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Risk Assessment of the Agricultural Pollution with Nitrates in Latvia
Lauksaimniecības izraisītā nitrātu piesārņojuma riska analīze Latvijā

Viesturs Jansons, Kaspars Abramenko, Laima Bērziņa
Department of Environmental Engineering and Water Management, LLU
LLU Vides un ūdenssaimniecības katedra
e-mail: Viesturs.Jansons@llu.lv
Regīna Timbare
Centre for Agrochemical Research
Agroķīmisko pētījumu centrs
e-mail: Regina.Timbare@apcentrs.lv

Abstract. The legislation of the EU and Latvia obligate the control and mitigation of the environmental impact of the agriculture (nitrate pollution). The article summarises the main results arising from long-term measurements of nutrient concentrations within agricultural run-off monitoring programme. The assessment of the long time data series (1994-2007), obtained from the non point source agricultural run-off monitoring programme, has shown that nitrate nitrogen concentrations depend on the scale of monitoring system (drainage plot, drainage field, small catchment) and intensity of agricultural production system. The available long-term data series and use of the probability curves allow the assessment of the variations of nitrate concentration on the scale of the plot, drainage field and small catchments. The article provides the estimation of risk exceeding the threshold limits (11.3 mg L^{-1} NO_3-N) of the nitrates concentrations. High risk to reach nitrates concentrations over the limits has been found (about 30% of samples) in the field drainage of Bērze monitoring site. With regard to the small catchments' scale nitrates concentrations over limits could be expected (15% of samples) in the Bērze catchment with high intensity of agriculture. To some degree the presented study and interpretation of nitrate data may be used for designation of water quality standards and designation of nitrate vulnerable zones.
Key words: agriculture, nitrates, pollution risk.

Introduction

Most of the human activities may have a significant impact on the environment. For agriculture the pollution risk is related to accumulation of persistent contaminants and to leaching of nutrients to the groundwater and surface water (European Environment Agency, 2005; Executive Summary …, 2003). At the moment HELCOM is working extensively to control the environmental impact of agricultural sector in the Baltic Sea coastal states (HELCOM Baltic …, 2007). Intensive farming production systems result in the nutrient pollution of inland waters. According to the PLC assessments agriculture by far is the polluter number one for the Baltic Sea basin (The Baltic Marine …, 2003; Executive Summary …, 2003) and the main source of nitrogen implication as the basic nutrient in the development of algal blooms, whether in fresh, estuarine, coastal or marine waters.

Certainly the share of agricultural contribution to the non-point source pollution varies widely due to a complex impact of land use, cropping system, soil type, climate, topography, hydrology, animal density and nutrient management techniques (Position Statement …, 2000). However, it is clearly set out that in the natural water ecosystems nutrient pollution always is presented to some extent and could be determined by the background concentrations. In other words, water quality is a net result of both natural and anthropogenic factors due to the different origin of the nutrients. Most often, we are not being able to see visually poor run-off quality in the tile drains, drainage channels, and small streams. However, it is clearly set out by many authors (Vagstad et al., 2001a; 2001b; Haygarht, Jarvis, 2002; Guidelines for the Monitoring …, 2004; Kyllmar et al., 2006) that water leaching from the soil transports large amount of the nutrients (N; P; K and microelements) that can contribute to the nutrient enrichment of the surface water ecosystems and eutrophication.

Both the EU Nitrates Directive (ND) and Water Framework Directive (WFD) require that Latvia like all the Member States control the impact of agriculture on the surface and ground waters (Jansons et al., 2005). When assessing the results of water monitoring, it should be considered whether all the territory of Latvia or only part of it, with the highest impact of agriculture measured in terms of high nitrate content (≥50 mg L^{-1}) or eutrophication phenomena, should be designated as nitrate vulnerable zones (NVZs). In addition, the risk that in the near future freshwater bodies or marine waters may contain more than 50 mg L^{-1} nitrates (11.3 mg L^{-1} NO_3-N) become euthropic, if actions in agriculture are not taken, also is a relevant aspect for designation of the NVZs. Due to the lack of monitoring data the first designation of vulnerable zones in Latvia was performed using GIS Multi-Criteria decision-making analysis. The risk assessment was based on the data on soil and groundwater media, run-off, potential erosion risk, agricultural activities, such as agricultural land and arable land use, animal density, soil drainage, and application of fertilizers (Jansons et al., 2005). Factor weights have been computed according to the results of expert evaluation. The resulting impact data layer yields a map for the potential agricultural risk areas in Latvia. Finally, part of the territory in the central part of country, in the Lielupe river basin or Dobele, Jelgava, Bauska and Riga administrative regions, with the most intensive agricultural production and highest pollution risk today, was designated as NVZs. The designation of NVZs should be revised every four years; unless not the whole territory of the country is designated as NVZ.

In conformity with the EU and national legislation (LR MK noteikumi Nr. 531, 2001) Water monitoring and Action Programme should be implemented in Latvia for water quality assessment and nutrient pollution control. The environmental conditions of the Baltic Sea, and particularly the Gulf of Riga, are still a matter of great concern. The results from the Gulf of Riga project showed that eutrophication still prevail with a moderately high primary production. The results have also showed that the Gulf of Riga is basically nitrogen limited (Stalnacke et al., 1999; Vagstad et al., 2000).

The considerable amount of the nitrogen concentration data and information necessary to carry out risk assessments is already accumulated during the implementation of the agricultural run-off monitoring programme in Latvia University of Agriculture. However, the study also shows that the agricultural contribution to the nutrient loads is extremely variable over time and space (between catchments). Therefore nutrient concentrations usually vary considerably from year to year and interannually (Haygarht, Jarvis, 2002; US Geological Survey, 1999; Stalnacke, 1996). That large amount of data and information is far from being fully and adequately used. There is need to develop capacities to interpret data and to carry out risk assessments to be able to conduct a detailed evaluation of nitrogen concentrations, and making it more easy to draw conclusions on the vulnerability of agricultural territories.

Materials and Methods

HELCOM recognizes (HELCOM Baltic …, 2007) that countries should apply harmonised principles and methods for quantifying non point losses throughout the Baltic Sea catchment area in order to obtain comparable and reliable estimates on the waterborne inputs from both point sources and non-point sources entering into the Baltic Sea. The similar task is proposed and attempts on harmonisation have been made in different EU documents and research papers (Implementation of Council Directive …, 2002; Guidelines for the Monitoring …, 2004; Ital, 2005). Agricultural run-off monitoring network in Latvia was established with the assistance of the Nordic countries (Sweden, Norway) using the same monitoring methods and technologies (Jansons, 1998; Vagstad, 2001a; Lauksaimniecības noteču …, 2003; Deelstra et al., 2004).

The inland water bodies receive nitrogen and phosphorus emissions which are a net result of both diffuse and point source pollution. In the assessment of non-point agricultural pollution, it is crucial to be able to control nutrient emissions and exclude other loads, i.e., from point sources: large livestock farms and wastewater from households. Therefore, an agricultural non-point source monitoring programme (Jansons, 1998) in Latvia was implemented in 3 small agricultural catchments (Bērze, Mellupīte and Vienziemīte streams) with ordinary agricultural practice and in 3 drainage fields within these catchments (Fig. 1). A description of monitoring sites is presented in Table 1.

The soils at the monitoring sites are imperfectly to poorly drained. Therefore most of the agricultural land in the small catchments is drained with tile drains (depth 1.1-1.3 m, and internal spacing between drains 10-32 m). Tile drainage in drainage fields has surface run-off inlets, which may result in direct inflow of eroded soil particles during flood periods. Due to the presence of a calcareous material soil pH is rather high (pH_{H2O}=6.7-7.9). The status of major plant nutrients ranges from good (Bērze site: C_{org}=1.2%, N=0.15%, $P_{AL\ method}$=10.5 mg 100 g^{-1}) to moderately good (Mellupīte site: C_{org}=1.2%, N=0.08%, $P_{AL\ method}$=8.3 mg 100 g^{-1}).

Due to the specific water balance conditions of humid climate (Jansons, 1998; Vagstad et al., 2000; Deelstra et al., 2005; Ital, 2005; Kyllmar et al., 2006), the assessment of the nutrient leakage in Latvia has been implemented in 3 geographical scales/levels (Fig. 2):

– firstly, soil, plant, nutrient, and water relationships could be studied on the plot level. In such experiments data of the nutrient leaching from farmland with both different application rates and times of mineral or organic fertilizers for various crops and soil management might be studied;

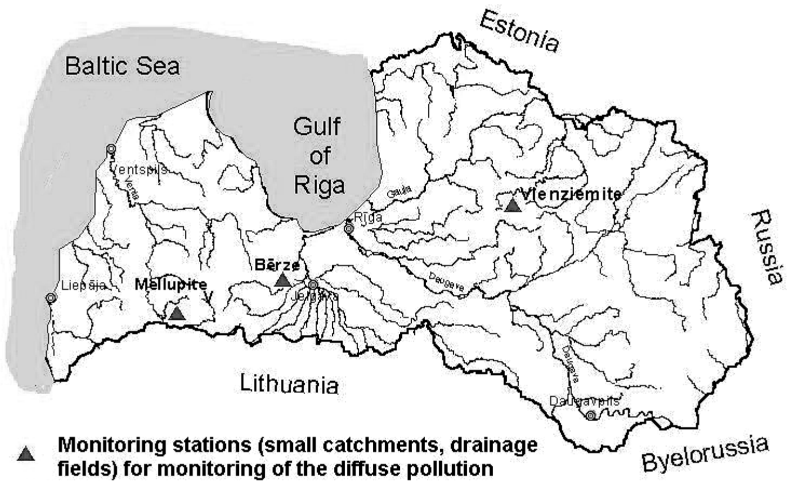

Fig. 1. Agricultural run-off monitoring stations and points (LLU data).

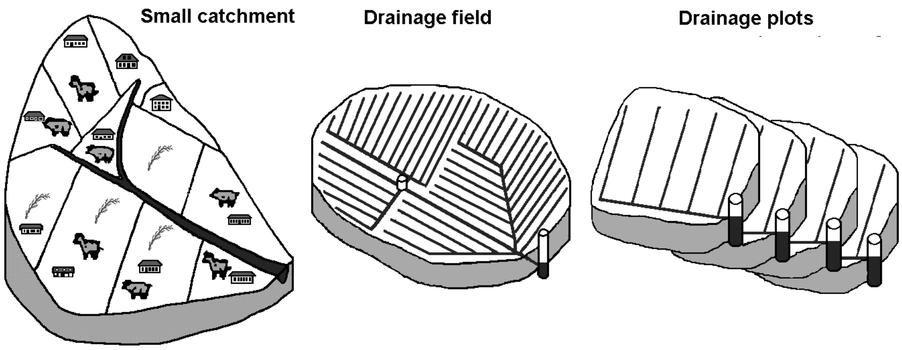

Fig. 2. Scales of the agricultural run-off monitoring in Latvia (LLU data).

– secondly, nutrient losses from arable land could be measured on a field level. Field scale run-off represents an integrated effect of farming practice, crop rotation, application of fertilizers, etc. on the water quality;
– the third level is a small catchment (watershed) scale. The climate and agricultural practices influence the nutrient transport in a stream. There are no point sources in the catchments. The integrated influence on run-off of variations in farming practices, erosion, soil, and topography within the drainage basin might be studied in a better way than in the field scale.

The measurements (Table 1) in Bērze, Vienziemīte and Mellupīte catchments were based on fixed measurement structures, i.e., Crump, V-shape and combined profile weirs and automatic data loggers, and sampling equipment for continuous water level registration and automatic water sampling. Collection of the composite water samples were based on a flow proportional sampling procedure. One flow-proportional composite sample consists of a large number of sub-samples gathered during a period of one month. Logger triggered sampling frequency was 10-15 sub-samples per day. Tipping buckets with magnetic switches are installed in the cellar of a monitoring station and have been used for drainage plot discharge recording and water sampling. The measurements in the Bērze and Vienziemīte catchments were started in 1994, while in 1995 they were started in the Mellupīte catchment.

The Bērze catchment is characterised by relatively intensive crop production as compared to the present average conditions in Latvia. The landscape is flat lowland and 98% of the catchment soils are cultivated. Due to natural high soil fertility, winter wheat, sugar beets and winter rape have become the main crops in the Bērze catchment. The share of arable crops increased up to 80-90% during 1997-2007. Farmers use modern equipment, and rather intensive technology for the Baltic conditions, e.g., an average fertilizer application amounting to 100 kg N ha^{-1} $year^{-1}$, but in few fields the use of fertilizers reached 300 kg N ha^{-1} $year^{-1}$ in 2007.

Table 1

Description of the agricultural run-off monitoring sites in Latvia

Site, level of monitoring	Measurement methods	Area, ha	% cultivated	Soil (WRB 2006)	Intensity of agriculture, arable land, %
Bērze					
Small catchment	Data logger, automatic sampling	368	98	Haplic Cambisol (Calcric)	Intensive grain farming, arable land 80-90% within the catchment.
Drainage field	Data logger, automatic sampling	77	100	Silty clay loam	
Mellupīte					
Small catchment	Data logger, automatic sampling	960	69	Stagnic Luvisol	Moderately intensive farming representing the average situation in Latvia, arable land 60-70% within the catchment.
Drainage field	Data logger, automatic sampling	12	100	Loam and clay loam	
Drainage plots (15 plots)	Data logger, automatic sampling	0.12	100		
Vienziemīte					
Small catchment	Data logger, manual sampling	592	78	Haplic Cambisol (Chromic)	Low input farming, arable land 4-5% within the catchment.
Drainage field	Recorder, manual sampling	67	100	Sandy loam	

The landscape in Vienziemīte catchment is rather hilly for the Baltic conditions. Soil, slopes, and market conditions are less favourable for agriculture, and only two farms in the catchment are producing something for the market. Almost no fertilizers (only 4-5 kg N ha^{-1} $year^{-1}$) were applied in the catchment. During the measurement period 1994-2007 most of the farmland was abandoned land or low productivity grassland. The Vienziemīte catchment is a typical example of low input agricultural land use, and can be used as a reference site for diffuse pollution.

The Mellupīte catchment represents the average farming conditions and could be considered typical for the present agriculture in Latvia. Several large farms are using intensive agricultural technology, whereas a few farms are producing only for self-consumption with low fertilization rates and without pesticides. During the period of 1994-2007 the use of the fertilizers and pesticide increased slowly, the average use of mineral fertilizers changed from 10 to 70 kg N ha^{-1} $year^{-1}$. The highest application rates in farms with intensive technology reached 155 kg N ha^{-1} $year^{-1}$ in 2007.

Nitrogen analyses of water samples (N_{tot}, NO_3-N, NH_4-N) were carried out according to the standard methods (LVS 340:2001, LVS 339:2001, LVS ISO 7150/1-1984). Laboratory analyses with the standard methods were combined with measurements of nitrate concentrations with the multiparameter sonde YSI 6920-C-M. Sonde monitors several water quality parameters simultaneously at the user-selectable intervals. In order to provide an accurate assessment of the short term changes, in response to the changes in precipitation and discharge, the measurements with sonde were started in autumn 2006. Nitrate sensor application range is 0-200 mg L^{-1} for NO_3-N, resolution (0.001-1 mg L^{-1} for NO_3-N) depends on the measurement range, and sensor accuracy is ±10% of reading. The analyses of the soil mineral nitrogen were carried out in the "Centre for Agrochemical Research" with standard methods (LVS EN ISO/IEC 17025).

Results

Nitrate Concentrations

Small catchment and drainage field scale. Generally, during dry periods in summer drainage and sometimes run-off in the catchment scale was not observed. Composite water samples in drainage and catchments' scales were analysed once a month. Total number of analysed (1994-2007) water samples depended on site, and both in drainage and catchments' scale ranged between 120 and 170.

The highest average nitrate concentrations were observed in Bērze monitoring station (Table 2).

Table 2

Nitrate concentration in the run-off of field drainage and small catchment, 1994-2007 (LLU data)

Monitoring site	Number of samples	NO_3-N concentrations, mg L^{-1}			CV, %
		average	minimal	maximal	
Small catchment scale					
Mellupīte	151	2.71	0.01	14.30	87
Bērze	156	7.31	0.01	20.90	66
Vienziemīte	172	0.84	0.01	4.09	89
Field drainage scale					
Mellupīte	121	6.57	0.13	16.60	42
Bērze	144	10,70	1.30	97.30	87
Vienziemīte	164	0.81	0.02	5.70	99

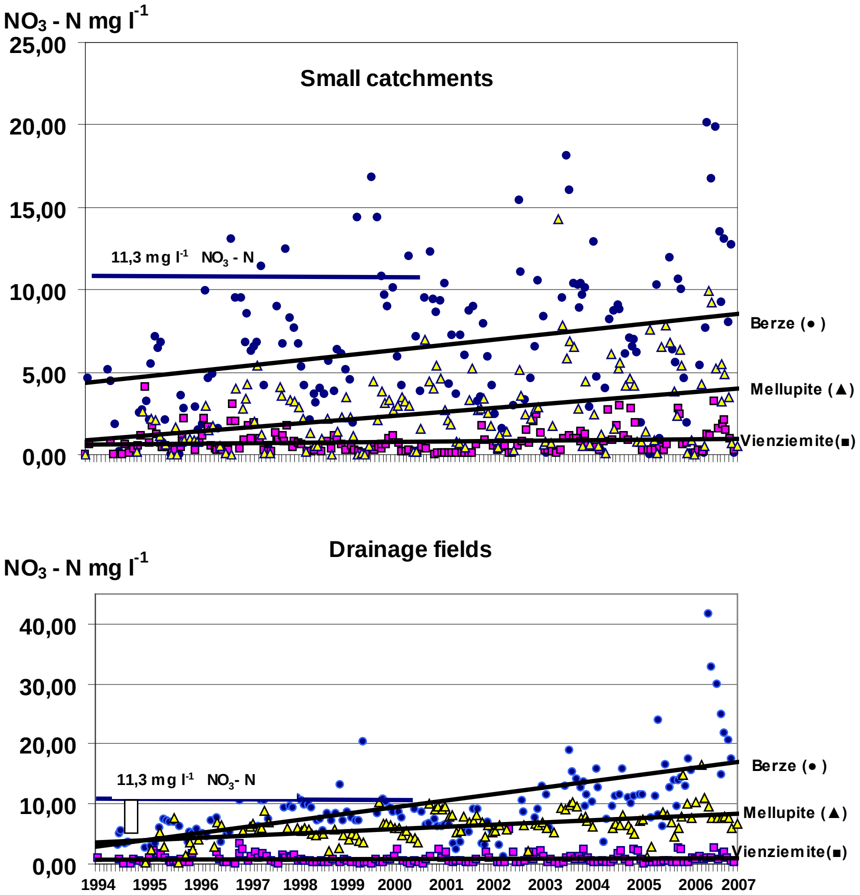

Fig. 3. Nitrate concentrations in small catchments and drainage fields, 1994-2007 (LLU data).

Nutrient concentrations in all monitoring sites varied throughout the year, largely in response to the changes in precipitation, ground water level and flow rate. The coefficient of the variation ranged from 42% to 99%. In the autumn of 2006, after dry and hot summer, the highest nitrate values were measured. With regard to the Nitrate Directive, it should be noted that the threshold values of nitrate (11.3 mg L^{-1}) established by directive was often exceeded.

