 4,44	13,74 / 10,36	18,07 / 22,20	10,52 / 35,52	7,80 / 26,64	2,01	79,46
A1 15-30	31,13 / 0,00	9,72 / 1,39	8,30 / 1,46	12,83 / 3,99	12,17 / 15,96	13,30 / 29,26	6,89 / 33,25	5,66 / 14,66	1,72	90,43
A1 30-45	24,35 / 0,00	16,13 / 0,00	12,93 / 1,66	17,54 / 6,64	12,53 / 30,21	8,92 / 30,98	4,01 / 18,28	3,61 / 12,33	2,58	91,04
AB 45-55	24,84 / 0,00	18,84 / 1,30	15,32 / 1,02	18,63 / 12,85	11,18 / 39,21	6,42 / 18,84	2,48 / 14,62	2,28 / 12,02	2,69	89,90
B 55-100	45,06 / 0,00	13,90 / 1,28	10,75 / 2,56	12,70 / 11,52	8,25 / 32,12	5,54 / 25,61	2,06 / 15,81	1,74 / 11,25	1,14	90,47
Cenius										
Aп 0-15	21,05 / 0,00	7,33 / 3,92	6,57 / 2,63	9,33 / 6,24	10,38 / 15,72	18,00 / 33,75	13,90 / 14,24	13,43 / 23,54	1,90	88,38
A1 15-52	16,44 / 0,00	11,29 / 0,00	8,83 / 1,42	17,18 / 10,21	16,56 / 26,14	15,09 / 29,98	7,36 / 16,82	7,24 / 15,25	3,32	91,18
AB 52-65	34,19 / 0,00	13,64 / 2,41	10,23 / 5,92	12,91 / 16,85	11,05 / 28,81	9,40 / 21,67	4,44 / 12,25	4,13 / 12,07	1,61	91,71
B > 65	48,79 / 0,00	12,13 / 0,00	8,54 / 2,62	11,14 / 13,14	7,82 / 29,63	5,66 / 24,41	2,61 / 16,95	3,32 / 13,22	0,92	89,72
Catros										
Aп 0-8	41,49 / 0,00	10,21 / 3,42	7,33 / 5,74	10,21 / 7,98	7,72 / 17,12	9,42 / 23,25	5,89 / 28,24	7,72 / 14,21	1,03	92,93
A1 8-51	29,08 / 0,00	10,31 / 0,00	8,71 / 2,44	14,60 / 5,25	12,52 / 31,02	11,78 / 27,78	6,01 / 15,52	6,99 / 18,02	1,77	88,17
AB 51-75	41,89 / 0,00	12,25 / 2,49	9,22 / 2,52	12,37 / 16,12	8,63 / 27,36	7,35 / 26,03	3,73 / 13,42	4,55 / 11,81	1,15	92,14
B 75-100	32,70 / 0,00	11,92 / 0,00	9,33 / 0,00	13,93 / 14,05	10,63 / 25,02	9,09 / 30,13	5,31 / 17,07	7,08 / 13,06	1,51	92,85
Note: the numerator accounts for dry, the denominator – for wet seeding										

Apparently, the low water permeability contributed to a great respect to the development of water erosion on the soil of the tested area located on a gentle slope. This is because during the spring snowmelt and (or) heavy rain under conditions of unsatisfactory absorption, surface runoff develops fairly quickly.