Nitrogen concentrations in drainage run-off from fields with intensive farming were higher than in the catchment scale in Bērze and Mellupīte monitoring sites. These monitoring sites both catchments' and field scale nitrate concentrations show up ward trend (Fig. 3). In Vienziemīte site the variation of nitrate content between the field and catchment scale in not high, and concentrations are close to natural background values. There, with low input agriculture,

Table 3

Nitrate concentration in the run-off from drainage plots, 1994-2007 (LLU data)

Fertilization	Number of samples	NO_3-N concentrations, mg L^{-1}			Standard deviation	CV, %
		average	minimal	maximal		
Without fertilizers	52	9.37	3.65	23.96	3.81	41
Normal fertilization rate	49	10.02	3.00	30.10	4.96	50
High fertilization rate	48	10.67	2.31	23.76	4.26	40
Solid manure	48	11.11	3.80	39.97	6.59	59
Slurry	48	11.44	5.00	27.00	4.91	43

long term water quality data does not show nitrate upward trend.

Drainage plot scale. Due to the limited size of one plot (0.12 ha), and therefore relatively small total length of drainage pipes collecting water flow, the duration of run-off period, total discharge and number of collected samples was smaller than in the field and catchments' level. Plot drainage discharge most often occur during spring and autumn flood periods. Plots have no structures for surface run-off inflow, i.e., the impact of water erosion on water quality is excluded. Therefore, it is not surprising that nitrate content variation that ranged from 41% to 59% (Table 3) was lower than in drainage field and catchments' scale.

Discussion

Evaluation of the nitrate pollution risk. The contribution of agriculture to the non-point source pollution varies widely as a complex function of land use, cropping system, soil type, climate, topography, hydrology, animal density, and nutrient management techniques (Position statement …, 2000). Moreover, long term data series of nutrient values (1994-2007) reflect the variation in water quality in both spatial and temporal terms, e.g., from year to year and interannually. Probability analysis that is a common method in hydrologic studies could be used to describe the water quality, e.g., the likelihood of an event where an event is defined as occurrence of a specified value of the random variable (McCuen, 1998; Ward, Robinson, 2000; Gordon et al., 2004). A number of different probability functions can be used to represent a random variable (water sample), and to determine the probability of occurrence. A probability curve is presented as a cumulative distribution function. Gamma frequency curve was recommended by Sudars et al. (2005) to evaluate risk of the water pollution in agricultural point source monitoring catchments. Small catchments' run-off quality described with the probability curves for the nitrate values are presented in Figure 4. Comparison of all water samples, tested with these reference values, showed that approximately 85% of the Bērze catchments samples (Fig. 4) and over 70% of the field drainage samples had values below the threshold level.

In the Mellupīte site only few water samples from both catchment and drainage field values had exceeded threshold limits of the directive. In the Vienziemīte site high nitrate pollution risk was not observed.

Both winter (October to March) and the concentrations in early spring, measured just before the significant algal growth started in water bodies, should be estimated as an important factor contributing eutrophication phenomena of surface water bodies (Guidelines for the Monitoring …, 2004). Moreover, the relatively large proportion of N loss during the winter period indicates that a considerable part of diffuse pollution has been generated through infiltration into the frozen or partly frozen soils. Therefore the assessment of winter concentrations of nitrates in the drainage (Fig. 5) and small catchments' run-off has high importance considering control of the nutrient leakage.

The average nitrate concentration has a tendency to increase in the plots with higher fertilization rate and with animal manure applications, e.g., nitrate concentration in run-off from non fertilized plots was lower by 2.1 mg L^{-1} than from plots with slurry application. Difference of the mean values is small. In that context, it can be mentioned that the nitrate trends have not statistical significance for the given number of samples and confidence level α=0.05. Therefore, our risk analysis is based on the preposition that concentrations of nitrates in the discharge from plot drainage represent one sample population.

Extremes of the nitrate concentrations. Monthly sampling frequency is insufficient to cope with the high variability of nutrient concentrations. Especially for the smaller catchments and field drainage run-off, the monitoring results suggest the necessity to consider hourly water quality measurements for better

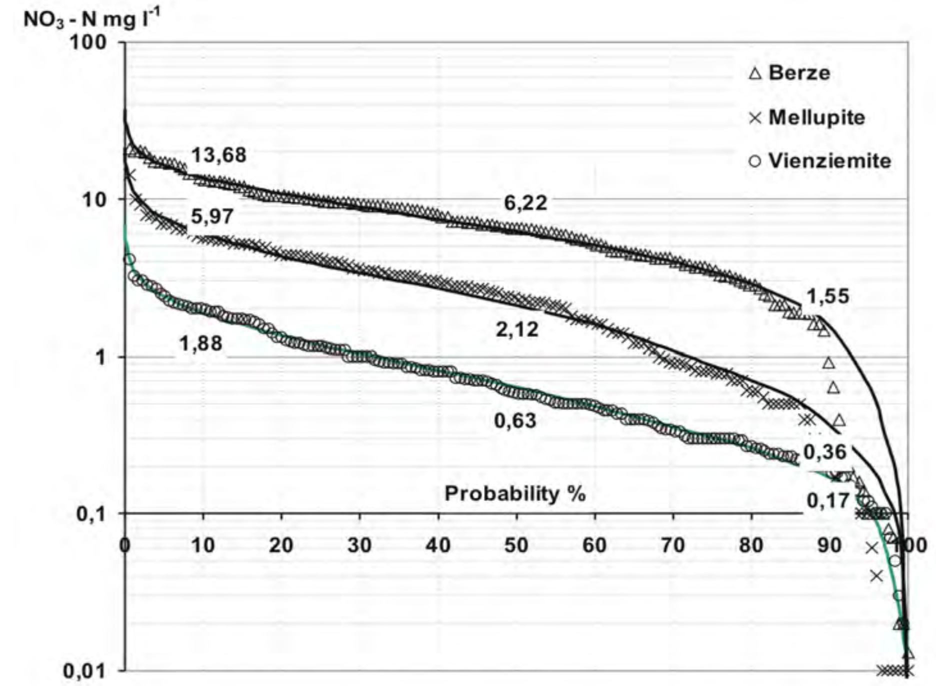

Fig. 4. Probability curves for the nitrate values in the small catchments' run- off.

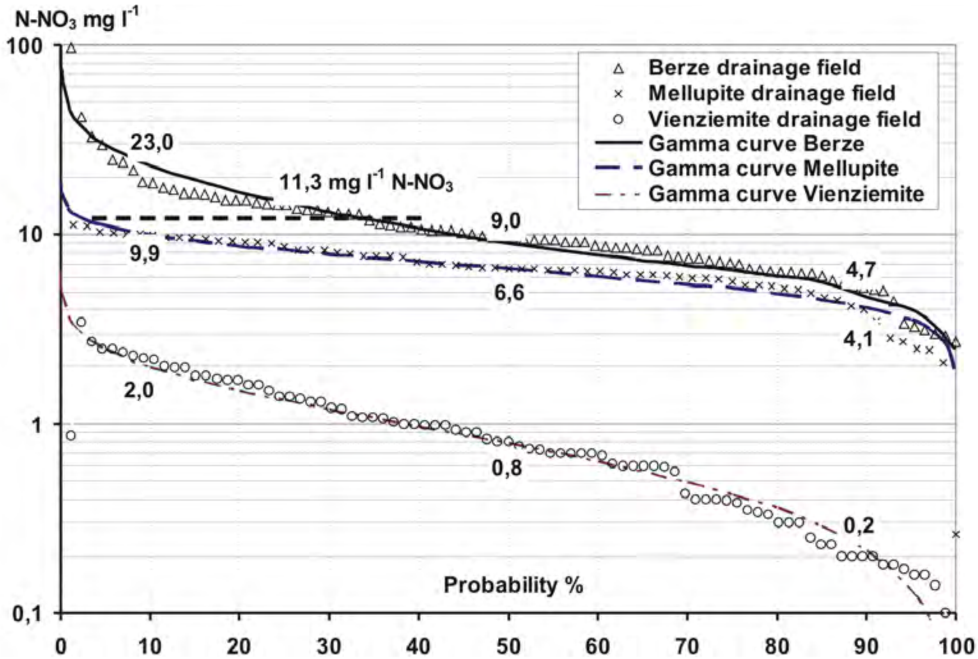

Fig. 5. Probability curves for NO_3-N winter concentration in the drainage field run-off (LLU data).

interpretation of hydrological processes and their possible effects on nutrient loss. Nitrate monitoring with sonde at the user-selectable short time intervals started in autumn 2006. Surprisingly high nitrate values in Bērze drainage field run-off were found in November 2006, when drainage run-off appeared after dry summer-autumn period (Fig. 6). Nitrate concentration (41.6 mg L^{-1} in 21 November 2006) found in the water sample analysed in laboratory, proved the accuracy of measurement results with sonde.

About 40% of the Bērze drainage water samples (Fig. 4) and over 5% of the Mellupīte field drainage samples had values higher than the threshold level

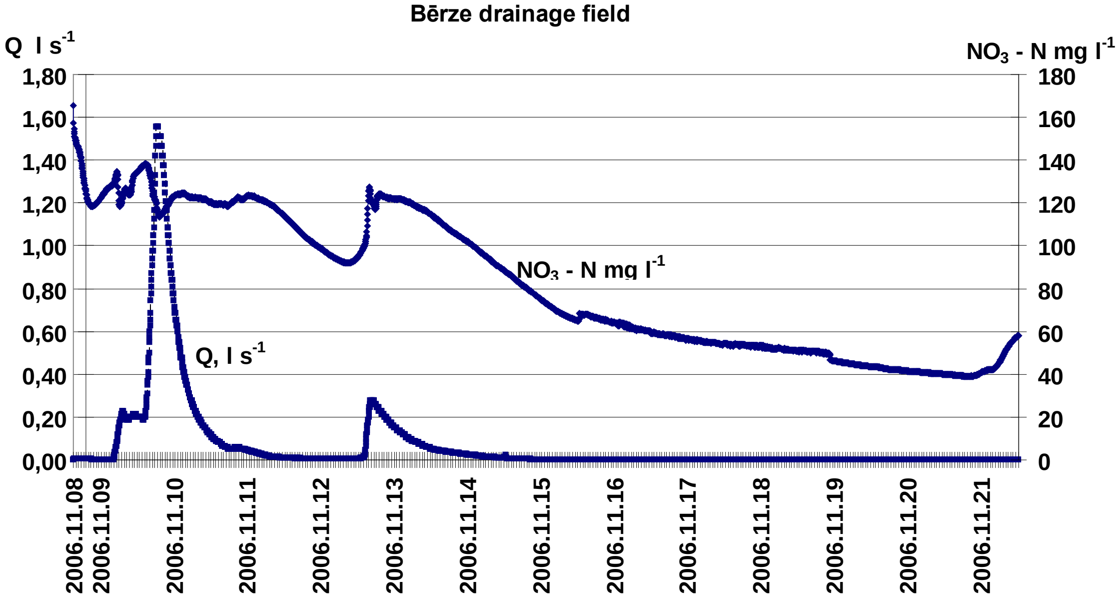

Fig. 6. Nitrate run-off extremes in Bērze drainage field run-off, sonde measurement intervals – 15 minutes, November 8-21, 2006 (LLU data).

Table 4

Values of the nitrate concentrations from Gamma probability curves (LLU data)

Monitoring site/scale	NO_3-N, mg L^{-1} (winter concentrations/annual concentrations)						
	Probability, %						
	1	5	10	25	50	75	90
Bērze							
Drainage field	**45.7/36.0**	**29.7/23.2**	**23.0/18.2**	**15.0/12.3**	9.0/7.9	6.5/6.0	4.7/4.4
Small catchment	**24.4/22.7**	**18.2/16.4**	**15.3/13.7**	11.2/9.8	7.6/6.2	4.8/3.4	3.1/1.6
Mellupīte							
Drainage plots	**27.9/25.8**	**21.2/20.4**	**18.1/17.7**	**13.7/13.7**	9.9/9.9	7.0/6.8	5.8/5.5
Drainage field	**13.3/14.5**	11.0/**11.6**	9.9/10.3	8.2/8.3	6.5/6.3	5.2/4.6	4.1/3.3
Small catchment	**10.6/11.2**	7.8/7.5	6.6/6.0	4.7/3.8	3.1/2.1	1.9/0.9	1.2/0.4
Vienziemīte							
Drainage field	3.6/3.8	2.5/2.5	2.0/1.9	1.3/1.2	0.8/0.6	0.4/0.2	0.1/0.1
Small catchment	3.8/3.6	2.6/2.4	2.1/1.9	1.4/1.2	0.8/0.6	0.4/0.3	0.2/0.2

set by ND. Due to the climate in Latvia the cycles of drying and wetting may have a significant effect on the rate of mineralization, and freezing and thawing of the soil may stimulate elevated soil nitrate concentration upon thawing. The nitrate anion is highly soluble in water, and therefore subject to movement in any water leaving the soil by drainage down the profile and run-off from the soil surface. Most of run-off and erosion events take place during winter conditions. Both winter and annual concentration values obtained from probability curves are presented in Table 4. Generally, except part of Mellupīte drainage field data, winter data show higher pollution risk than full year data set. The problem, with regards to mitigation of nitrate leakage, is that farmers have not wide variation of actions needed to achieve the agreed environmental objectives during winter and spring flood period when the highest concentrations and nutrient loads take place.

Risk of the nitrate run-off extremes. As it was shown in Figure 6, the nitrate concentration may be extremely high. VSIA "Centre for Agrochemical Research" in several fields of Jaunbērze municipality has analysed mineral nitrogen. Data of the soil mineral nitrogen, presented in Table 5, provide the information on soil leakage potential in the autumn of

Table 5

Content of the soil mineral nitrogen, autumn 2006-spring 2007, data of of the Centre for Agrochemical Research

Field	Soil layer, cm	Content of the mineral nitrogen, mg kg^{-1} dry soil			
		autumn 2006		spring 2007	
		NO_3-N	NH_4-N	NO_3-N	NH_4-N
Silarāji	0-30	21.4	6.6	2.6	4.1
	30-60	6.8	3.3	6.1	3.1
	60-90	1.3	2.7	8.2	2.7
Klaipiņi	0-30	16.6	4.1	7.1	2.9
	30-60	3.3	3.3	5.7	3.1
	60-90	0.9	3.4	5.1	2.6
Puķes	0-30	11.4	3.9	3.4	3.5
	30-60	1.7	3.1	3.1	3.2
	60-90	1.3	2.6	2.4	2.7
Vāverītes	0-30	14	4.1	3.5	3.2
	30-60	9.6	3.4	5.5	3.4
	60-90	1.9	3	4.9	3
Kāpas	0-30	34	3.7	5.9	3.7
	30-60	18.9	3.7	7.9	3.3
	60-90	7.1	3.2	11.3	3.1

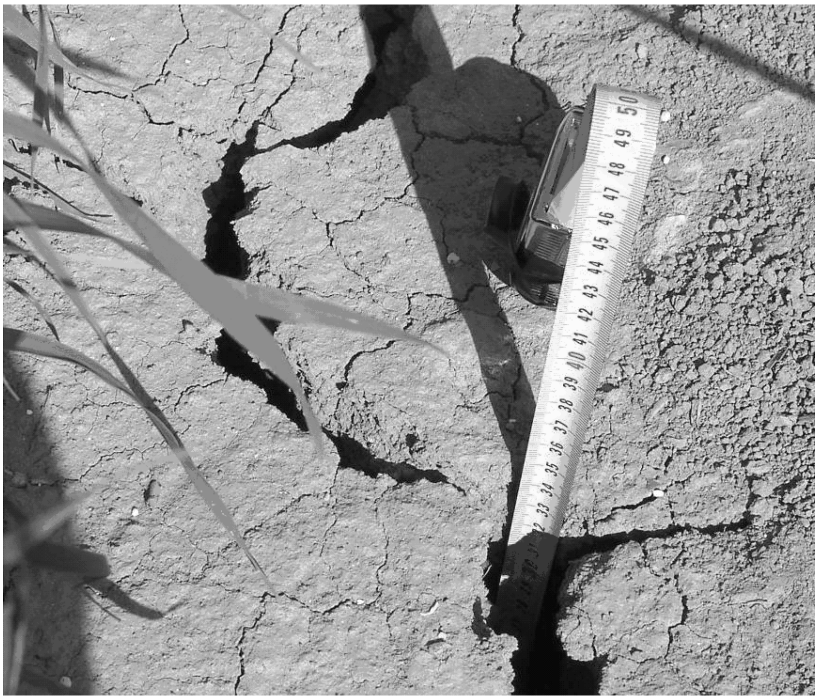

Fig. 7. Soil cracks in Bērze drainage field on June 19, 2006 (LLU data).

2006 resulting in high concentrations when drainage run-off started in November. Run-off transported considerable amount of the nitrogen that was accumulated in soil during summer and early autumn due to the dry and hot weather conditions. In addition, soil has many cracks and macropores (Fig. 7).

This nitrate leaking risk depends upon a number of factors, such as the climatic, hydrological, and soil conditions. In the case of drainage run-off, for example in Bērze site, vulnerability to pollution by nitrates (and other soluble contaminants) is greatest when:

– temperature and moisture regimes in summer promote the nitrate accumulation and probability of high soil nitrate levels;
– the composition of the unsaturated zone (including top soil) is coarse and/or has macro pores and cracks;
– intensive precipitation produce fast drainage discharge with high rate, when the period of hydrological activity started in autumn.

Conclusions

1. Long term water monitoring data (1994-2007) from agricultural run-off monitoring sites indicates that most important nitrate leaching risk factor is intensity of farming (share of arable land and land use).
2. Monitoring data in several geographical scales (plot, field and catchment) shows that the highest nitrate values exceeding 11.3 mg L^{-1} NO_3-N belong to run-off from drainage plots. Retention of nitrates decreased nitrate concentrations in field and small catchments' scale.
3. The results of risk assessment shows that the highest impact of agriculture measured in terms of high nitrate content was observed in the territory designated as nitrate vulnerable zones (Bērze monitoring station).
4. The real time measurements with nitrate sensor shows that concentration peaks are observed relating to high flow conditions and high content of the mineral nitrogen in soil. The risk of nitrate pollution is greatest when levels of available nitrate in the soil profile (especially in the soil surface) are high, and coincide with other circumstances which add to the vulnerability of underlying or adjacent waters to diffuse pollution.
5. Extreme weather conditions in summer and winter, due to the climate change in the future, might increase the nutrient concentration in agricultural run-off and role of diffuse pollution.