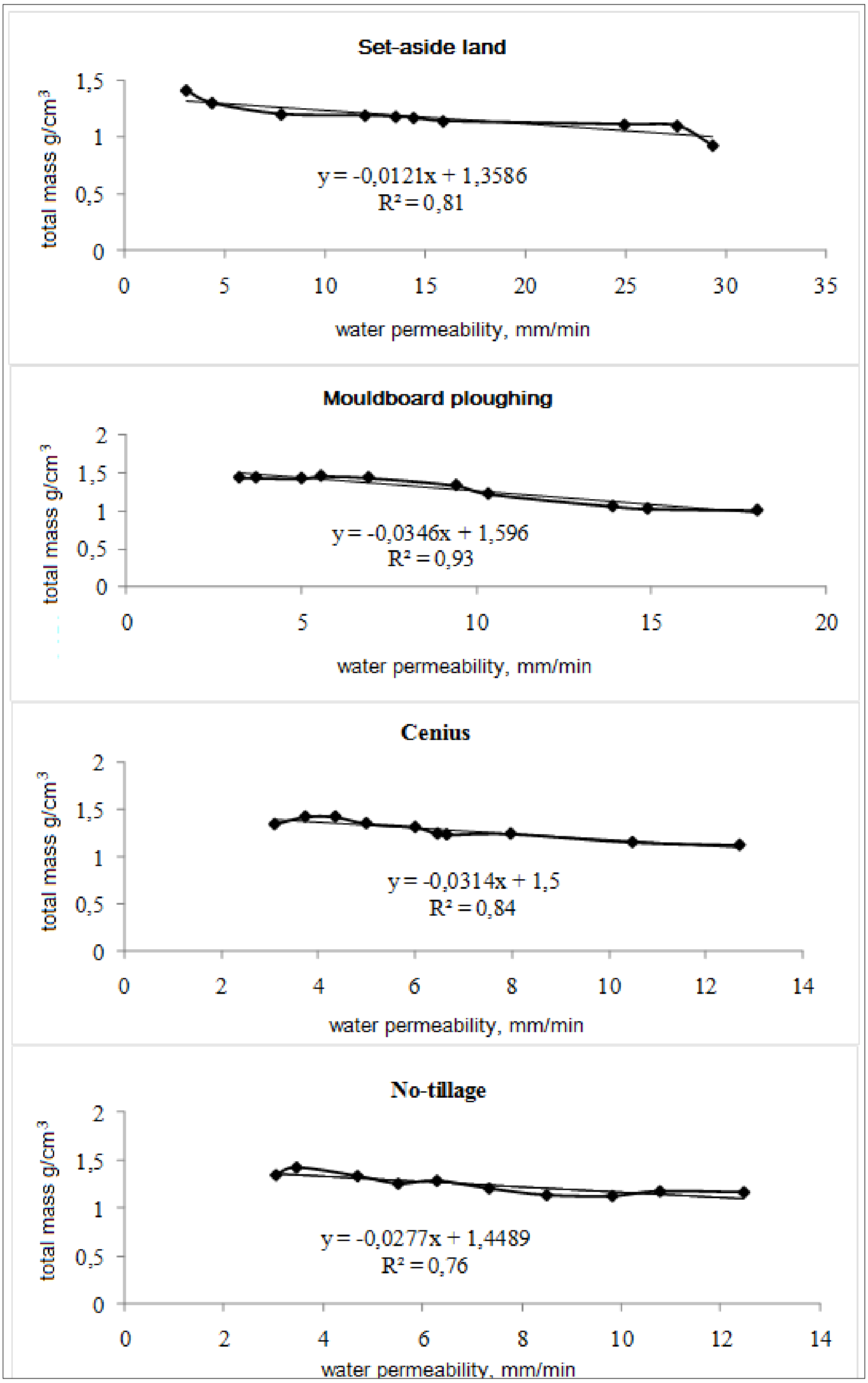

Fig. 5: The dependency of water permeability on the total mass of soils in respect to the tillage method

In contrast to the hydro-physical properties, the usage of soil-protective tillage methods did not substantially affect the soil`s agrochemical properties. As indicated in table 7, a certain tendency can be traced in respect to the humus content in the soil when ploughed with a furrow slice plough.

The content of the alkali-based hydrolysable nitrogen, loose phosphorus and exchangeable potassium varied within the range of one and the same rate of supply, which equated to the medial (nitrogen), the lower (phosphorus) and the higher (potassium) levels. What becomes apparent is that minimal tillage does not lead to a decrease of nutrients in the soil.

Table 7: Crop yield

Tillage method	Wheat (2011)	Barley (2012)	Sugar beet (2013)
	Yield, centner/ha		
Mouldboard ploughing	40,7	13,2	770
Cultivation (Cenius)	33,3	17,8	570
No tillage	28,3	21,8	550

Fig. 6 *(Liebelt 2011)*

In light of a slight worsening of the physical properties of the soil where direct seeding (no tillage) was applied in conditions of the medial-moisty cropping season of the first year of research, the yield of spring wheat was the lowest (table 7). When cultivating, the crop yield was 4 centner/ha higher, and when applying mouldboard ploughing – 12 centner/ha higher. During the following highly droughty year, maximal yield was obtained on test areas with direct seeding, which was 8,6 centner/ha higher than on test areas with mouldboard ploughing. In the third medial-moisty year (2013), the yield of sugar beet decreased when tillage was minimized. This can be explained by a resulting increase in the soil density. It is interesting to note that when direct seeding was applied, the size of the root plants turned out to be almost 200 gram smaller; the plants had a flattened form and many lateral roots.

Table 7: Agrochemical properties of leached chernozem when using different tillage methods

Method	pH H_2O		Humus, %				Nitrogen, mg/kg				Phosphorus, mg/100 g				Potassium, mg/kg	
	2011	2012	2011		2012		2011		2012		2011		2012		2012	
	autumn		spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Tillage method																
Plough (28-30 см)	6,3	5,8	7,73	7,74	7,67	7,64	211,3	212,3	198,3	191,7	3,92	3,67	4,51	4,30	81,7	100,0
Cenius (14-16 см)	6,1	6,0	7,88	7,80	7,78	7,79	227,5	226,3	210	207,7	4,45	4,20	4,39	3,99	101,7	91,7
Catros (8-10 см)	6,3	6,2	7,88	7,86	7,89	7,92	198,0	217	207,7	213,3	4,24	3,88	4,98	4,87	88,3	93,3
No-tillage	6,1	6,2	7,62	7,51	7,46	7,52	193	198,3	196	206,7	5,92	4,82	4,79	4,88	91,7	91,7

Conclusion

The application of minimal tillage, including direct seeding and cultivation in a depth of 14-16 cm, during the period of two years led to a substantial change of the agro-physical properties of the soil in the 0-30 cm layer - an increase in its total mass, a worsening of the soil structure, a decrease in the soil ability to absorb water, a decrease of soil temperature, and an increase of soil moisture.

No substantial changes of the agro-chemical properties of the soil were detected during the two years period.

In averagely humid years, the yield of spring wheat (2011) and sugar beet (2013) decreased according to the following sequence: mouldboard ploughing, cultivation, direct seeding. The effectiveness of minimal tillage manifested itself during the highly droughty year 2012, when the yield of barley was the highest on the test area where no tillage was applied.

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Ways to restore and increase the fertility of degraded soils

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Introduction

One of the major agro-technical measures to counter erosion is the enrichment of soil with organic substances. The basic organic fertilizer is manure, but its amounts are limited and do not suffice for productive land use (Ulyanova & co., 2010). Appropriate alternatives can be provided by natural fertilizers and renewable biological resources, such as peat, sapropel, crop residues, straw, floating bogs etc., which will not only serve as sources of organic carbon, but also have a regulative function in the mineral nutrition of plants (Efremov, 2006). As indicated elsewhere, the insertion of sapropel and floating bogs, extracted during the cleaning of a nearby lake, into the soil led to an increase of the fertility of the eroded southern type of chernozem. (Gabbasova & co., 2008). Yet, the positive effects mainly concerned the hydro-physical properties of the soil, while a minor improvement in the properties of humus and soil nutrition became visible only by the third year after the application of floating bogs, which induced humification. In light of these findings, the aim of the conducted research was it to find methods to accelerate the humification process of the floating bogs and to turn it into a full-value organic-mineral fertilizer. As a result of a number of model experiments, a technology for such a fertilizer`s creation was founded. The technology`s essence lies in the composting of the floating bog under optimal moisture and temperature conditions maintained for one full cropping season, while adding fungicides *(Trichoderma* sp.14*)* in combination with natural phosphorites (Felorov & co., 2009).

In light of these findings, this research aims at a study of the effectiveness of the use of natural agrarian ores (floating bog, straw) treated with fungicides *Trichoderma* in comparison with traditional fertilizers (manure, sodium humate) and zeolites.