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Anotācija

ES un LR pieņemtie likumdošanas akti prasa kontrolēt un ierobežot lauksaimniecības izcelsmes nitrātu piesārņojuma ietekmi uz ūdens vidi. Rakstā apskatīti ilggadīga (1994–2007) izkliedētā (difūzā) lauksaimniecības piesārņojuma monitoringa rezultāti, kas liecina, ka nitrātu slāpekļa koncentrācijas ir atkarīgas no monitoringa sistēmas līmeņa (izmēģinājumu lauciņi, drenu lauks, mazais sateces baseins) un lauksaimnieciskās ražošanas intensitātes. Izmantojot ilggadīgās datu rindas un nitrātu piesārņojumu raksturojošās teorētiskās ilguma līknes, parādītas nitrātu savienojumu koncentrāciju atšķirības izmēģinājumu lauciņu, drenu lauku un mazo sateces baseinu līmeņos. Novērtēts nitrātu koncentrācijas robežlieluma (11.3 mg L^{-1} NO_3-N) pārsniegšanas risks. Augsts robežvērtības pārsniegšanas risks pastāv notecēs no drenu lauka (30% gadījumu Bērzes monitoringa stacijā). Mazo sateces baseinu līmenī nitrātu robežvērtība visbiežāk (15% gadījumu) tiek pārsniegta Bērzes monitoringa stacijā platībās ar intensīvu lauksaimniecību. Pētījumu rezultātus var izmantot ūdens kvalitātes standartu pamatošanai lauksaimniecībā izmantojamās platībās un īpaši jūtīgo teritoriju noteikšanai.

Analysis of *Toxocara* Infection
Toksokarozes invāzijas analīze

Pēteris Keidāns, Anna Krūklīte, Ruta Medne
Institute of Food and Environmental Hygiene, LLU
LLU Pārtikas un vides higiēnas institūts
e-mail: Ruta.Medne@lzra.gov.lv

Abstract. Several cases of human infection with *toxocara* are registered every year in Latvia. Humans are being infected by *T. canis* and *T. cati*. Epizootical situation was investigated, analysing data from 1 January 1999 to 31 December 2007 of the Public Health Agency. Sand samples of 49 sandboxes of children playgrounds were examined to assess the environmental infestation and possible human infection risk sources. The infection intensity (II) and infection extensity (IE) were established in home and stray dogs and cats as well as IE in foxes. The extensity of *Toxocara* infection (IE) in dogs was 23.03%, in cats IE was 45.10%, but in foxes – 48.0%, as well as both IE and II were higher in stray animals than in home animals. Besides, IE and II were higher in young animals (up to one year) compared to older ones. A very high IE (18.4%) was found in sandboxes of children playgrounds.

Key words: Toxocarosis, *T. canis*, *T. cati*, risk, human.

Introduction

Nowadays dogs and cats are not rarity at our homes. Humans have domesticated these animals and have taught them to be docile and to do various tasks, at the same time creating a risk to contact different parasitizes common to animals and human. Literature analysis shows that in many countries 3-80% of dogs are infected with *Toxocara canis* and surroundings are contaminated with *Toxocara* eggs (Straume, 2004; Акбаев, 1998; Overgauw, 1997; Greene, 1990; Eckert, 1992). *Toxocara* eggs can resist frost, moisture, sharp pH change, and can survive in the soil from one to two years. If the dogs or animals of other species, or humans (non-specific host) swallow embrionised parasite eggs, the larvae hatch in the small intestine within one or two days, and then they migrate through the blood stream, liver, lungs, other organs, and tissues causing various lesions.

In puppies, a typical migratory course of *T. canis* is from the lungs to the trachea through the mouth and finally larvae establish themselves in the small intestine were they sexually mature within 10 days. Eggs appear in the puppy faeces in three to four weeks following infection. Infection in young puppies may be responsible for pneumonia, dyspnoea, salivation, weight loss, abdominal distension, dull coat, sometimes vomiting, dermatitis, intestinal torsion, or rupture (Straume, 2004; Eckert, 1992; Акбаев, 1998). In most dogs older than six months and in non-specific hosts, including humans, somatic tissue migration of larvae takes place, when they pass through the lungs to the heart, then through the systemic circulation to various tissues (muscles, kidneys, eyes, brain etc.), and finally they encapsulate retaining vitality for several years (in humans up to 9-10 years). In older dogs, matured parasites usually are found in small number. During the perinatal period, the immunity of the bitch is partly suppressed, and substantial numbers of eggs may be passed in faeces. In pregnant bitches, somatic *T. canis larvae* reactivate on the 40th-42nd day of pregnancy, presumably due to the presence of prolactine and migrate to the placenta where they establish a prenatal infection; or a transmammary transmission occurs when puppies are infected via the milk of the bitch till the 35th day after birth (lactogenic infection). Bitches may infect puppies at the prenatal stage several litters in succession because larvae may remain in the bitch body for several years, and a repeated infection is not necessary (Straume, 2004; Overgauw, 1997; Акбаев, 1998; Greene, 1990; Eckert, 1992). In contrast, a prenatal infection does not occur in cats. *Toxocara* infection more often occurs when cats ingest meat or organs of infected non-specific host, e.g., rodents.

In humans, *Toxocara larvae* during somatic migration may cause lesions in internal organs resulting in *Visceral larva migrans* syndrome: fever, cough, difficulty in breathing, anaemia, eosinophilia, hepatomegaly, weakness, CNS disturbances etc; ocular tissue lesions resulting in *Ocular larva migrans* syndrome: impaired vision, pain, strabismus, occasionally endophthalmitis with a secondary retinal detachment, uveitis, eyeball abscess etc. The invasion more often occurs as inapparent Covert toxocarosis (Anane, 2006; Kwon, 2006; Zavadska, 2004; Overgauw, 1997; Greene, 1990; Glicman, Scanz, 1987).

Toxocarosis in animals is usually diagnosed by coprological floatation (Fuelleborn, etc.) methods but more rarely diagnosed by immunological methods (ELISA, etc.); whereas in human, diagnosis is based mainly on serological and haematological examinations. In cases of ocular and inapparent toxocarosis, eosinophilia is less expressed, and antibody titre are rather low (Акбаев, 1998; Overgauw, 1997; Eckert, 1992).

The control of toxocarosis is based on preventive measures and treatment by administering fenbendazol, menbendazol, febentel, ivermectin, levomisol, pyrantel, piperazine, and others at the same time treating symptomatically (Zavadska, 2004; Straume, 2004; Macpherson, 2000; Keidāns, 1998; Greene, 1990; Eckert, 1992). *Ocular larva migrans* cases are treated surgically and by local administration of corticosteroids (Zavadska, 2004).

The epizootical situation and toxocarosis distribution should be found out to control and prevent this infection successfully.

Hypothesis: stray animals and foxes are risk factors for human infection of toxocarosis.

The aim of the research was to find out the risk of *Toxocara* infection in humans, and to evaluate the epizootical situation in Latvia.

The following tasks were set:

– to investigate the epizootical situation of human toxocarosis in Latvia;
– to determine the distribution of toxocarosis in cats and dogs;
– to assess the infection level in foxes as a risk factor of toxocarosis;
– to determine risk factors of human toxocarosis.

Materials and Methods

The present investigation of epizootical situation of *Toxocara* infection in Latvia was based on statistical data obtained from the Public Health Agency about human infection with toxocarosis during the period of time from January 1999 to 31 December 2007.

Sand samples of 49 sandboxes of children playgrounds were examined to assess the environmental infestation by *Toxocara* eggs and larvae.

The nature of *Toxocara* infection of dogs and cats depending on the animal age, sex and lifestyle was determinated by coprological examination of standardised Fuelleborn technique (Акбаев, 2006; Keidāns, Krūklīte, 2000). Faecal samples of 521 dogs and 93 cats were examined during the investigation.

Helminthological necropsies of 48 wild foxes were performed according to K. Skryabin technique (Акбаев, 2006; Keidāns, Krūklīte, 2000). Foxes were acquired from hunters.

The nature of *Toxocara* infection of dogs and cats was determined depending on the animal age, sex and lifestyle. The risk of human infection was assessed by statistical methods.

The infection intensity (II) was calculated by the formula:

$$\boldsymbol{I} = X \pm S_X (\lim X_{\min} ... X_{\max}), \quad (1)$$

where $X \pm S_x$ – the number of parasites or eggs in one sample.

The infection extensity (IE) was calculated by the formula

$$\boldsymbol{E} = (X_{(infected)} / X_{(examined)}) \cdot 100. \quad (2)$$

Parasitological examination was carried out in the parasitology laboratory of the Institute of Food and Environmental Hygiene of Latvia University of Agriculture.

All data analyses were performed using the statistical methods (Arhipova, Bāliņa, 2000).

Results

The statistical data of the Public Health Agency show evidence that people were *Toxocara* infected from January 1999 to 31 December 2007 (Table 1).

The data given in Table 1 suggest that the number of *Toxocara* infected people fluctuated reaching the highest number of 149 cases in 2002 and the lowest number – 9 cases in 2006. In 2007 the number of infected people was 10, i.e., 0.44 of cases per 100,000 inhabitants that is 85.1% less than in 2002.

There were 498 people infected by toxocarosis from 1999 to 2003, including 355 (71.3%) in the cities and 143 (28.7%) in the country. Most of infected people amounting to 329 (66.1%) were in Riga (Epidemioloģiskie biļeteni, 1999-2003).

When establishing *Toxocara* infection in dogs and cats, animal lifestyle, age, and sex were taken into consideration.

Samples of dog and cat faeces were coprologically examined. The extensity of *Toxocara* infection (IE) (Fig. 1) in dogs was 23.03%, in cats IE – 45.10%, and in foxes – 48.0%.

As to the extensity of *Toxocara* infection (IE) according to dogs and cats lifestyle, we found out that intensity of *T. canis* infection in stray dogs (35.7%) was significantly higher ($p<0.05$) than in home dogs 13.05%.

Table 1

Number of *Toxocara* infected people from 1999 to 2007

Year	Number of infected people	Number of infected people per 100,000 inhabitants
1999	41	no data
2000	77	3.16
2001	104	4.4
2002	149	6.35
2003	127	5.45
2004	66	2.85
2005	100	4.34
2006	9	0.35
2007	10	0.44
Total	**642**	average (2000-2007) **27.34**

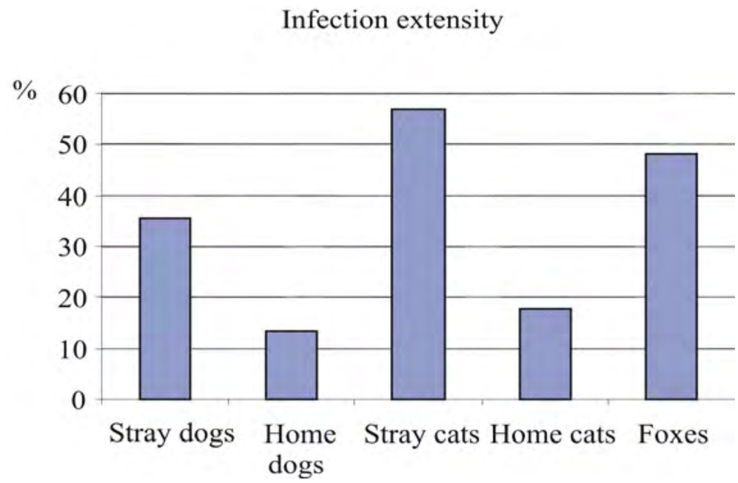

Fig. 1. Extensity of *Toxocara* infection (IE) in dogs and cats by their lifestyle, and in foxes.

As to cats lifestyle, we found out that intensity of *T. cati* infection in stray cats was 56.9% that is significantly higher ($p<0.05$) than in home cats (17.80%), consequently creating a higher risk for people to get *Toxocara* infected.

Analysing the intensity of *Toxocara* infection (II) according to dogs and cats lifestyle, Figure 2 shows that II is significantly higher ($p<0.05$) in stray cats (the mean 6±0.7 eggs per drop) and in stray dogs (the mean 8±2.0 eggs per drop) compared to home animals. The lowest II is in home dogs. Comparing II in home dogs and home cats, the data show evidence that II in home dogs is significantly lower ($p<0.05$) than in home cats.

The data of Table 2 demonstrate that intensity ($p>0.05$) and extensity ($p>0.05$) in male dogs and bitches do not differ significantly.

Investigations carried out in male and female cats show that IE was 47.6% in male cats and 37.5% in female cats meaning that the contact with male cats is more risky (Table 2).

Coprological examinations presented in Table 3 show that extensity of the infection is the highest in dogs up to one year of age – 82%, also II is the highest in this group 6±2.0 (eggs per drop) that might be associated with prenatal or/and lactogenic infection of puppies. The same situation is seen in cats (Table 3): coprological examinations show that the highest IE and II are observed in younger cats up to one year of age: 58.3% and 7±1.2 (eggs per drop) respectively.

Alongside coprological examinations, samples of 49 sand boxes of children playgrounds were examined for the presence of eggs or larvae of *Toxocara*. Nine

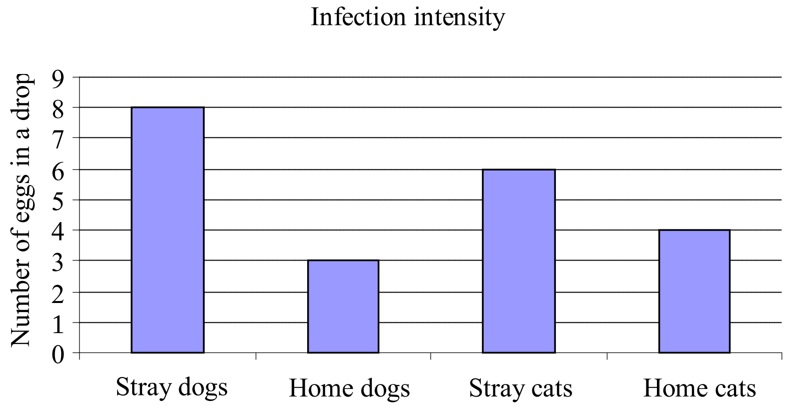

Fig. 2. Intensity of *Toxocara* infection (II) in dogs and cats by their lifestyle.

Table 2

Intensity of *Toxocara* infection (II) in dogs and cats by their sex

Sex	Number of examined samples	Number of infected animals	Infection	
			extensity, %	intensity, number of eggs per drop ±standard error
Male dogs	39	6	15.3	3±0.8
Bitches	40	5	12.5	2±1.1
Male cats	21	10	47.6	4±1.2
Female cats	24	9	37.5	3±0.8

Table 3

Intensity and extensity of *Toxocara* infection (II) in dogs and cats by their age

Age, years	Number of examined samples	Number of infected animals	Infection	
			extensity, %	intensity, number of eggs per drop ±standard error
Dogs (0–1)	67	55	82.0	6±2.0
Dogs (1–3)	21	16	76.1	3±0.4
Dogs (older)	18	8	44.4	2±0.9
Cats (0–1)	48	28	58.3	7±1.2
Cats (1–3)	15	14	31.1	5±0.8

sand boxes were Toxocara infected with extensity of the infection 18.4%.

Figure 3 presents the most important sources of *Toxocara* infection risk in humans. The highest contamination of environment comes from stray cats (40% of cases), and a little less from stray dogs (25%). Sand boxes may be the source of infection in 13% of cases.

Discussion

An increased tendency of human morbidity by toxocarosis in Latvia was seen up to the year 2002, after that it decreased, while in 2007 it increased again. The information of Public Health Agency shows that in 1999 toxocarosis was diagnosed for 41 persons, but in 2002 – already for 149 persons. The number of diseased people per 100,000 inhabitants increased more than three times in these years (Epidemioloģiskie biļeteni, 1999-2007).

This investigation assessed several risk sources of human toxocarosis. The risk of *Toxacara* infection is greater when contacting with cats than dogs. Considering that *Toxocara* eggs stick to the animal

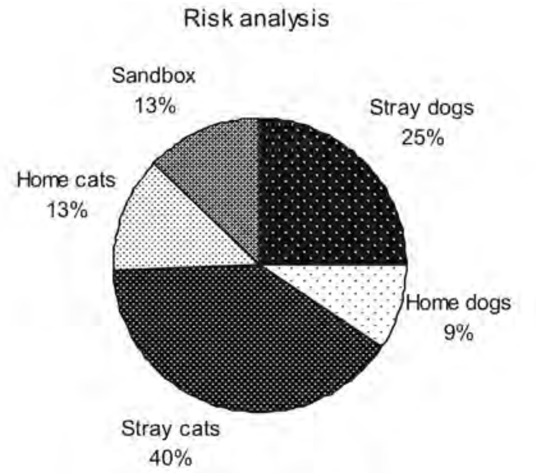

Fig. 3. Risk of toxocarosis.

hair (Buijs et al., 1994), it is important to wash hands after the contact with animals.

Habluetzel et al. (2003) established that IE (64.7%) in hunting dogs in Italy was higher than in other home dogs. The fact that hunting dogs have a contact with contaminated environment in the forests might explain this phenomenon. The present investigation revealed that IE 35.7% of stray dogs is significantly higher than IE 13.5% in home dogs. It might be explained by the weather conditions as in Latvia winters are colder than in Italy; therefore a survival ability of parasite eggs and larvae is reduced.

As *T. cati* infection was established in home cats, it means that a cat litter box is a significant risk factor. The cat litter box should be cleaned every day, and protective gloves should be used.

Literature sources present data that most of morbidity cases by toxocarosis in children are from one to four years of age (Ferreira et al., 2007; Zavadska, 2004; Buijs et al., 1994; Feldman, Parker, 1992; Glicman et al., 1987). According to the data of Public Health Agency about one third of *Toxocara* infected people were children at the age up to seven years. A high-ranking extensity of infection in sand boxes of children playgrounds is an infection risk for children.

Education of people about zoonosis and antiparasitic treatment of pets as well as good co-operation between animal owners and veterinarians would decrease the risk of *Toxocara* infection both in humans and domestic animals.

Conclusions

1. Human toxocarosis in Latvia has affected people of all ages, especially children.
2. Infection intensity and extensity is higher in stray dogs and cats, and most of cases are animals up to one year of age.
3. Foxes are a risk factor for domestic animals and humans because foxes contaminate the environment.
4. Risk of *Toxocara* infection to humans is greater by contacting with cats than dogs.
5. Risk of *Toxocara* infection to humans is greater by contacting with stray dogs and stray cats.
6. There is a risk for children to become toxocarosis infected in the sand playgrounds and playing with young pets.
7. *Toxocara* infected foxes may contaminate the forest environment causing a risk to people to become ill picking berries and mushrooms in forests and consuming without washing them.

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Anotācija

Latvijā katru gadu tiek reģistrēti saslimšanas gadījumi ar toksokarozi. Cilvēkam šo slimību ierosina *Toxocara* ģints nematodes *T. canis* un *T. cati*. Toksokarozes invāzijas epizootisko situāciju pētījām, analizējot Sabiedrības Veselības aģentūras datus laika posmā no 1999. gada 1. janvāra līdz 2007. gada 31. decembrim. Lai novērtētu toksakarozes iespējamos invāzijas avotus, apsekojām bērnu spēļu laukumus, ņēmām smilšu paraugus 49 smilšu kastēs. Noteicām toksokarozes II (invāzijas intensitāti) un IE (invāzijas ekstensitāti) mājas un klaiņojošiem suņiem un kaķiem, kā arī IE lapsām. Suņiem IE bija 23.03%, kaķiem – 45.10%, lapsām – 48.0%, turklāt gan IE, gan II augstāka bija klaiņojošiem dzīvniekiem, salīdzinot ar mājas dzīvniekiem. Arī jauniem dzīvniekiem (līdz gada vecumam) IE un II bija augstāka nekā vecākiem. Ļoti augsta IE (18.4%) bija bērnu rotaļu laukumu smilšu kastēs.