Methods

The research was carried out in LLC „Artemida“, Karmalinsky district, Republic of Bashkortostan. The testing parcels were located on a gently westward slope covered by leached chernozem. Its long-term agricultural use contributed to the development of erosion on this slope and at the present time, these soils can be classified as slightly eroded. In spring 2011, the application of fertilizers was tested on parcels where classic ploughing (using a furrow slice inversion plough with a reach of 28-30 cm) and direct seeding without tillage (no-tillage, seeding depth 5-6 cm) have been applied. The total area of the parcels amounted to 4 m^2 (2×2 m). The test was carried out on three surfaces having following variations: 1. Control; 2. Floating bog + NP(60); 3. Floating bog + *Trichoderma* + NP(60); 4. Manure; 5. Straw + NP(60); 6 Straw + *Trichoderma* + NP(60); 7. Zeolite; 8. Na humate.

Fig. 1: Meliorations tests on the Artemida-Test plots *(Liebelt 2011)*

The floating bog was extracted during the cleaning of a pond located near the test area. It consisted of plant material mainly composed of typha, scirpus and carex. It was comminuted along with the included roots and added to the soil in a moisty state. For an acceleration of the floating bog`s and straw`s humification, the suspension of the fungicide *Trichoderma* sp.14 was added. The fungicide`s biomass has been cultured in Czapek's medium (2% saccharides) for a period of 14 days. The parcel was fertilized by 10 g of raw biomass suspended in 10 l of water. The titer of the working suspension amounted to 10^8 CFU/ml. Organic fertilizer, zeolite (quarried in the Tuzbekian laumontite-mordenite deposit) and sodium humate (commercially purchased fertilizing product in powder form obtained from brown coal) were added at a rate of 10 kg per parcel.

The laboratory-analytical research of the soil samples was carried out in accordance with the classical methods of pedology. The agrochemical parameters and the physicochemical properties of the soils were identified according to the generally applied methodology (Arinushkina, 1970; Agrochemical…, 1975). The total humus content was determined according to the Tyrin method; alkali-based hydrolysable nitrogen − according to the Kjeldal method; total phosphorus – through wet combustion with potassium perchlorate; loose phosphorus – by using the Chirikov method; exchangeable potassium – by using the

Maslova method; pH of aqueous suspension – potentiometrically. The received data was analyzed statistically by means of the programme Microsoft Office Excel 2003 (Dospehov, 1979; Dmitriev, 1995), the tables show averaged data.

Results

All soils of the testing parcels can be characterized by a sub-acid reaction of the medium in the upper horizons (pHH2O 5,9-6,4) which gradually transforms into a neutral up to a faintly alkaline reaction in the lower horizons (pHH2O 7,0-7,4). The soils are sated with roots holding predominantly absorbed calcium. They have a medial humus content (7,67-7,86%), entail easy hydrolysable nitrogen (217-231 mg/kg) and total phosphorus (157-188 mg/100 g), while being badly equipped with loose phosphorus (3,33-4,52). In plough land soils, the humus and nutrient content is slightly smaller than in set-aside land soils.

The starting value of the humus content in the tested soils, which amounted to 7,62-7,73 %, was rated as medial for chernozem soils of that region. Three years after the start of the experiment, a clear increase in the humus content was verified on all fertilized test variants for all types of tillage, except for those where zeolites and - to some extent - sodium humate were applied, whereby the effectiveness of floating bogs, straw and manure turned out to be almost identical (table 1). When the biomass of *Trichoderma* was added to the floating bog and straw, the increase of its total humus content was insignificant, while major differences could be detected in its dynamic. As illustrated in table 1, the humus content of the soil of the test variant containing the fungicide sequentially rose, while when the floating bog was added to the soil without the fungicide treatment, it remained rather steady and decreased by the third year. By the third year of the experiment, plant residues of the floating bog, straw and manure became morphologically undistinguishable, which presupposes a process of humification. Rated upon the quantitative and qualitative characteristics of the humus content in the soil, the applied fertilizers can be placed in an ascending sequence according to their effectiveness: Zeolite – Na humate– Floating bog – Straw – Floating bog + *Trichoderma* – Straw + *Trichoderma* – Manure. There were no significant differences in the humus qualities of the soil when using diverse tillage methods.

Along with an improvement of the humus properties, the content of loose phosphorus, potassium and alkali-based hydrolysable nitrogen in the soil grew, although the accessibility of phosphorus and potassium during the period of three years remained low for all the tested variants (table 1).

Table 1: Chemical parameters of the soil (soil depth 0-30 см)

Variant	pH H_2O		Humus, %				Nitrogen, mg/kg				Phosphorus, mg/100 g				Potassium, mg/kg	
	2011	2012	2011		2012		2011		2012		2011		2012		2012	
	autumn		spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn
No tillage																
Control	6,2	6,2	7,62	7,51	7,46	7,49	193	198,3	196	193,7	5,9	5,0	4,5	4,7	95	96,7
Floating bog + N60P60	6,2	6,1	Test begin	7,68	7,63	7,75	Test begin	198,3	198,3	193,7	Test begin	6,7	4,8	5,1	123,3	96,7
Floating bog + Trichoderma +N60P60	6,3	6,1		7,67	7,81	7,83		207,7	191,3	186,7		7,3	6,3	4,6	181,7	91,7
Manure	6,6	6,2		8,08	7,93	7,92		205,3	198,3	191,3		7,9	6,2	7,0	146,7	118,3
Straw+ N60P60	6,3	6,1		8,02	7,98	7,97		205,3	214,7	196		5,9	4,9	4,9	98,3	93,3
Straw + Trichoderma+N60P60	6,3	6,0		8,04	8,01	7,99		205,3	205,3	193,7		5,9	4,5	5,4	96,7	98,3
Zeolite	6,3	6,1		7,73	7,66	7,65		214,7	210	198,3		7,1	5,0	5,5	105	105
Na humate	6,4	6,0		7,84	7,74	7,80		221,7	214,7	189		6,3	5,3	5,16	121,7	88,3

Variant	pH H_2O	Humus, %		Nitrogen., mg/kg		Phosphorus, mg/100 g		Potassium, mg/kg	
	2013	2013		2013		2013		2013	
	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn
No tillage									
Control	6,3	7,58	7,59	200,7	198,4	5,0	4,5	95,4	95,7
Floating bog + N60P60	6,2	7,88	7,89	212,3	200,2	5,8	5,4	114,1	102,4
Floating bog + Trichoderma +N60P60	6,2	7,74	7,82	203,0	197,4	7,0	6,4	121,1	111,4
Manure	6,2	7,91	7,89	203,0	202,8	6,5	6,6	124,6	120,8
Straw+ N60P60	6,3	7,89	7,87	228,7	221,5	5,8	5,1	105,3	94,2
Straw + Trichoderma+N60P60	6,2	7,88	7,94	221,7	220,8	5,9	5,6	102,5	97,6
Zeolite	6,2	7,63	7,65	219,3	217,9	6,0	5,3	103,8	100,3
Na humate	6,1	7,75	7,74	219,3	218,4	5,9	5,7	99,7	92,8

Appendix of table 1

Variant	pH H_2O		Humus, %				Nitrogen, mg/kg				Phosphorus, mg/100g г				Potassium, mg/kg	
	2011	2012	2011		2012		2011		2012		2011		2012		2012	
	autumn		spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Ploughing																
Control	6,0	5,8	7,73	7,74	7,67	7,67	211,3	212,3	198,3	200,7	3,9	4,9	4,1	4,5	76,7	110
Floating bog + N60P60	6,1	5,9	Test begin	7,92	7,90	7,92	Test begin	214,7	210	196	Test begin	6,1	4,3	4,4	123,3	160
Floating bog + Trichoderma +N60P60	6,2	5,9		8,03	8,04	8,01		200,7	207,7	207,7		6,2	3,8	7,9	98,3	108,3
Manure	6,3	6,3		8,09	7,99	8,05		200,7	219,3	198,3		6,4	4,7	4,4	108,3	123,3
Straw+ N60P60	6,1	6,0		7,94	7,84	7,89		205,3	200,7	198,3		5,1	4,0	4,5	76,7	98,3
Straw + Trichoderma+N60P60	6,2	5,8		7,98	7,95	7,94		210	219,3	198,3		5,1	4,3	4,3	106,7	91,7
Zeolite	6,2	5,8		7,84	7,86	7,84		207,7	207,7	198,3		5,8	3,8	4,7	88,3	90
Na humate	6,3	5,9		7,82	7,73	7,75		207,7	212,3	184,3		8,7	4,6	5,4	96,7	123,3