Economic Aspects of Growing Genetically Modified (GM) Rapeseed in Latvia
Ģenētiski modificēta(ĢM) rapša audzēšanas ekonomiskie aspekti Latvijā

Jānis Vanags
Faculty of Engineering Economy and Management, Riga Technical University
Rīgas Tehniskās universitātes Inženierekonomikas un vadības fakultāte
e-mail:Vanags.Janis@gmail.com
Ināra Turka
Institute of Soil and Plant Sciences, LLU
LLU Augsnes un augu zinātņu institūts
e- mail: Inara.Turka@llu.lv

Abstract. Growing of GM cultivated plants can be economically profitable for the following reasons: opportunity to gain more harvest due to the resistance to conventional diseases and pests characteristic to cultivated plants as well as opportunity to decrease costs for the use of plant protection means. Although presently there are no commercially available diseases resistant GM cultivated plants, yet only cultivated plants that are resistant to particular pests and mainly tolerant to common herbicides. Gene flow among GM herbicide tolerant plants can have important organising, economic and legal impacts on farmers due to considerably high additional costs for growing GM rapeseed crop. Farmers may incur the following costs: informational costs to avoid dissemination of GM products in sowings of other farms; costs of elimination of distribution of GM plants during their pre-processing, storage and transportation; costs for marking GM products on their presence in the corresponding item; costs of laboratory sampling and analyses; additional expenses for personnel training; expenses of maintenance of the state supervising departments; and expenses for insurance of sowings of GM cultivated plants. Growing of GM cultivated plants becomes profitable in a set territory if the net income gained by the planter of GM cultivated plants per unit of area exceeds the net income per unit of area in the case of growing conventional cultivated plants.
Key words: GM rapeseed crops, economic arguments.

Introduction

The rapid development of biotechnology offers new technologies for growing cultivated plants, and one of them is growing GM cultivated plants (Mesean, Angevin, 2006). Various genetic modifications of plants are capable to raise quality and productivity of plants, to enable technologies for processing cultivated plants, and to eliminate noxious organisms. However, together with the positive gains, by decreasing expenses required for growing plants of genetically modified sowings, growing of such plants causes problems as well. An uncontrolled dissemination of genes is observed from some genetically modified cultivated plants, thus breaking the competitiveness of the natural plant community as well as depleting the eco-system by growing congenial cultivated plants in huge areas. The genes are disseminated by the pollinators-insects and the wind if the cultivated plant has kindred wild plants in nature (Beckie et al., 2003). According to the data obtained by Canadian researchers (Knispel et al., 2007), in the Western part of Canada, an uncontrolled dissemination of the rape genes tolerant to herbicides (HT) was observed everywhere but the HT rape populations were most widely met at the sides of roads and railways. It is to be particularly noted that hazardousness of this process is stated as in nature the rape generation is found with multiple tolerance against three groups of herbicides – glyphosphate, glyphosinate as well as against the herbicides of the imidasolinon group. Within two years of the research, it is found that the maternal plants with one HT feature give descendants with the above multiple tolerance. According to the opinion of Canadian researchers, the process is practically unmanageable, and dissemination cannot be forecasted. Therefore, it causes a risk for the conventional and biological agriculture. On certain conditions, the uncontrolled dissemination of genes might affect the apicultural and biological managements, and the decrease of seed farming in Latvia (Turka, 2007; Turka, Ruža, 2007).

On the one hand growing of cultivated plants in the conditions of Latvia is connected with a possible decrease of operating costs; while on the other hand the farm before making a decision on growing GM cultivated plants has to elicit the requirements for the activities to be carried out set by the laws and regulations in order to decrease the possibility of spontaneous dissemination of GM cultivated plants. The fulfilment of requirements set by the laws and regulations will be followed by certain expenses within the period of soil cultivation before sowing, in the phase of growing the cultivated plants as well as in harvesting, primary processing and sales of the grown produce.

The hypothesis of the research. The cultivated plants obtained by the gene engineering with their main feature to be tolerant only to herbicides of the general effect, is not only a gain for agriculture, but they can also generate certain management, monitoring and ecologic problems. Growing GM winter and summer rape in Latvia may possibly cause economic losses to the neighbourhood farms.

The aim of the research is to obtain more detailed information on the profitability or losses of growing GM rape in the regions of Latvia by carrying out analysis of the economic conditions and evaluation at the micro level.

Materials and Methods

The costs for growing conventional and GM rape are estimated during the research.

To clarify profitability of growing GM cultivated plants or non-profitability in the conditions of Latvia, the most important economic aspects to be encountered by the potential growers of GM cultivated plants will be further discussed. Calculatation has been done by the authors using information by Certificate Enterprise of Association of Biological farms and Ministry of Agriculture of Latvia. The general condition of the economic profitability for growing GM cultivated plants can be shown by means of the following inequality:

$$(\sum TRN_{GM} : PL_{GM}) \geq (\sum TRN_{KKA} : PL_{KKA}, \quad (1)$$

where

$\sum TRN_{GM}$ – total net income in the case of growing GM cultivated plants;

$\sum TRN_{KKA}$ – total net income in the case of growing conventional cultivated plants;

PL_{GM} – the area for growing GM cultivated plants;

PL_{KKA} – the area for growing conventional (genetically unmodified) cultivated plants.

The economic condition for growing GM cultivated plants taking into account the inequality 1 can be defined in the following way: growing GM cultivated plants in a definite territory becomes favourable if the net income obtained by the grower of GM cultivated plants per one unit of area does not exceed the net income per one unit of area in the case of growing the conventional cultivated plants.

In the case of growing GM cultivated plants, the total net income per one unit of area

$$\sum TRN^{GM}{}_{PLV} = (\sum TR_{GM} - \sum TC_{GM}) : PL_{GM}, \quad (2)$$

where

$\sum TRN^{GM}{}_{PLV}$ – total net income per one unit of area in the case of growing GM cultivated plants;

$\sum TR_{GM}$ – total income obtained from the whole sowing area of GM cultivated plants;

$\sum TC_{GM}$ – total costs for growing, harvesting, primary processing and marketing of GM cultivated plants;

PL_{GM} – the growing area for GM cultivated plants.

It is important to include differences in income and costs compared to the conventional cultivated plants in the economic justification for growing GM cultivated plants. Therefore, peculiarities of costs and incomes in growing GM cultivated plants will be further described.

In the event of growing GM cultivated plants, it is important to identify all the costs which can considerably differ from the costs of growing conventional cultivated plants. The total costs can be shown by means of the following equation:

$$TC_{GM} = \sum C^{GM}_{SMA} + \sum C^{GM}_{P} + \sum C^{GM}_{V} + \sum C^{GM}_{PP}, \quad (3)$$

where

TC_{GM} – costs for growing, harvesting, primary processing and marketing GM cultivated plants;

C^{GM}_{SMA} – costs for the seeds, fertilizers, plant protection measures of GM cultivated plants;

C^{GM}_{P} – service costs for growing GM cultivated plants;

C_{V}^{GM} – general costs for growing GM cultivated plants;

C_{PP}^{GM} – additional costs for growing GM cultivated plants related to observing requirements set by the laws and regulations.

To estimate costs for the seeds, fertilizers and plant protection measures of growing GM rape per one unit of area, the following equation is used:

$$C_{SMA}^{GMR} = \frac{(Q_S^{GM} \times P_S^{GM}) + \sum C_{MM}^{GM} + \sum C_{AAL}^{GM}}{\sum PL^{GM}}, \quad (4)$$

where

C_{SMA}^{GMR} – specific expenses for the seeds, fertilizers and plant protection measures of growing rape;

Q_S^{GMR} – the amount of seeds of GM cultivated plants per ha;

P_S^{GMR} – the price for the seeds of GM cultivated plants;

C_{MM}^{GMR} – the amount of fertilizers required per one unit of area for growing GM cultivated plants;

C_{AAL}^{GMR} – the costs required for plant protection measures in growing GM cultivated plants;

$\sum PL^{GM}$ – the area for growing GM cultivated plants.

It is important to note that the comparison of the costs for the seeds, fertilizers and plant protection measures of GM cultivated plants and genetically unmodified cultivated plants can make the following differences:

a) the price of GM cultivated plants can be on 20-30% higher compared to the seeds of the conventional cultivated plants. It means that the seed prices are raised due to growing of GM cultivated plants which are expensive;
b) for sowings grown in similar agro-climatic conditions, the amount of used fertilizers will not change. Wherewith, there are no differences in relation to fertilizer costs between GM and conventional cultivated plants;
c) the specific expenses per one unit of area, for plant protection measures in growing GM cultivated plants decreases compared to the expenses for plant protection measures in growing conventional cultivated plants.

It means that growing expenses per ha for growing GM cultivated plants decrease due to the new properties to resist definite diseases, pests obtained through modification and capability to bear treatment by herbicides.

Certain differences also exist in services compared to the services and their costs required for growing GM cultivated plants and conventional cultivated plants as well. These differences are included in the following equation:

$$C_P^{GM} = \sum CP_{ASS}^{GM} - \Delta CP_{AAL}^{GM} + \sum CP_{NSA}^{GM} + \Delta \sum C_{MMZ}^{GM}, \quad (5)$$

where

C_{P}^{GM} – costs for growing, harvesting and primary processing of GM cultivated plants;

$\sum CP_{ASS}^{GM}$ – service costs for the treatment of soil before sowing and sowing of GM cultivated plants;

ΔCP_{AAL}^{GM} – decrease of the service costs required for plant protection;

$\sum CP_{NSA}^{GM}$ – service costs for harvesting and pre-treatment of seeds of GM cultivated plants;

$\Delta \sum C_{MMZ}^{GM}$ – service costs for the machinery needed for growing, transportation and primary processing of GM cultivated plants as well as for washing the machinery.

As it is evident, in equation 5 two deltas are included – one with a positive sign, while the other with a negative one. It gives a chance to get a clearer idea of the cost comparison result for the services used in the production of GM cultivated plants and the conventional ones. The positive delta increases service costs for growing GM rape- machinery used in growing, transporting the seeds and harvest as well as primary processing of GM cultivated plants and cleaning agricultural machinery. But the negative delta decreases the service costs used for plant protection measures of GM cultivated plants.

The total costs in growing GM cultivated plants are equalled to the total costs for growing genetically unmodified cultivated plants, excluding the costs related to the fulfilment of activities set by the corresponding laws and regulations for the growers of GM cultivated plants to decrease an uncontrolled dissemination of GM cultivated plants.

The most important cost increase in the event of growing GM rape in the territory of Latvia compared to the genetically unmodified cultivation of rape is related to the activities which are to be carried out by the growers of GM rape to decrease the threat of the surrounding environment and other subjects of the economic management as a result of the dissemination of uncontrolled genetically modified cultivated plants. Within the framework of the research, these costs are defined as extra costs in relation to implementation of the requirements set by the laws and regulations.

In estimating the above costs, the following equation is offered:

$$\sum C_{PP} = \sum C_{PP}^{GM} + \sum C_{PP}^{VI}, \qquad (6)$$

where

$\sum C_{PP}$ – total additional costs in the event of growing GM cultivated plants;

$\sum C_{PP}^{GM}$ – additional costs arising in relation to the fulfilment of requirements set by the laws and regulations for a farm which grows GM cultivated plants;

$\sum C_{PP}^{VI}$ – additional costs for the state institutions which arise in relation to fulfilment of the requirements set by the laws and regulations.

Additional extra costs which arise in a farm growing GM cultivated plants to fulfil requirements set by the laws and regulations for eliminating dissemination of uncontrolled genetically modified cultivated plants are estimated taking into account the following equation:

$$C_{PP}^{GM} = C_{INF}^{GM} + \sum C_{PM}^{GM} + \sum C_{LA}^{GM} + \sum C_{DK}^{GM} + \sum C_{PA}^{GM} + \sum C_{VI}^{GM} + C_{APD}^{GM} + NP_{INF}^{GM} + C_{CI}^{GM}, \qquad (7)$$

where

C_{PP}^{GM} – additional costs related to the fulfilment of the requirements set by the laws and regulations for a farm growing GM cultivated plants;

C_{INF}^{GM} – dissemination of additional information on cost coordination for the possible growing of GM cultivated plants;

C_{PM}^{GM} – costs for packaging and marking of the harvest of GM cultivated plants;

C_{LA}^{GM} – costs for the laboratory analyses to control an uncontrolled dissemination of GM cultivated plants;

C_{DK}^{GM} – additional costs for processing documentation reflecting growing, harvesting, primary processing and preparation of GM cultivated plants for sales;

C_{PA}^{GM} – additional training costs for farms desiring to grow GM cultivated plants;

C_{VI}^{GM} – additional costs of the state institutions related to the fulfilment of supervision and control process set by the laws and regulations on the fulfilment of the requirements set by the laws and regulations on growing GM cultivated plants;

C_{APD}^{GM} – insurance costs for sowings of GM cultivated plants;

NP_{BFJ}^{GM} – the lost income from the area which is used to establish the buffer belt around the fields where GM cultivated plants are grown;

C_{CI}^{GM} – other costs related to the fulfilment of other requirements not given here for a farm which grows GM cultivated plants.

Determining additional costs, the grower of GM cultivated plants has to take into account the necessity for packaging and marking GM cultivated plants. Mutually agreeing, the grower can attribute these costs to the wholesaler of GM cultivated plants. But in such case, the grower of GM cultivated plants has to consider upon a lower sales price. It means that with the decrease of the sales revenues, the grower of genetically modified plants will have to decrease packaging and marking costs of the grown harvest.

The question remains open on attributing the additional costs in full amount to the grower of GM cultivated plants. According to the principle of the economic fairness and the principle "the polluter pays", all additional costs should be attributed to the farm which desires to grow the GM rape including the additional costs of the state institutions to control the fulfilment of requirements set by the respective laws and regulations. It means that the grower of GM cultivated plants in his expenses should include all additional costs arising on the farms which do not grow GM cultivated plants, if the farm where GM cultivated plants are grown has worsened the management conditions, and the nonconformity of the grown harvest with the requirements for obtaining the highest sales revenues causing GM plant threat and/or allowing an uncontrolled dissemination of uncontrolled GM cultivated plants.

The fulfilment of requirements set by the laws and regulations on growing GM cultivated plants and manufacturing food products using the GM raw material is attributed to additional costs. Presently it is impossible to determine the amount of these costs in Latvia as there is no experience accumulated in this country. Though other EU countries deal with GM products and certain experience is accumulated which enables to estimate additional costs related to the presence of GM products in the process of manufacturing.

The condition of the economic profitability for GM cultivated plants based on sales revenues and costs per one unit of area or the amount unit of the harvest was described above. Attributing incomes and expenses to the growing area of GM cultivated plants or the weight of harvest is related to the fact that the harvest is affected by both the internal factors depending on the farm and the external factors not depending on the farm, for instance, the climatic conditions.

In the formation of sales revenues in farms growing GM cultivated plants, the most essential factor is the sales price of the grown harvest and the following aspects are to be taken into account in creating it:

a) potentially low price – the forecasted sales price of the harvest for GM cultivated plants can be at least 10-15% lower than the sales price for the conventional cultivated plants and the experience of farms growing GM cultivated plants in other countries give evidence of that;
b) the use opportunities – the sales price of the harvest for GM cultivated plants to a great extent depends on the use opportunities set for the final output;
c) the impact on the environment – the impact of the respective GM cultivated plant on the environment, health of animals and people;
d) to a certain extent the sales price is affected by the regulations set in the EU countries for marking GM cultivated plants.

The sales revenues of the farm selling the harvest of GM cultivated plants can be expressed by the following equation:

$$TR_{GM} = (Q_{GM} \text{ x } P) \text{ x } K_{iz} \text{ x } K_v \text{ x } K_m \text{ x } K_n \text{ ,} \qquad (8)$$

where

TR_{GM} – income from the harvest of GM cultivated plants;

Q – the amount of sold GM cultivated plants;

P – sales price for GM cultivated plants;

K_{iz} – the correction coefficient for sales price which depends on the type of using GM cultivated plants set for manufacturing a definite output;

K_v – the correction coefficient for sales price which depends on the impact of cultivated plants of a definite modification on the environment, animal and human health;

K_m – the correction coefficient for sales price related to the fulfilment of the marking requirements for GM cultivated plants;

K_n – the correction coefficient for sales price related to other factors affecting dissemination of GM cultivated plants.

Results

According to equation 8, the economic content is not unequivocal. Separate factors can reduce sales revenues from the harvest of GM cultivated plants, while the others can increase them. In addition, it is to be taken into account that the society and scientists are uncertain of the effect of GM cultivated plants on the diversity of species and the sustainable development of the environment. It means that the law makers and the potential growers of these cultivated plants have to observe in their activities not only the principle “the polluter pays” but also the precautionary principle in eliminating the threat of an uncontrolled spread of GM cultivated plants.

The comparatively poor experience of the society on the use of GM cultivated plants and their output shall be considered when evaluating the potential income in selling the harvest of GM cultivated plants. The researches related to improving properties of cultivated plants and in the sphere of using GM products can essentially affect both costs for growing GM cultivated plants and sales revenues. The following subjects of the economic activities in the countryside are included in the evaluation of the potential direct losses as a result of an uncontrolled dissemination of GM cultivated plants:

a) the potential losses, primarily, are attributed to the biological farms growing the cultivated plants threatened by the uncontrolled dissemination of GM cultivated plants;
b) the potential losses attributed to the centres of seed farming and research which augment high-rate quality seed material in their territory and provide the needed seed material for cultivated plants of the mustard family in cooperation with the neighbourhood farms;
c) the potential losses are attributed to any agricultural farm where cultivated plants endangered by an uncontrolled dissemination of GM cultivated plants are grown;
d) the potential losses attributed to the farms dealing with apiculture;
e) the potential losses attributed to the farms and enterprises dealing with rural tourism and providing health rehabilitation services as well.

The lost part due to the dissemination of GM cultivated plants is set for the endangered objects by means of the expertise method. The opinion of specialists on the amount of losses for the subjects of the threat is shown in Table 1.

Table 1

Experts' view on the amount of losses

Subjects of risk	Endangered branch	Amount of losses
Organic farms	Organic farming, certification, support	Not less than 7-10% of the gained income
Seeds cultivation farms	Branch of seeds cultivation	Essential losses, even to 100%, if seeds of biologically endangered cultivated plants are grown
Farms growing rape seed	Growing of rape seed	Not less than 25-30% of the gained income
Apiculture farms	Apiculture	Not less than 50-70% of the gained income
Farms of rural tourism and health improvement	Rural tourism, medical services	Not less than 7-10% of the gained income

The amount of potential losses depicted in the table is estimated considering information available by the specialists on the properties obtained by GM cultivated plants and their impact on the environment, animal and human health in the vegetation period and in the form of a ready product. The amount of potential losses will be adjusted if supplementary and more complete information on the properties of GM cultivated plants and their environmental impact is at the disposal of the society. In addition, the actual opportunities are to be considered to receive new lines of GM cultivated plants which might have different impact on other cultivated plants, environment, animal and human health.

Potential Losses to the Bological Farms

During recent years biological agriculture is rapidly developing. The number of biological farms certified in 2007 as well as the farms standing as candidates for receiving the certificates and the area of the agricultural land for these farms are considered when estimating the number of the endangered farms and the area for the agricultural land of these farms. Therefore, the number of the endangered farms exceeds 4.8 thousand and their land – over 16.4 thousand ha. Even presently more than 3 thousand biological farms deal with cultivation of plant-growing produce and more than 150 farms are engaged in the biological apiculture. Many farms cultivate nectar plants, develop growing of herbal teas, and field plant teas, develop environmental and health services in all the regions (Vanags, 2007).

The state programme for developing biological agriculture for the period from 2007 to 2013 is directed towards improving the qualitative properties of the produced product and increasing the value added for the produce in the system of biological agriculture. The programme envisages enhancing the material and technical basis of the farms, to favour the vertical and horizontal development of cooperation for processing the products and delivering them to the consumer. The support rendered by the LAP is envisaged for implementing the set assignments. It is envisaged to develop special programmes of training, show farms, and to develop the biological seed farming.

In Latvia, suitable conditions are created for manufacturing biological produce with a high value added. It is an important natural priority of Latvia in the global cross-country competition which enables Latvia to enter the world by own exclusive biological produce with a high value added. The above mentioned gives evidence that 10% of the income included in the estimation of the potential losses are considered to be the minimum potential losses which might arise as a result of an uncontrolled dissemination of genetically modified organisms both for individual farmers and the country on the whole, and it is forecasted that the specific weights of losses can increase up to 15-20% in the near years. The results of the estimated potential losses for the biological farms in the regions of Latvia are shown in Table 2.

Only the certified biological farms and their agricultural lands are used in the loss estimation included in the table. It ensures precision of the obtained results and increases its application in making decisions. The total estimated sum of the potential losses exceeds LVL 2 million. The highest amount of losses is attributed to Vidzeme region – LVL 487 thousand or 24.3% where the largest areas are biologically managed. In accordance with the increase in prices for the agricultural produce, in 2007 the average income per ha in the regions is fluctuating from LVL 90 in Latgale region to LVL 170 in Riga region, where better opportunities to grow vegetables and to sell the manufactured biological produce for a higher price are possible. Wherewith, in Riga region, the potential losses for the biological farms reach LVL 360 thousand and make 16.8% of the total losses of the biological farms in the country. Similar potential losses are possible in Zemgale region – LVL 340 thousand. Although, in Latgale region the

Table 2

Potential losses of organic farms in case of uncontrolled distribution of GMO

Region	Calculation of losses, year 2007		
	UAA of organic farms, ha	average income, LVL ha^{-1}	potential losses =10%, thousand LVL
Vidzeme	44 264	110	486.9
Kurzeme	32 452	140	454.3
Latgale	44 595	90	401.4
Zemgale	22 462	150	336.9
Pierīga	21 227	170	360.9
Total/the country	165 000	132	2040.4

Table 3

Potential losses for rapeseed growing farms

Region	Calculation of losses, year 2007			
	area of rapeseed, ha	average income, LVL ha^{-1}	lost part, %	potential losses, thousand LVL
Vidzeme	14 600	700	30	3066
Kurzeme	13 800	900	20	2484
Latgale	9800	500	30	1470
Zemgale	43 700	900	5	1967
Pierīga	9300	700	10	651
Total/the country	91 200	–	–	9638

land for the biological farms 2 times exceeds the area of the biological farms in Zemgale region.

Potential Losses for the Farms Growing the Rape

Due to the favourable market conjuncture, the country support, and the constant increase of the purchase price, the area of rape sowings rapidly increases. In the period from 2000, they have increased more than ten times. This increase is stipulated by widening of the rape usage-in food as well as for the renewable energy resource in bio-fuel and utilization of the rape shoots in fodder. The rape areas are directly subjected to the hazardous impact of genetically modified organisms in the event of uncontrolled dissemination. For the growers of the rape, the potential losses are estimated considering the region where the rape is grown and the opportunities to grow the genetically modified rape in this region. For every region, an individual loss coefficient is used.

The information on the results of estimation is shown in Table 3.

The estimation of the potential losses in Table 3 is based on the assumption that in the event of invasion of genetically modified organisms, the usage of the rape seeds in food will essentially decrease. Therefore, the rape seeds with the presence of the GMO, will be sold for the production of bio-fuel which will decrease the sales price of the produce. In addition, the rape cakes with the biological contamination will not be applicable in fodder. Therefore, it is assumed that the real threat inflicted by GM cultivated plants can decrease income for the rape growers at least by 30%. Wherewith, the region is considered where the farm of the potential rape grower is located.

As it is evident from the figures given in Table 3, the total losses exceed LVL 9.6 million. The highest losses are attributed to Vidzeme region-slightly over LVL 3 million or 33.8%. Considerably high losses are possible to be encountered in Kurzeme region as well – LVL 2.5 million or 24.1%. While in Riga region the potential losses for the farms growing the rape make only LVL 600 thousand, growers of the rape orientate themselves, mainly, to manufacturing bio-fuel, except Limbaži district.

Due to the agro-climatic conditions in Latgale region, the rape seed grown in the biological and conventional systems of farms can be used in food production; while sowing of the rape is mainly done for agro-technical purposes – as one of the cultivated plants in the crop rotation. Therefore, in this region, rape sowings are not widely spread and total potential losses make only LVL 1.5 million or 15.9% of the total losses for the farms growing rape seeds.

Potential Losses for the Apiculture Farms

The favourable climatic conditions and the established traditions favour a rapid increase of bee families in the countryside of Latvia. In accordance with the information provided by the association of bee growers, the beehives are found in small amounts almost in every farmstead of Latvian countryside. The urban population and households of the city outskirts like bees as well.

Within the recent year, the number of the beehive families has increased from 43 to 62 thousand families in the beginning of 2007. Over 150 biological farms deal with apiculture which set even higher requirements for quality of the manufactured produce. In the event of genetically modified organisms, in exceeding the permissible level of contamination, serious problems might appear with sales of the manufactured produce at prices acceptable to apiarists. Consulting the apiculture specialists, it is assumed that the sales price for honey with the presence of GMO will decrease on a half, at least. The estimation results of the potential losses are shown in Table 4.

As it is evident from the results of estimation for the potential losses, the forecasted amount of losses for apiculture farms nearly reach LVL 2.5 million, out of which the majority – LVL 726 thousand or 29.5% refer to Kurzeme region and LVL 583 thousand or 23.7% to Vidzeme region. Considerably lower losses are possible to incur in Riga region – LVL 400 thousand. In Latgale region relatively low losses can be observed as well – LVL 370 thousand or 15% of all the losses for the apicultural farms. It is related to considerably tiny number of bees per one unit of the agricultural land area.

Evaluating the losses incurred upon the bee farms, it is to be considered that the bees act as active vectors of GM organisms in the environment. Therefore, the forecasted losses may increase taking into account the damage incurred upon the environment.

Potential Losses for the Facilities of Rural Tourism and Medical Services in the Countryside

Rural tourism as a new alternative branch has come into the countryside of Latvia in line with its successful developing. The rural entrepreneurs are gradually acquiring the aspect of the countryside, the aspect of the people's desire to relax in simple farmsteads, closer to the untouched natural environment. As it is seen by the foreign experience, the fans of rural tourism find GM cultivated plants in the rural environment to be unacceptable and interfering factors. Therewith, they refuse from such type of recreation. Particularly, foreign tourists find the comparatively untouched nature and the expressive non-industrial rural landscape with country estates as a positive and favouring factor for rural tourism. The potential losses as a result of an uncontrolled dissemination of GMO set by specialists are presented in Table 5.

In the estimations, according to the evaluation done by the specialists, a comparatively small part of the losses is presented – 10% of the present level which is evaluated as comparatively low but with a pronounced increase in the recent years. The total potential losses nearly reach LVL 520 thousand. The facilities operating in the branch of the rural tourism calculate that in the future the real potential losses might be higher as the number of the objects of rural tourism is increasing with every year and the public requirements for the quality and security set to the environment are increasing as well, particularly in the places of recreation and health rehabilitation.

Table 4

Potential losses for apiculture farms

Region	Calculation of losses, year 2007		
	number of beehives of bees	average income, LVL per swarm of bees	potential losses =50%, thousand LVL
Vidzeme	14 600	80	583.3
Kurzeme	14 500	100	725.6
Latgale	12 300	60	370.0
Zemgale	10 600	70	372.8
Pierīga	10 200	80	404.9
Total/the country	62 200	–	2456.6

Table 5

Potential losses for rural tourism and health rehabilitation enterprises

Region	Calculation of losses, year 2007		
	number of endangered enterprises	average income, thousand LVL year^{-1}	potential losses =10%, thousand LVL
Vidzeme	63	20	126.0
Kurzeme	44	25	110.0
Latgale	29	15	43.5
Zemgale	28	20	56.0
Pierīga	73	25	182.5
Total/the country	237	–	518.0

Table 6

Calculation of potential losses for seed farming

Region	Calculation of losses, year 2007		
	number of farms	average income, thousand LVL year^{-1}	potential losses =10%, thousand LVL
Vidzeme	35	50.0	175.0
Kurzeme	45	100.0	450.0
Latgale	12	40.0	48.0
Zemgale	28	100.0	280.0
Pierīga	52	100.0	520.0
Total/the country	172	–	1473.0

Moreover, it is to be considered that the rural tourism is rapidly developing, increasing and stabilising incomes, and diversifying the assortment of the offered services. An absolute leader in the development of rural tourism is Riga region. Therefore, in this region, the highest potential losses are found as well – LVL 182.5 thousand or 35% of the total forecasted losses for the threatened facilities in the countryside. Riga, Vidzeme and Kurzeme regions comprise 80% of the potential losses in the event of uncontrolled dissemination of GMO.

Potential Losses for the Seed Farming Agricultural Farms

The potential losses for the seed farming agricultural farms as a result of an uncontrolled dissemination of GM organisms can be considered from several aspects:

– the farm grows seeds from biologically endangered cultivated plants. Then the amount of losses might amount up to 100%;
– the farm grows seeds from biologically secure cultivated plants. Then the losses might be at minimum – up to 10% which are attributed to the behaviour of the consumer in the market.

It is to be noted that in the recent years, the branch of seed farming is on the decline due to the wide offer of seeds from other countries. However, it is argued and also topical if the seeds of the offered cultivated plants are suitable to the agro-climatic conditions of Latvia. By the gain of efficiency in growing cultivated plants, higher requirements will be set to the seed material which will enhance the demand for the seeds of the most suitable varieties of cultivated plants for the local conditions. It will favour the increase of competitiveness of the farms not only at the local but also at the cross-country scale.

At the same time it is to be noted that part of the farmers use self-grown rape seeds. The seed growing for the biological farms is developed. In small amounts, vegetable seeds are grown in “Kurzemes sēklas” (Seeds of Kurzeme) Ltd and other farms.

The approximate losses which might arise for the seed farming agricultural farms as a result of an uncontrolled dissemination of GMO are shown in Table 6.

It is to be noted that in the estimation, seed farming agricultural farms of different sizes and different specialisation and other seed farming centres are presented as, for instance, Stende GSI, Priekuļi LSI, Pūre DIS, Latgale LZC, training and research farms and agencies of Latvia University of Agriculture, etc.. The total estimated potential losses nearly reach LVL 1.5 million, of which the majority – LVL 520 thousand or 35% – are attributed to Riga region. The comparatively high potential losses are forecasted for Kurzeme region – LVL 450 thousand or 30.5% of the total losses for the seed farming agricultural farms in the country. Comparatively low potential losses are forecasted for Latgale region – only LVL 48 thousand or 3.25%.

The greatest part of the seed farming is located in all the regions of Latvia to a greater of smaller extent, and the farms are trying to reduce the operating costs. Although, the lowest possible losses are estimated in Latgale region, this is exactly the region which is evaluated as the region with higher natural priorities used for widening the cultivated crops within the system of the biological agriculture as well as widening of rural tourism and health services.

Summary of the Potential Losses

The estimated potential losses for various subjects of economic activities in the countryside are summarised in Table 7.

As it is evident from figures shown in Table 7, the total potential losses in the event of an uncontrolled dissemination of GM cultivated plants slightly exceed LVL 12 million. The highest potential losses are attributed to the rape growers, the apiculture branch and biological agriculture – LVL 9.6 million, LVL 2.5 million and LVL 1.5 million respectively.

According to the breakdown of regions, more than one third of the potential losses are attributed to Vidzeme and Kurzeme regions each. For both the regions, the total potential losses exceed 51% of the total potential losses in the country in the event of an uncontrolled dissemination of GM cultivated plants. It can be explained by the fact that these regions concentrate the highest peculiar weight of all the endangered subjects of the economic activities in the countryside.

A relatively small part – LVL 2.3 million for losses are attributed to Latgale region. Although, one of the most favourable conditions to develop growing of cultivated plants in the system of the biological agriculture exactly exists in this region. In this evaluation it is to be considered that in Latgale region, a considerably lower economic activity is observed. Therefore, in this region the potential losses make a considerably higher peculiar weight in the balance of the subjects of the respective economic activities than in other regions of Latvia.

The estimated structure figures of the potential losses in the event of an uncontrolled dissemination of GM cultivated plants are depicted in Table 8.

The figures presented in the table give evidence that the potential losses for the farms growing the rape make 72.4% of the total forecasted sum of losses.

Comparing the specific weight of the forecasted losses presented in Table 8, it can be concluded that the estimated losses for the biological agriculture are divided considerably evenly in the regional section, and are fluctuating within the limits of 6%, the highest specific weight in Vidzeme region is 27.5%, but the lowest specific weight in Riga region is 13.4%, and in Latgale region – 14.5%.

Evaluating the potential losses in the biological farms, it is found that the highest specific weight of the potential losses is attributed to Vidzeme and Kurzeme regions – 23.9% and 22.3%, respectively. It is connected with the intensive development of biological agriculture in these regions. Evaluating the potential losses for the farms growing the rape,

Table 7

Summarization of potential losses in regions

Regions	Distribution of potential losses, thousand LVL					
	organic farms	rapeseed growers	seed growers	apiculture	rural tourism	total in regions
Vidzeme	486.9	3066	175.0	583.3	126.0	4437.2
Kurzeme	454.3	2484	450.0	725.6	110.0	4223.9
Latgale	401.4	1470	48.0	370.0	43.5	2332.9
Zemgale	336.9	1967	280.0	372.8	56.0	3012.7
Pierīga	360.9	651	520.0	404.9	182.5	2119.3
Total/the country	2040.4	9638	1473.0	2456.6	518.0	12 196.4

Table 8

Regional structure of potential losses

Regions	Structural division of potential losses, %					total in regions
	organic farms	rapeseed growers	seed growers	apiculture	rural tourism	
Vidzeme	23.86	31.81	11.88	23.74	24.32	27.52
Kurzeme	22.27	25.77	30.55	29.54	21.24	26.19
Latgale	19.67	15.25	3.26	15.06	8.40	14.47
Zemgale	16.51	20.41	19.01	15.18	10.81	18.68
Pierīga	17.69	6.75	35.30	16.48	35.23	13.14
Total/the country	100.00	100.00	100.00	100.00	100.00	100.00

it is found that the dominant position in this index belongs to Vidzeme region with 31.8%, while the lowest specific weight in Riga region is 6.8%, and in Latgale region – 15.3%.

The estimated potential losses for the seed growers in the event of an uncontrolled dissemination of GMO in the regions fluctuate from 3 to 35%. The highest relative amount of the potential losses is attributed to Riga and Kurzeme regions – 30.6%. To a lesser extent, in the event of threatening seed growing, Latgale region can suffer – only 3.3% of the total losses for the seed farming agricultural farms.

Comparing the potential losses for the apiculture branch, it is found that to a great extent, its relative distribution correlates with the potential losses for the biological farms. The highest comparative amount – 29.5% is attributed to Kurzeme region where in recent years, a particularly rapid tendency of increasing bee families can be observed. In Vidzeme region, the potential losses inflicted upon the bee growers equal to 23.7%, and this region is located comparatively near Kurzeme region.

The agricultural enterprises which deal with rural tourism and provide health rehabilitation services, to a greater extent, can be endangered in Riga and Vidzeme regions. Thirty-five per cent of all the potential losses inflicted upon the rural tourism are attributed to the enterprises of rural tourism located in Riga region. The lowest losses are attributed to Zemgale and Latgale regions – 10.8% and 8.4% respectively of the total potential losses in this sphere of activities.

Conclusions

The results of estimating the potential losses give opportunity to make the following most important decisions:

– the potential losses for various subjects of the economic activities in the countryside are estimated using the available information sources and involving specialists. Having considered the uncertainty of the situation on the further development of GM cultivated plants and their impact on the environment, the actual amount of losses for agricultural farms and the environment may be considerably higher;
– the highest relative losses are attributed to Vidzeme region – 27.6% and Kurzeme region – 26.2%. For these regions the forecasted losses exceed 50% of all the potential losses for the biological farms in the country which might arise as a result of an uncontrolled dissemination of GM products;
– comparatively high potential losses are possible for the apiculturists. In Vidzeme and Kurzeme regions – from LVL 0.6 to LVL 0.73 million. It is to be noted that in these regions, the specific weight of the indirect costs is comparatively high in the event of the threat which cannot be unequivocally transformed in the terms of money in relation to the development of tourism and health services in the countryside environment;
– specialists are forecasting increase of the potential losses for different growers of cultivated plants in all the regions as in Latvia a tendency is observed that the number of manufacturers of the biological produce is rapidly increasing as well as the market prices for the biological products are increasing every year with the annual rate of the increase exceeding 7-10%. It increases the competitiveness in growing the biological produce and increases the potential losses as a result of dissemination of GM cultivated plants;
– in eliminating the potential losses as a result of an uncontrolled dissemination of GM cultivated plants, potential losses related to the impact of GMO on the environment, animal and human health are not included. For estimating these losses, the needed information and certainty

of the GMO impact on the environment are missing;

– the applied method for estimating the potential losses can be used in evaluating the necessity of establishing free zones in a larger or smaller territory of the country.

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Anotācija

ĢM kultūraugu audzēšana Latvijas apstākļos no vienas puses saistīta ar iespējamo ražošanas pašizmaksas samazināšanos uz tiešo izmaksu rēķina, bet no otras puses, lauku saimniecībai, pirms lēmuma pieņemšanas par ĢM kultūraugu audzēšanu, jānoskaidro normatīvajos aktos noteiktās prasības par veicamajiem pasākumiem, lai samazinātu ĢM kultūraugu patvaļīgas izplatīšanās iespējas. Šo normatīvajos aktos noteikto prasību izpilde būs saistīta ar zināmām izmaksām pirmssējas periodā, kultūraugu audzēšanas stadijā, kā arī izaudzētās produkcijas novākšanā, pirmapstrādē un realizācijas laikā. Gēnu inženierijas ceļā iegūtie kultūraugi, kuru galvenā iezīme ir tikai tolerance pret vispārējas iedarbības herbicīdiem, ir ne tikai ieguvums lauksaimniecībā, bet tie var radīt arī zināmas pārvaldes, kontroles un ekoloģiskas problēmas. ĢM ziemas un vasaras rapša audzēšana Latvijā iespējams radīs kaimiņos esošām saimniecībām ekonomiskus zaudējumus. Iegūt detalizētāku informāciju par ĢM rapša audzēšanas izdevīgumu vai zaudējumiem Latvijas reģionos, veicot ekonomisko apstākļu analīzi un izvērtēšanu mikrolīmenī. Pētījumu gaitā tiek aprēķinātas konvencionālā un ĢM rapša audzēšanas izmaksas. Lai precizētu ĢM kultūraugu audzēšanas izdevīgumu, jeb neizdevīgumu Latvijas apstākļos, pētījumā atklāti nozīmīgākie ekonomiskie aspekti, ar kuriem jārēķinās potenciālajiem ĢM kultūraugu audzētājiem.