Variant	pH H_2O	Humus, %		Nitrogen, mg/kg		Phosphorus, mg/100 g		Potassium, mg/kg	
	2013	2013		2013		2013		2013	
	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Ploughing									
Control	5,9	7,72	7,70	205,3	204.3	4,5	4,4	84,1	85,4
Floating bog + N60P60	6,0	8,03	7,94	200,7	198,0	4,6	4,6	115,6	117,5
Floating bog + Trichoderma +N60P60	6,0	7,92	7,93	210,0	208.2	4,5	4,7	114,5	100,8
Manure	6,3	8,04	8,02	207,7	204,9	4,9	4,2	115,2	110,9
Straw+ N60P60	6,1	7,85	7,85	212,3	211,4	4,2	4,0	99,4	97,2
Straw + Trichoderma+N60P60	5,9	7,99	8,04	219,3	218,4	4,6	4,8	100,5	97,5
Zeolite	5,9	7,83	7,84	212,3	210,6	4,4	4,1	90,4	88,6
Na humate	6,1	7,80	7,72	207,7	206,8	5,9	5,6	113,2	117,9

The test areas were seeded with cultures according to the crop rotation adopted for the agrarian sector: 2011 – wheat, 2012 – barley, 2013 – sugar beet. For the tested tillage methods (mouldboard ploughing and no-tillage) applied on all variants using organic ores (manure, straw, floating bog), an increase in crop yield was observed. It should further be noted that the productivity of grain-crops (wheat and barley) was higher on test parcels with no tillage than on those where mouldboard ploughing was applied - presumably, a consequence of moisture retention in the soil. The crop yield of sugar beet was greater on variants where mouldboard ploughing was applied. Here, a decisive limiting factor was, most likely, the density of soil.

The average increase in the productivity of land according to the test variant during the research period of three years was the following: application of manure - 67 %, straw – 65%, floating bog – 40%, floating bog + *Trichoderma* – 47%, straw + *Trichoderma* – 73%, zeolite – 17% and Na humate– 53% for all variants using classic ploughing; and: manure - 32%, straw - 26%, floating bog – 37%, floating bog + *Trichoderma* – 28%, straw + *Trichoderma* – 10%, zeolite – 12% and Na humate – 14% for all variants where no tillage was applied (table 2).

Table 2: Crop yield of agrarian cultures

Test variants	Wheat (mass of sheaf, g/m^2) 2011	Barley (mass of sheaf, g/m^2) 2012	Sugar beet (mass of root plants, kg/m^2) 2013
mouldboard ploughing			
Control	2000,0	401,7	7,7
Floating bog+ N60P60	2900,0	463,3	8,4
Floating bog + Trichoderma +N60P60	3066,7	471,7	10,2
Manure	3500,0	510,0	10,0
Straw + N60P60	3566,7	413,3	7,0
Straw + Trichoderma +N60P60	3666,7	483,3	8,7
Zeolite	2466,7	343,3	5,6
Na humate	3300,0	383,3	7,0
No tillage			
Control	1950,0	393,3	5,5
Floating bog + N60P60	2733,3	466,7	8,0
Floating bog + Trichoderma +N60P60	2433,3	570,0	7,5
Manure	2316,7	783,3	7,4
Straw+ N60P60	2483,3	470,0	4,8
Straw + Trichoderma+N60P60	2000,0	568,3	6,2
Zeolite	2250,0	380,2	5,6
Na humate	2283,3	386,7	6,4

Conclusion

The use of organic fertilizers and plant residues treated with the fungicide *Trichoderma* contributes to an improvement of the agrochemical properties of typical leached chernozem – the quantity of humus, loose phosphorus, potassium, as well as alkali-based hydrolysable nitrogen increases in soils. This leads to a greater productivity of land.

In light of the quantitative and qualitative characteristics of the soil cover, the applied fertilizers can be placed in an ascending sequence according to their effectiveness: Zeolite – Na humate – Floating bog – Straw – Floating bog + *Trichoderma* – Straw + *Trichoderma* – Manure.

Rated upon their effect on the soil properties and the productivity of land, plant residues treated with fungicides *Trichoderma* don not substantially differ from manure. Next to the reasoning above, the use of floating bogs and straw as organic fertilizers additionally provides a solution to the ecological problem of their efficient utilization.

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