Economic Arguments for Establishing Free Zones from Genetically Modified (GM) Rape in Latvia
Ekonomiskais pamatojums brīvo zonu izveidošanai no ģenētiski modificēta rapša (ĢM) Latvijā

Jānis Vanags
Faculty of Engineering Economy and Management, Riga Technical University
Rīgas Tehniskās universitātes Inženierekonomikas un vadības fakultāte
e-mail: Vanags.Janis@gmail.com
Ināra Turka
Institute of Soil and Plant Sciences, LLU
LLU Augsnes un augu zinātņu institūts
e- mail: Inara.Turka@llu.lv

Abstract. Free biological zone is a definite part of the state territory where possible growing of GM cultivated plants become economically unprofitable after the fulfilment of state norms and/or cause real threat of worsening (losses) of natural circumstances for other farming subjects as well as for sustainable development of environment, and for animals and human health. The necessity of forming the free zones can be economically based. Farms in the free biological zones would be state protected from threat of GM agricultural cultivated plants which could be caused by genetically modified pollution. It would increase trust in the processors of the produced agricultural production – the producers of foodstuffs – to suppliers creating certitude in no presence of genetically modified organisms in the obtained raw materials of agricultural character. Producers and consumers of foodstuffs are ready to pay higher price for this assurance. The identified subjects of potential losses in case of growing GM cultivated plants are biological farms, rapeseed crop growing farms, seed farmers for rapeseed crop or some other member of mustard family, and apiculture farms. Mathematical and demonstrative graphic models are elaborated for the economic basis of the free zones.
Key words: GM rapeseed crops, free zones.

Introduction

For Latvian manufacturers of farm produce when they meet with global challenges, the new EU approaches to the reforms related to manufacturing of the farm produce, and with the increase of the global pressure of competitiveness, the growth of GM cultivated plants is becoming urgent in the territory of Latvia.

The biologically free zones were established (BZ) to solve the problems arisen in the world. Initially, they appeared in Canada and the USA but somewhat later in the European countries as well as where the GM corn was raised (Angevin, 2006). The reason for establishing free zones is the existing uncertainty about the effect of biologically modified cultivated plants and organisms on the sustainable development of environment and human health within a longer period of time.

The primary task of the free zones is to protect the environment from uncontrolled dissemination of GM cultivated plants. Farms operating in the free biological zones are kept nationally protected from the threat inflicted by GM agricultural crops (Hirzinger, Monrad, 2006). It increases confidence from the part of the agricultural processors-food manufacturers towards the suppliers generating conviction that the purchased agricultural raw material is without the presence of genetically modified organisms. For this conviction, the food processors and the final consumers willingly pay more. Thus, mutually favourable pre-conditions are created for economic activities which enhance appearing of free zones. Tourists give preference to territories where GM crops are not grown as well.

The free biological zone can be defined in the following way: “The free biological zone – a definite part of the state territory where the possible growing of GM cultivated plants becomes economically unfavourable in fulfilling the requirements set by the laws and regulations and/or it can create a real threat of worsening (losing) of the natural conditions of manufacturing to other subjects of the economic activities as well as to the sustainable environmental development, to health of animals and humans.”

Effectively and purposefully cooperating with state institutions, municipalities can develop a flexible approach in establishing free zones incorporating territories where growing GM plants can incur losses to subjects of the economic activities in the countryside and can make harm to the sustainable development of the environment (Sondergaard et al., 2006). The state has to forecast the opportunity of establishing such a zone at the national and cross-border level as well.

The hypothesis of the research. An accidental and uncontrollable GM dissemination can inflict losses to separate types of economic management and their concurrent coexistence with GM cultivated plants is impossible if their isolated existence is not ensured, i.e., free zones are not established.

The aim of the research is to develop methods for estimation of the economic justification for establishing free zones from GM cultivated plants.

Methods

When dealing with growing cultivated plants, harvesting, transportation and technologies of primary processing and costs in diverse systems of manufacturing agricultural produce, we pass to the subject of the research and the data are processed applying corresponding statistical and descriptive methods. As a result, different estimation indices are obtained to attain the aim of the research and to fulfil the assignments. Conclusions are made by analysing the results of estimations. Proposals are moved forward on the basis of the conclusions applying synthesis, logical and historical approaches and other applicable methods for justification of free zones in their development phase.

Developing the economic justification for establishing free zones, several assumptions and restrictions are imposed. The most significant are as follows:

1) it is assumed that the growers of GM cultivated plants will comply with laws and regulations set by the legislation and will fulfil all the requirements in relation to the protective zones, establishing the buffer zone at the sides of the fields and in relation to cleaning machinery, etc.;
2) the growers of GM cultivated plants will be capable to come on terms with owners of the near farms on distribution of field crops taking into account the requirements for crop rotation;
3) the growers of GM cultivated plants will provide sowings of GM cultivated plants and their economic activities against the threat of uncontrolled dissemination of GM cultivated plants and the biologic contamination of the soil;
4) the growers of GM cultivated plants will cover losses inflicted upon the conventional and biologic farms by growing, harvesting and/or storing and transporting GM cultivated plants;
5) in the economic justification, the potential losses and/or additional payments are included which can arise to other subjects of the economic activities in the countryside;
6) in the economic justification, the potential additional incomes are included which may arise when growing GM cultivated plants and the potential additional expenditures which are related to fulfilment of the requirements set by laws and regulations in relation to eliminating the uncontrolled dissemination of GM cultivated plants and to threat insurance of the economic activities.

Evaluating the restrictions and assumptions incorporated in establishing free zones, it is to be taken into account that they are constantly occurring in the rapidly changing political, economic, social, scientific and technological environment. Therefore, information updating is required (Enabling the Coexistence .., 2005).

In the conditions of Latvia, growing of GM cultivated plants is connected with the possible decrease of the production cost due to the direct costs on the one hand but before making a decision to grow GM cultivated plants, the farm has to elicit the requirements set by laws and regulations for the activities to be carried in order to reduce possibilities of lawless and inevitable dissemination of GM cultivated plants on the other hand. Fulfilment of the requirements set by laws and regulations will be related with certain costs in the period of cultivating the soil before sowing, the phase of growing cultivated plants as well as within harvesting of the grown produce, primary processing and marketing. In comparing and estimating costs, a definite technology of crop management, harvesting and primary processing and its close relation with the technology of growing, harvesting and primary processing of grains of the corresponding GM cultivated plants are to be taken into account. Thus, the cost elements of growing, harvesting and primary processing of cultivated plants will be found which will decrease or increase the costs.

Results

To clarify profitability of growing GM cultivated plants or non-profitability in the conditions of Latvia, the most important economic aspects to be encountered by the potential growers of GM cultivated plants will be further discussed. The general condition of the economic profitability for growing GM cultivated plants can be shown by means of the following inequality:

$$(\sum TRN_{GM} : PL_{GM}) \geq (\sum TRN_{KKA} : PL_{KKA}, \quad (1)$$

where

$\sum TRN_{GM}$ – total net income in the case of growing GM cultivated plants;

$\sum TRN_{KKA}$ – total net income in the case of growing conventional cultivated plants;

PL_{GM} – the area for growing GM cultivated plants;

PL_{KKA} – the area for growing conventional (genetically unmodified) cultivated plants.

The economic condition for growing GM cultivated plants taking into account the inequality 1 can be defined in the following way: "Growing GM cultivated plants in a definite territory becomes favourable if the net income obtained by the grower of GM cultivated plants per one unit of area does not exceed the net income per one unit of area in the case of growing the conventional cultivated plants."

In the case of growing GM cultivated plants, the total net income per one unit of area:

$$\sum TRN^{GM}{}_{PLV} = (\sum TR_{GM} - \sum TC_{GM}) : PL_{GM}, \quad (2)$$

where

$\sum TRN^{GM}{}_{PLV}$ – total net income per one unit of area in the case of growing GM cultivated plants;

$\sum TR_{GM}$ – total income obtained from the whole sowing area of GM cultivated plants;

$\sum TC_{GM}$ – total costs for growing, harvesting, primary processing and marketing of GM cultivated plants;

PL_{GM} – the growing area for GM cultivated plants.

It is important to include differences in income and costs compared to the conventional cultivated plants in the economic justification for growing GM cultivated plants. Therefore, peculiarities of costs and incomes in growing GM cultivated plants will be further described. In the event of growing GM cultivated plants, it is important to identify all the costs which can considerably differ from the costs of growing conventional cultivated plants. The total costs can be shown by means of the following equation:

$$TC_{GM} = \sum C^{GM}_{SMA} + \sum C^{GM}_{P} + \sum C^{GM}_{V} + \sum C^{GM}_{PP}, \quad (3)$$

where

TC_{GM} – costs for growing, harvesting, primary processing and marketing GM cultivated plants;

C^{GM}_{SMA} – costs for the seeds, fertilizers, plant protection measures of GM cultivated plants;

C^{GM}_{P} – service costs for growing GM cultivated plants;

C^{GM}_{V} – general costs for growing GM cultivated plants;

C^{GM}_{PP} – additional costs for growing GM cultivated plants related to observing requirements set by the laws and regulations.

To estimate costs for the seeds, fertilizers and plant protection measures of growing GM rape per one unit of area, the following equation is used:

$$C^{GMR}_{SMA} = \frac{(Q^{GM}_{S} \times P^{GM}_{S}) + \sum C^{GM}_{MM} + \sum C^{GM}_{AAL}}{\sum PL^{GM}}, \quad (4)$$

where

C^{GMR}_{SMA} – specific expenses for the seeds, fertilizers and plant protection measures of growing rape;

Q^{GM}_{S} – the amount of seeds of GM cultivated plants per ha;

P^{GM}_{S} – the price for the seeds of GM cultivated plants;

C^{GM}_{MM} – the amount of fertilizers required per one unit of area for growing GM cultivated plants;

C^{GM}_{AAL} – the costs required for plant protection measures in growing GM cultivated plants;

$\sum PL^{GM}$ – the area for growing GM cultivated plants.

It is important to note that the comparison of the costs for the seeds, fertilizers and plant protection measures of GM cultivated plants and genetically unmodified cultivated plants can make the following differences:

a) the price of GM cultivated plants can be on 20-30% higher compared to the seeds of the conventional cultivated plants. It means that the seed prices are raised due to growing of GM cultivated plants which are expensive;
b) for sowings grown in similar agro-climatic conditions, the amount of used fertilizers will not change. Wherewith, there are no differences in relation to fertilizer costs between GM and conventional cultivated plants;
c) the specific expenses per one unit of area, for plant protection measures in growing GM cultivated plants decreases compared to the expenses for plant protection measures in growing conventional cultivated plants.

It means that the costs for growing GM cultivated plants decrease per ha for the reason of the new properties obtained by means of modification to resist definite diseases, pests and ability to bear treatment by herbicides. Certain differences exist in services as well if comparing services and their costs needed for growing GM cultivated plants and conventional ones. These differences are shown in the following equation:

$$C_{P}^{GM} = \sum CP_{ASS}^{GM} - \Delta CP_{AAL}^{GM} + \sum CP_{NSA}^{GM} + \Delta \sum C_{MMZ}^{GM} \quad , (5)$$

where

C_{P}^{GM} – service costs needed for growing, harvesting and primary processing of GM cultivated plants;

$\sum CP_{ASS}^{GM}$ – service costs for cultivation of the soil before sowing of GM cultivated plants and sowing;

ΔCP_{AAL}^{GM} – decrease of service costs for plant protection measures;

$\sum CP_{NSA}^{GM}$ – service costs for harvesting and primary processing of GM cultivated plants;

$\Delta \sum C_{MMZ}^{GM}$ – service costs for the machinery needed for growing, transportation and primary processing of GM cultivated plants as well as for washing the machinery.

As it is evident, in equation 5 two deltas are included – one with a positive sign, while the other with a negative one. It gives a chance to get a clearer idea of the cost comparison result for the services used in the production of GM cultivated plants and the conventional ones. The positive delta increases service costs for growing GM rape – machinery used in growing, transporting the seeds and harvest as well as primary processing of GM cultivated plants and cleaning agricultural machinery. But the negative delta decreases the service costs used for plant protection measures of GM cultivated plants. In the research, the general costs for growing GM cultivated plants are equalised to the general costs for growing genetically unmodified cultivated plants except the costs related to the fulfilment of the activities set by the laws and regulations for the growers of GM cultivated plants to reduce dissemination of uncontrolled GM cultivated plants.

The most important cost increase in the event of growing GM rape in the territory of Latvia compared to the genetically unmodified cultivation of rape is related to the activities which are to be carried out by the growers of GM rape to decrease the threat of the surrounding environment and other subjects of the economic management as a result of the dissemination of uncontrolled genetically modified cultivated plants. Within the framework of the research, these costs are defined as extra costs in relation to implementation of the requirements set by the laws and regulations. To state the above costs, the following equation is offered:

$$\sum C_{PP} = \sum C_{PP}^{GM} + \sum C_{PP}^{VI}, \quad (6)$$

where

$\sum C_{PP}$ – total extra costs in the event of growing GM cultivated plants;

$\sum C_{PP}^{GM}$ – extra costs for a farm growing GM cultivated plants which arise in relation to the fulfilment of requirements set by laws and regulations;

$\sum C_{PP}^{VI}$ – extra costs of the state institutions which arise in relation to the fulfilment of requirements set by the laws and regulations.

Extra costs which arise in a farm growing GM cultivated plants to fulfil requirements set by the laws and regulations for eliminating dissemination of uncontrolled genetically modified cultivated plants are estimated taking into account the following equation:

$$C_{PP}^{GM} = C_{INF}^{GM} + \sum C_{PM}^{GM} + \sum C_{LA}^{GM} + \sum C_{DK}^{GM} + \sum C_{PA}^{GM} + \sum C_{VI}^{GM} + C_{APD}^{GM} + NP_{INF}^{GM} + C_{CI}^{GM} \quad , (7)$$

where

C_{PP}^{GM} – extra costs related to the fulfilment of requirements set by the laws and regulations for growing GM cultivated plants on the farm;

C^{GM}_{INF} – extra costs to coordinate growing costs for the prospective growing of GM cultivated plants;

C^{GM}_{PM} – the packaging and marking costs for the harvest of GM cultivated plants;

C^{GM}_{PM} – costs for the laboratory analyses to control the uncontrolled dissemination of GM cultivated plants;

C^{GM}_{DK} – extra costs for processing documentation reflecting growing, harvesting, primary processing and preparation of GM cultivated plants for sale;

C^{GM}_{PA} – extra costs for training of the personnel of farms which desire to grow GM cultivated plants;

C^{GM}_{VI} – extra costs of the state institutions related to the fulfilment of the supervisory and control process set by the laws and regulations to fulfil the requirements set by the laws and regulations for growing GM cultivated plants;

C^{GM}_{APD} – insurance costs for sowings of GM cultivated plants;

NP^{GM}_{BFJ} – the lost income from the area which is used for establishing the buffer zone around the fields where GM cultivated plants are grown;

C^{GM}_{CI} – other costs related to the fulfilment of other requirements set by the laws and regulations for farms growing GM cultivated plants.

In estimating extra costs, the grower of GM cultivated plants has to take into account the packaging and marking costs of GM cultivated plants. Mutually agreeing, the grower can attribute these costs to the wholesale dealer of GM cultivated plants. But in such case, the grower of GM cultivated plants has to consider a lower sales price. It means that it will be necessary for the grower of GM cultivated plants to pay for packaging and marking of the harvest due to the decrease of the sales revenues. In the formation of sales revenues in farms growing GM cultivated plants, the most essential factor is the sales price of the grown harvest and the following aspects are to be taken into account in creating it:

a) potentially low price – the forecasted sales price of the harvest for GM cultivated plants can be at least 10-15% lower than the sales price for the conventional cultivated plants and the experience of farms growing GM cultivated plants in other countries give evidence of that;
b) the use opportunities – the sales price of the harvest for GM cultivated plants to a great extent depends on the use opportunities set for the final output;
c) the impact on the environment – the impact of the respective GM cultivated plant on the environment, health of animals and people;
d) to a certain extent the sales price is affected by the regulations set in the EU countries for marking GM cultivated plants.

The sales revenues of the farm when selling the grown harvest of GM cultivated plants can be expressed by the following equation:

$$TR_{GM} = (Q_{GM} \text{ x } P) \times K_{iz} \times K_v \times K_m \times K_n, \qquad (8)$$

where

TR_{GM} – income from the harvest of GM cultivated plants;

Q – the amount of sold GM cultivated plants;

P – sales price for GM cultivated plants;

K_{iz} – the correction coefficient for the sales price which depends on the type of using GM cultivated plants in manufacturing a definite final output;

K_v – the correction coefficient for the sales price which depends on the impact of a certain modification of cultivated plants on the environment, health of animals and people;

K_m – the correction coefficient of the sales price related to the fulfilment of the requirements for marking GM cultivated plants;

K_n – the correction coefficient of the sales price related to other factors affecting dissemination of GM cultivated plants.

According to equation 8, the economic content is not unequivocal. Separate factors can reduce sales revenues from the harvest of GM cultivated plants, while the others can increase them. In addition, it is to be taken into account that the society and scientists are uncertain of the effect of GM cultivated plants on the diversity of species and the sustainable development of the environment. It means that the law makers and the potential growers of these cultivated plants have to observe in their activities not only the principle “the polluter pays” but also the precautionary principle in eliminating the threat of an uncontrolled spread of GM cultivated plants (Džeroski et al., 2006).

The scientific research in improving properties of cultivated plants and the sphere of using GM products can drastically affect both growing costs of GM cultural plants and sales revenues. Being in such uncertainty conditions in relation to the prospective growing of GM cultivated plants in the territory of Latvia, in creating free zones in Latvia; it is more useful to use the economic methods. It means that additional requirements for eliminating the threat of an uncontrolled dissemination of GM cultivated plants should be forecasted in the laws and regulations, and their implementation for the prospective grower being in the free zone, will increase operating costs, thus growing GM cultivated plants in this territory will become unfavourable compared to other alternatives available for the use of natural resources.

The definition of free zones offers the opportunity to apply the following basic principles:

a) the principle of the economic profitability. It means that in the free zones additional requirements are set for eliminating the uncontrolled dissemination of GM cultivated plants which increase operating costs for the prospective grower of GM cultivated plants;

b) the principle of the administrative ban. This principle envisages the opportunity that the state can set the ban in definite territories to grow GM cultivated plants taking into account the prospective threat and the prospective losses for other subjects of the economic activities in the countryside.

Every of the above principles have certain priorities and drawbacks. Their comparison is depicted in Table 1.

The positive and negative aspects for evaluating the principles of establishing the free zone shown in Table 1 may help the state institutions to take a decision on the tactical ways which are directed to eliminating an uncontrolled dissemination of GM cultivated plants and maintaining of the natural advantages of the state in growing cultivated plants which are used for manufacturing foodstuffs and non-food products with a high value added.

Developing the economic justification for establishing economically free zones, the applied mathematical model can be expressed by the equation system in the following way:

$$\frac{\sum TR_{GM}}{\sum PL_{GM}} - \frac{\sum TC_{GM} + \Delta C_{GM}^{PRP} + \sum EC_{GM}^{SB}}{\sum PL_{GM}} \leq \frac{\sum TR_{KKA}}{\sum PL_{KKA}} - \frac{\sum TC_{KKA}}{\sum PL_{KKA}}, \quad (9)$$

$$\frac{\sum TR_{GM}}{\sum R_{GM}} - \frac{\sum TC_{GM} + \Delta C_{GM}^{PRP} + \sum EC_{GM}^{SB}}{\sum R_{GM}} \leq \frac{\sum TR_{KKA}}{\sum R_{KKA}} - \frac{\sum TC_{KKA}}{\sum R_{KKA}}, \quad (10)$$

Table 1

Comparison of the Free zones (FZ) forming principles

Principle of forming FZ	Positive aspects	Negative aspects
Principles of economic profitability	– based on the principle of alternative costs and rational behaviour of market members; – diminishes threats of illegal growing of GM cultivated plants;	– in addition to the determination of preventive enterprises for diminishing threats of illegal dissemination of GM cultivated plants it can be also eliminated by the EU norms regarding the issue; – determining preventive enterprises, it is necessary to calculate their sales costs; – profitability of preventive enterprises can be influenced by different agro climate circumstances in the regions of the state; – effectively working farms can gain sufficient profitability sufficient profitability by growing GM cultivated plants also in Free zones.
Principle of administrative prohibition	– economic calculations on possible costs of preventive enterprises are not necessary; – principle of rational behaviour and alternative costs.	– based on legal consciousness, moral and material responsibility of the market members in case of inobservance of the prohibition that would not be an obstacle in particular cases to grow GM cultivated plants also in the free zones if it was economically profitable; – state institutions need additional resources to ensure the implementation of the prohibition; – prohibition to grow GM cultivated plants in the free zones can be in conflict with the EU norms with all the following consequences.

where

$\sum TR_{GM}$ – total income for farms where GM cultivated plants are grown;

$\sum TC_{GM}$ – total costs for growing GM cultivated plants;

$\sum PL_{GM}$ – the total area for GM cultivated plants;

ΔC_{GM}^{PRP} – extra costs for the grower of GM cultivated plants in relation to the preventive measures set by the laws and regulations for eliminating the threat of dissemination of GM cultivated plants;

$\sum EC_{GM}^{SB}$ – extra costs for the society (the state, other subjects of the economic activities and households) which arise if GM cultivated plants are grown in the country;

TR_{KKA} – total income from a farm growing a conventional cultivated plant as the alternative to the GM cultivated plant;

TC_{KKA} – total costs when growing a conventional cultivated plant as an alternative to the GM cultivated plant;

PL_{KKA} – the area for the conventional cultivated plant grown as an alternative to the GM cultivated plant;

R_{KKA} – weight of the harvest for the conventional cultivated plant grown as an alternative to the GM cultivated plant;

R_{GM} – weight of the harvest for GM cultivated plants.

The economic content of inequalities 9 and 10 shows that as a result of growing GM cultivated plants in the territory of the free zone, the obtained net income on a weight unit of the area and the grown harvest will be lower than the net income of the respective conventional cultivated plant per a weigh unit of the grown area and the harvest. Thus, the possibility of the grown harvest to change upon the effect of the agro-climatic conditions and other outer factors is included in the developed mathematical model.

From the point of view of the sustainable development of the society and the environment, it can be concluded that growing GM cultivated plants can be favourable for the state and society only in the case if the specific income (income per one unit of area) of growing GM cultivated plants is higher than the direct and indirect costs arising for the grower himself as well as for the near farms and other subjects of the society in carrying out the preventive and corrective measures to eliminate and/or decrease dissemination of uncontrolled GM cultivated plants, and to decrease the threat of the biological contamination. In addition, in this case it is assumed that the principle of the free choice is observed. It means that the farms which choose to grow GM cultivated plants will not cause any burden for the economic environment and extra costs for farms which will operate according to the technologies of the conventional and biological agriculture, or will recompense the arisen extra costs and the inflicted losses as a result of an uncontrolled dissemination of GM cultivated plants.

Growing GM cultivated plants causes losses to other subjects of the economic activities in the countryside and causes extra costs for state institutions in whose competency is to carry out preventive measures at the state level to eliminate and/or to decrease an uncontrolled dissemination of GM cultivated plants. The content of extra costs for other economic subjects in the countryside and state institutions can be revealed by the following mathematical equation:

$$\sum EC_{GM}^{SB} = \sum EC_{BL} + \sum EC_{KL} + \sum EZ_{LU} + \sum EC_{VI}, \quad (11)$$

where

$\sum EC_{GM}^{SB}$ – additional costs for the society in the event of growing GM cultivated plants;

$\sum EC_{BL}$ – additional costs for biological farms related to the preventive measures to decrease and/or to eliminate threat which might be caused by the growers of GM cultivated plants;

$\sum EC_{KL}$ – additional costs for conventional farms related to the preventive measures which might be caused by the preventive measures to decrease and/or to eliminate the threat which might be caused by the growers of GM cultivated plants;

$\sum EZ_{LU}$ – additional losses in the form of the lost income for other countryside businesses which provide services related to tourism, relaxation, health rehabilitation and similar businesses which raise their competitiveness through the advantages of the natural environment of Latvia;

$\sum EC_{VI}$ – total expenses of the state institutions related to the preventive measures to decrease and/or to eliminate threat which might be caused by the growers of GM cultivated plants.

The global practice witnesses that the preventive measures (measures directed to elimination of threats and/or their decrease) are economically more favourable, cost less than the corrective measures-measures related to starting of threats and elimination of the caused results (Frank, 2004). The results of the economic justification for the free zones have to give the reply to the question whether the potential gain of the society giving access to growing GM cultural plants in the territory of Latvia will be higher and will be able to compensate the extra costs to the manufacturers of GM cultivated plants themselves and will no harm the biological and conventional farms.

The graphical model developed for the economic justification of establishing free zones is envisaged for the comparison of operating costs in the case of growing GM cultivated plants and conventional cultivated plants. Besides, the graphical model gives the opportunity to estimate the minimum area for the farms so as the harvest income covers the expenses. To get a fuller insight of the graphical model used in the economic justification for establishing economically free zones, initially the model used in estimating costs and incomes for the conventional cultivated plants in relation to the sown area which can be used in developing the economic justification for establishing free zones is shown. The graphical model is shown in Figure 1.

By using the graphical model shown in Figure 1, it is possible to state the profitability of growing the conventional cultivated plants as the alternative to the GM cultivated plants and its connection with the sowing area. For the purpose of the model, the total costs of growing, harvesting, primary processing and sales of the respective cultivated plants are divided in the following parts:

$$\sum TC_{KKA} = \sum FC_{KKA} + \sum VC_{KKA}, \qquad (12)$$

where

- TC_{KKA} – total costs for growing, harvesting, primary processing and sales of the respective conventional cultivated plants;
- $\sum FC_{KKA}$ – fixed costs for growing, harvesting, primary processing and sales of the conventional cultivated plants;
- $\sum VC_{KKA}$ – variable costs for growing, harvesting, primary processing and sales of the conventional cultivated plants.

Within the framework of developing the economic justification of the free zones, the variable costs are defined in the following way: the variable costs in growing, harvesting, primary processing and sales of the conventional cultivated plant are the costs which are variable if the sowing area of the respective cultivated plant is increased on one hectare. The variable costs contain the following costs:

– sowing costs;
– costs related to fertilizers and plant protection measures;
– service costs needed for growing, harvesting, primary processing and sales of the respective cultivated plant if the farm does not perform this work themselves;
– other similar costs directly related to manufacturing a definite agricultural produce.

The fixed costs unlike the variable costs do not vary if the sowing area of the respective cultivated plant is increased within the limits of the available resources.

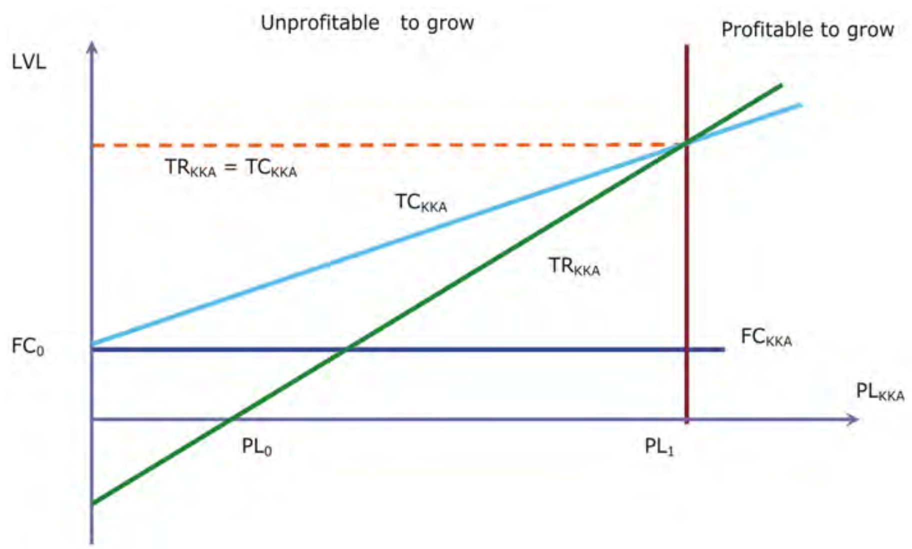

Fig. 1. The model of economic basis for conventional rapeseed crop growing.

The following costs are included in the group of the fixed costs:

– depreciation expenses for the fixed assets on the farm;
– farm management expenses;
– other similar expenses related to the operation of all the farms in manufacturing different types of agricultural produce.

In the evaluation of expenses and incomes for growing the conventional cultivated plants, the applicable model is described by the following lines and points:

a) the fixed costs are shown by the lower horizontal line and the respective symbol as they are not variable if the sowing area changes;
b) the variable costs included in the total costs are shown by a rising line which starts at the point FC0;
c) the line describing the income starts by a negative value as the field income, if the cultivated plants are not grown and other economic activities are not carried out, will be negative, i.e., losses will be incurred;
d) the point PL_0 describes the minimum area at which the incomes can cover the fixed costs;
e) the point PL_0 describes the minimum area which provides such sales income which can cover the variable and fixed costs;
f) by increasing the sowing area which is larger than PL_0, it becomes profitable to grow the respective cultivated plant.

Evaluating the expenses and incomes for growing the conventional cultivated plants, the applicable graphical model gives the opportunity to determine the minimum area for growing the respective cultivated plant at which the farm can cover all the operating costs and can start operating with profit. The graphical model used for the development of the economic justification of the free zones is given in Figure 2.

The indices of the economic profitability for growing the conventional cultivated plant as the alternative to the GM cultivated plant are shown by a broken line. The graphical model for the economic justification of establishing free zones shown in Figure 2, gives the opportunity to state different significant indices which can be later used in evaluating the economic profitability for growing GM cultivated plants compared to the alternative conventional cultivated plants. Wherewith, economically grounded information is obtained on the preventive measures to be carried out and of the required extra costs so as growing GM cultivated plants will not be profitable in the established free zones. The most significant elements of the model shown in Figure 2 are as follows:

a) the increase of the fixed costs ΔTC_{GM}. It is related to the additional resources used for implementing the

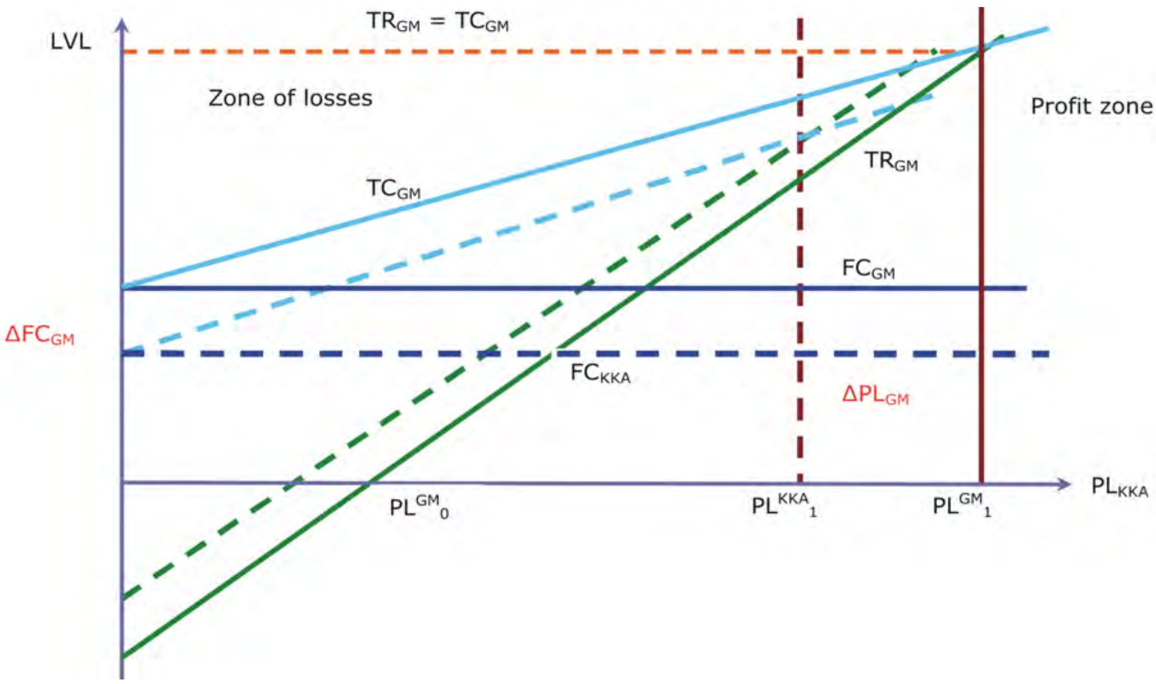

Fig. 2. The determination model of economic basis for forming of the Free zones.

preventive measures set by the laws and regulations;

b) due to the properties obtained as a result of modification of cultivated plants, the variable costs for GM cultivated plants will decrease. In the graphical model, it is shown by the diverse directions of the lines for the total costs of growing GM cultivated plants- the line of the total costs for growing GM cultivated plants is not parallel but slightly more sloping compared to the line for the total costs of the conventional cultivated plants;

c) the economic condition for establishing the free zone is related to a higher increase of extra costs compared to the decrease in costs which can be obtained applying the new properties of the modified cultivated plant;

d) by increase of the total costs, the area increases which is needed to cover the fixed costs to PL^{GM}_0. It means that in the case of growing GM cultivated plants, a larger area shall be sown in order to cover only the variable costs and, wherewith, all the costs. In other words, a larger area is needed to make growing of GM cultivated plants more profitable;

e) to cover all the operating costs in the event of growing GM cultivated plants, the minimum area corresponds to PL^{GM}_1, which in the event of establishing free zones will be larger than the area PL^{KKA}_1, which is needed for covering costs needed to grow conventional cultivated plants;

f) the model shows that growing GM cultivated plants in the free zones can become more profitable than growing alternative conventional cultivated plants only in huge areas.

The described method for the economic justification of establishing free zones is applicable when it is needed to protect a territory from the threat inflicted by GM cultivated plants which can cause fundamental threat to other subjects of the economic activities. It is useful to do such estimations after developing the respective laws and regulations, and taking into account properties of the cultivated plant.

It is possible to comparatively evaluate districts and regions of Latvia to find more or less endangered territories in the country. Such approach can decrease time for developing the economic justification for the free zones and for taking management decisions in relation to the opportunities of growing GM in one of the regions of the country. Different indices related to the threat of disseminating GM cultivated plants are used for the evaluation of the regions. These indices are shown in Table 2.

As shown by the information provided in Table 2, the selected absolute and comparative indices are mutually linked. However all the indices are linked with fundamental threat for other manufacturers of the agricultural produce in the countryside.

To combine the indices shown in Table 2 for the evaluation of the most endangered regions, at first, the regions are ranked in growing order according to every index. As a result, 10 charts are obtained with the absolute index and the rank for the respective index. Every of the evaluation criteria shown in Table 2 get a definite weight to use the obtained rank indices for evaluating the threat. The weight values are shown in Table 3.

As it is shown by the information depicted in the table a variable weight is set to evaluate more precisely the potential threat and the possible losses in the event of the threat for the indices used in evaluating districts. The highest weight in the group of the absolute indices is assigned to the land for the biological farming – 0.4 or 40% of the absolute value

Table 2

Indicators used in the regional evaluation

Absolute indicators	Comparative indicators
Number of organic farms in region	Proportion of organic farms in total number of farms in a region
Utilised agricultural areas of organic farms	Proportion of utilised agricultural areas of organic farms in total usable UAA in a region
Endangered areas in biological farms	Proportion of endangered area in total area of utilised agricultural areas of organic farms
Areas of rapeseed crop in all farms	Proportion of areas of rapeseed crop in all farms in total usable UAA in a region;
Number of beehive of bees in all the farms of a region	Number of beehive of bees in all farms per 1000 ha of usable UAA.

Table 3

Weight of indicators used in evaluation of regions

Absolute indicators		Comparative indicators	
Contents of indicator	Weight	Contents of indicator	Weight
Number of organic farms in a region	0.15	Proportion of organic farms in the total number of farms in a region	0.1
Utilised agricultural areas of organic farms	0.4	Proportion of utilised agricultural areas of organic farms in the total usable UAA in a region	0.45
Endangered areas in organic farms	0.1	Proportion of endangered area in the total area of utilised agricultural areas of organic farms	0.1
Areas of rapeseed crop in all farms	0.1	Proportion of areas of rapeseed crop in all farms in the total usable UAA in a region	0.05
Number of beehives of bees in all the farms of a region	0.25	Number of beehives of bees in all farms per 1000 ha of usable UAA.	0.3
Total	1.00	Total	1.00

of all the indices effect. It is related to a greater threat for dissemination of GM cultivated plants to the biological farms with a larger area of management. The smallest weight in this group of indices is left for the endangered areas of the biological farms and rape sowings in all the farms. Such weight is set taking into account the following aspects:

- comparatively small area of the endangered biological farms which deal with the endangered cultivated plant;
- the existing differences in the agro-climatic conditions between the districts growing rape;
- the existing differences between the districts in using the grown rapeseeds for manufacturing a definite final output.

In the group of the comparative indices, the highest value is assigned to the specific weight of the agricultural land available for the biological farms from the total used district of agricultural land – 0.45. The weight for this index can be explained by the increase of threat in districts where both the absolutely and relatively larger areas are managed by the biological farms. The lowest value in this group is set for the specific weight of the biological farms of the total number of the farms in the district – 0.1, for the specific weight of the rapeseed sowing area from all the farms of the total agricultural lands – 0.05, and the specific weight of the endangered area from all the agricultural land available for the biological farms – 0.1. For the assigned rate weight, the following explanation is given:

- the variable size of the biological farms in the districts which are considered as an indirect factor intensifying the threat;
- the specific weight of rape sowings in several districts is not considered to be an essential argument intensifying the threat and the potential losses as comparatively good alternative opportunities exist to sell the rape with the presence of GMO;
- comparatively small peculiar weight of the endangered areas on the biological farms is considered to be an insignificant threat intensifying factor.

Using the above indices and the weight of their impact on the endangered subjects in the countryside, every district gets definite points which are used for comparative evaluation of the districts in relation to the dissemination threat of GM cultivated plants. The application of the described method enabled to evaluate every district in a definite territorial region and country on the whole. The districts were grouped into the following 3 parts: districts with a strong threat/essential losses can arise for the subjects of the economic activities, districts with a medium threat, and districts with a low level of threat.

As it is seen in Table 4, the group of the endangered districts to a great extent includes districts which have received the evaluation starting from 34.8 points for Preiļi district to 42.4 points for Cēsis district. The difference in points does not form full 8 points or 19% of the value of the highest result. None of Kurzeme districts is included in the group of the most endangered districts. In the group of less endangered districts, all 8 districts are included where the threat is evaluated from 9.3 points for Jelgava district in Zemgale region to 21.4 points for Tukums district in Riga region.

Table 4

Indicators for the evaluation of common regional risk

Evaluation of regional risk		Most endangered regions	
Region	Points	Region	Points
Aizkraukle	37.95	Cēsis	42.4
Alūksne	30.70	Limbaži	42.1
Balvi	30.25	Madona	38.5
Bauska	12.50	Aizkraukle	38.0
Cēsis	42.35	Valka	37.9
Daugavpils	30.05	Preiļi	34.8
Dobele	12.30	Talsi	32.8
Gulbene	25.35	Liepāja	31.6
Jelgava	9.25	Alūksne	30.7
Jēkabpils	26.20	Balvi	30.3
Krāslavas	28.50	Daugavpils	30.1
Kuldīga	28.35	Saldus	29.9
Liepāja	31.55	Krāslava	28.5
Limbaži	42.05	Kuldīga	28.4
Ludza	18.25	Ventspils	28.0
Madona	38.50	Jēkabpils	26.2
Ogre	15.95	Valmiera	26.2
Preiļi	34.80	Gulbene	25.4
Rēzekne	21.15	Tukums	21.4
Rīga	10.60	Rēzekne	21.2
Saldus	29.85	Ludza	18.3
Talsi	32.80	Ogre	16.0
Tukums	21.40	Bauska	12.5
Valka	37.90	Dobele	12.3
Valmiera	26.20	Rīga	10.6
Ventspils	27.95	Jelgava	9.3

It is important to note that the districts of Bauska, Dobele and Jelgava find themselves in a very similar situation which points to the high competitiveness of the districts for an intensive manufacturing of the agricultural produce with wide prospects to use the scale effect.

Conclusions

1. The evaluation of the threat level for the districts can provide valuable information to the concerned persons on establishing free zones and developing the economic justification for a definite territory of the country.
2. The information and conclusions can be useful for making government decisions in the respective state institutions.
3. When starting to grow GM rape, the prospective free zones are to be established in the Districts of Cēsis, Limbaži, Madona, Aizkraukle, Valka, and Preiļi.

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Anotācija

Brīvā bioloģiskā zona ir noteikta valsts teritorijas daļa, kurā iespējamā ĢM kultūraugu audzēšana kļūst ekonomiski neizdevīga, izpildot valsts normatīvajos aktos noteiktās prasības un/vai var radīt reālus ražošanas dabisko apstākļu pasliktināšanās (zaudējumu) draudus citiem saimnieciskās darbības subjektiem, kā arī apkārtējās vides ilgtspējīgai attīstībai, dzīvnieku un cilvēku veselībai. Brīvo zonu izveidošanas nepieciešamību var ekonomiski pamatot. Brīvajās bioloģiskajās zonās strādājošās lauku saimniecības būtu valstiski aizsargāti no ĢM lauksaimniecības kultūraugu apdraudējuma, ko var izraisīt ģenētiski modificētais piesārņojums. Tas palielinātu saražoto lauksaimniecības produktu pārstrādātāju – pārtikas preču ražotāju uzticību piegādātājiem, radot pārliecību, ka iepirktajām lauksaimniecības rakstura izejvielām nav konstatējama ģenētiski modificēto organismu klātbūtne. Par šo pārliecību pārtikas produktu ražotāji un gala produktu patērētāji labprāt maksā lielāku cenu. Identificētie potenciālo zaudējumu subjekti ĢM kultūraugu audzēšanas gadījumā ir bioloģiskās lauku saimniecības, lauku saimniecības, kurās tiek audzēts rapsis, sēklkopības lauku saimniecības, kurās audzē rapsi vai citu krustziežu sēklu,saimniecības, kurās audzē bites. Izstrādāti matemātiskie un uzskatāmi grafiskie modeļi brīvo zonu ekonomiskā pamatojuma izstrādei.

Trends in Food Expenditure, Consumption and Nutrition in Latvia
Pārtikas izdevumu, patēriņa un uzturvērtības tendences Latvijā

Dina Popluga, Ligita Melece
Latvian State Institute of Agrarian Economics
Latvijas Valsts Agrārās ekonomikas institūts
e-mail: dina@lvaei.lv; ligita@lvaei.lv

Abstract. The population welfare level remarkably changed after 1990 when Latvia experienced dramatic economic changes. These changes affected the structure of food expenditure and consumption satisfying not only quantitative, but also qualitative food needs of inhabitants. The aim of this study was to analyse the trends of food consumption patterns and nutritive value of diet in Latvian households over the past decade. The study results showed that Latvian food consumption pattern had significantly changed over the last decade. At present food, transport, housing, water, electricity and gas constitute the largest categories of household expenditure. Furthermore, Latvian population constantly allocate more money for education, recreation, and culture. However, despite the fact that the share of food expenditure (expressed in % of total household expenditure) annually decreases, Latvia is still among those European Union member states which households spend relatively high share of their disposable income for purchasing food. A positive correlation was concluded between food consumption and income. For instance, consumption of cereal, oil and fat products tend to decline, whereas consumption of beverages, meat and fish appears to rise with the increase of income. Regardless some positive qualitative changes in the dietary pattern of Latvian population, the general situation is unsatisfactory due to high share of animal origin fat, sugar, and low share of plant origin calories in the nutritive value of Latvian population.
Key words: food consumption, expenditure, nutrition, household.

Introduction

Food consumption and nutrition are important factors in the promotion and maintenance of good health throughout the entire life course. Therefore these factors have been broadly investigated by different organizations, like World Health Organization (WHO) (WHO, 2006; 2003; 1999), United States Department of Agriculture (USDA) (USDA, 2007) and researchers (Friedl et al., 2006; Schenkel et al., 2005; Wu, 2004).

Many studies show close relationship between the consumption and income, which can be directly related with expenditure. It has been proved that economic development is normally accompanied by improvements in a country's food supply and the gradual elimination of dietary deficiencies, thus improving the overall nutritional status of the country's population (WHO, 2003).

Some authors point out that economic development also brings quantitative and qualitative changes in the diet. These changes include shifts in the structure of the diet towards a higher energy density diet with a greater role for fat and added sugars in foods, greater saturated fat intake (mostly from animal sources), reduced intakes of complex carbohydrates and dietary fiber, and reduced fruit and vegetable intakes (Elsner, Hartman, 1998; Frazao et al., 2007).

At the beginning of the 1990s, radical changes in Latvia's economics occurred. K. Elsner and M. Hartman point out that due to these changes most families bought food[1] products solely to satisfy their quantitative food needs. At the end of the 1990s, within the improvements in economic situation, the diversification of these expenses begun – the assortment of food purchased expanded, and nutrition value of the consumed products expanded and improved (Elsner, Hartman, 1998).

Therefore Latvia is a good example where broad research studies in the field of food consumption considering development of inhabitant's welfare level could be carried out. However, only few research studies about food consumption patterns in Latvia can be found (LVAEI, 2007; Pirksts et al., 2007)

Such evaluation of current situation encouraged carrying out this research and the following **hypothesis** was highlighted: income level is an important factor

[1] Here and further "food" – food and non-alcoholic beverages.

affecting food consumption pattern and nutritive value of consumed food and its trends.

The **aim** of this study was to analyze the trends of food consumption patterns and nutritive value of diet in Latvian households over the past decade. The main **objectives** were:

– to characterize food expenditure in the budget of Latvian households and its main trends;
– to describe trends of Latvian households food consumption, and to examine the possible development trends over the next several years;
– to evaluate trends of consumed food nutritional value.

Materials and Methods

Data output to meet the objectives of this study were obtained from Central Statistical Bureau of Latvia (CSB) (Central Statistical Bureau of Latvia, 2007) as well as from the Household Budget Survey (HBS) (Central Statistical Bureau of Latvia, 2006).

Data grouping and analysis methods were used to describe food expenditure in the budget of Latvian households, and to identify its main trends.

Quintile groups were used to characterise the food consumption and expenditure in households of different levels. In Household Budget Survey households are divided into quintiles according to their disposable income per household member. Quintile groups are formed by arranging all households in ascending sequence by income per one household member and dividing them afterwards in five equal groups. Each quintile represents 20%, or one fifth, of all households, where Quintile 1– the poorest households, Quintile 5 – the richest households.

A squared correlation coefficient (R^2) was calculated to estimate the main tendencies of a household's consumption of staple food groups (cereal products, meat products, dairy products and fat) in the past decade. If the R^2 is greater than 0.8 then there is a *marked tendency* towards a growth or decrease in consumption of certain food groups.

Statistical data analysis equalising the dynamic rows with analytical equalising methods, resulting in a straight or regular curved trend line, thus best reflecting the data analysis were performed in order to establish permanent connections. The calculations were done with the least square method, and the results were expressed as the trend lines.

Other important characteristics calculated in order to compare quantity and price that households with different income levels (Quintile 1 and Quintile 5) have paid for purchasing the same products were the ratio of product quantity (1) and ratio of price (2):

$$y = \frac{Q_5}{Q_1}, \quad (1)$$

where

y – ratio of product quantity;
Q_5 – quantity of consumed products in households representing Quintile 5, kg;
Q_1 – quantity of consumed products in households representing Quintile 1, kg;

$$y = \frac{P_5}{P_1}, \quad (2)$$

where

y – ratio of price;
P_5 – purchase price of consumed products in households representing Quintile 5, LVL;
P_1 – purchase price of consumed products in households representing Quintile 1, LVL.

In order to forecast the food consumption in Latvia for the period of next seven years (2007 to 2013) the following methods and materials were used: food consumption dynamics in Latvia from 1990 to 2006; consumption regularities (consumption of various foods depending on income – the Engel curve); forecasts of other European countries' food consumption, and also the analysis of consumption forecasts done by international institutions.

The calculations of nutritional or nutritive value were done using the norms of chemical content of different food products by Souci and co-authors (Souci et al., 1994).

The methods of analysis and synthesis as well as induction and deduction methods were used to draw conclusions.

Results and Discussion

Food Expenditure in the Budget of Latvian Households and its Trends

According to the data of CSB, within the last decade, the Latvia' s household's disposable income has increased more than two times (from LVL 51.52 in year 1996 to LVL 110.30 in year 2006) due to rapid economic development and employment growth (Central Statistical Bureau of Latvia, 2007). As a result of this structure of households' consumption expenditure has changed and since year 1996 consumption expenditure per one household member has increased by 70%.

In 2006, the largest categories of household expenditure were:

– food, with the average monthly household expenditure of LVL 43.69 per household member, representing 28% of the total household expenditure on goods and services;

- transport, with the average monthly household expenditure of LVL 20.27, representing 13% of the total household expenditure on goods and services;
- housing, water, electricity, gas and other fuels, with the average monthly household expenditure of LVL 19, representing 12% of the total household expenditure on goods and services.

Two general tendencies related to the increase of a household's income level can be observed in Latvia and also in other developing and developed countries.

Firstly, although household's food expenditure annually increases, its percentual share of total household expenditure decreases (Table 1). This trend is consistent with Engel's Law, a phenomenon first observed by Ernst Engel, who found that, as income increases, food spending also increases, but the proportion of income devoted to food declines (Merella, 2006). Here it should be noted that the percentage of consumption expenditure on food is one of the internationally comparable material of welfare indicators. Austrian and American researchers (Friedl et al., 2006; Frazao et al., 2007) stressed that in low-income countries food expenditure forms the vast majority of total household budget (up to 50%) while in high-income countries, for example, Organisation for Economic Co-operation and Development (OECD) countries, expenditure for food is small (about 15% of total household budget) as more money is allocated to education, recreation and culture, and for purchasing nonexpendable goods.

Despite that in Latvia the food expenditure share annually decreases (since 1996 food expenditure share of total household expenditure has decreased for 22.8 points or 55.2%), Latvia is still among those European Union member states whose households spend relatively high share of their disposable income for purchasing food (Latvia is on the sixth place). Higher share is only in Slovakia, Poland, Lithuania, and Rumania (USDA, 2007).

Secondly, the trend toward consuming more food away from home was observed due to spending less time for preparing meal at home (Fig. 1). A similar result is given by Irish researchers estimating Irish household's expenditure (Keelan et al., 2005).

Nevertheless, the proportion of income spent on food in Latvian households varies, depending on their income level. For instance, in 2006, a household member in the lowest income quintile (Quintile 1) spent for food 35% of total consumption expenditures per month, while in the highest income quintile (Quintile 5) – only 20%. However, assessing the structure of household's budget, we can conclude that the welfare level of all households rises with the decrease of the annual share of consumption expenditure on food.

Figure 2 shows that the expenditure for meat and meat products, milk, cheese and eggs, vegetables,

Table 1

The structure of household's consumption expenditure in Latvia (% of total expenditure), between 1996 and 2006

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Food and beverages	50.9	46.8	41.0	38.2	36.5	36.4	35.2	32.4	30.6	31.0	28.1
Transport	6.0	7.0	6.7	7.4	7.5	9.4	9.7	10.7	11.9	11.6	13.1
Housing, water, electricity, gas and other fuels	14.3	15.0	16.6	17.3	16.3	14.3	13.0	12.7	12.6	12.0	12.2
Clothing and footwear	5.7	5.7	6.9	6.5	6.5	6.4	6.8	7.5	7.2	7.8	7.7
Recreation and culture	4.1	4.6	5.5	5.6	6.2	6.2	6.5	6.6	6.2	6.7	7.5
Communication	1.4	2.0	3.1	4.2	5.2	5.3	5.9	6.0	6.6	6.1	6.1
Hotels, cafes and restaurants	2.4	2.6	2.4	2.2	2.4	4.9	5.6	4.9	5.3	5.6	5.9
Furnishings and household equipment	2.5	3.0	4.0	4.9	4.8	4.3	4.4	5.4	5.1	5.5	5.8
Miscellaneous goods and services	3.1	3.7	4.0	4.3	4.1	4.3	4.8	5.0	5.2	5.1	5.2
Health	3.7	3.8	3.4	3.7	4.0	3.9	3.2	3.6	3.9	3.9	3.7
Alcoholic beverages and tobacco	5.1	5.0	5.4	4.8	5.5	3.1	3.4	3.6	3.5	3.3	3.3
Education	0.8	0.8	1.0	0.9	1.0	1.5	1.5	1.6	1.8	1.5	1.4
Total	100	100	100	100	100	100	100	100	100	100	100

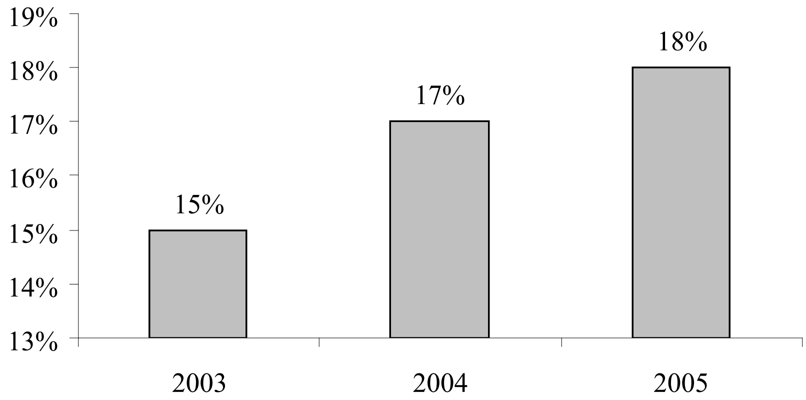

Fig. 1. The average share of food expenditures spent for food out of home in Latvia between 2003 and 2005 (%).

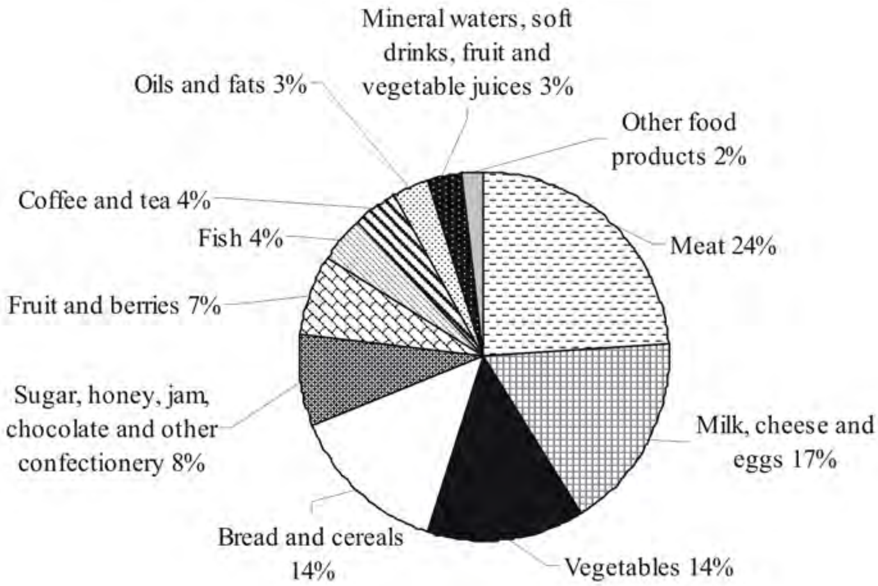

Fig. 2. The structure of food expenditure (% of total food expenditure), 2006.

bread and cereals has dominated in Latvian food consumption.

According to American researchers, staple food products, such as cereals, fats and oils, fruits and vegetables, account for a larger share of the total food budget in low-income countries than in higher income countries, while meat and dairy budget shares are greater for high-income countries (Martin, 1999).

Trends of Latvian Food Consumption

The food consumption structure and its trends in Latvia are analyzed on the basis of HBS assuming that average household's consumption reflects per capita consumption.

Figure 3 presents the main trends of staple food consumption per capita between 1997 and 2006 in Latvia. The product groups the consumption of which has the sharpest decrease are bread and cereal products (R^2=0.80), and fats (R^2=0.83), whereas consumption of meat and its products have increased (R^2=0.98).

Total meat consumption has increased by 31% since 1997. In general consumption of pork, poultry, sausages, smoked meat and semi-manufactured meat products has increased, while consumption of beef – decreased.

Bread and cereal consumption has decreased by 20% largely due to decline of wheat and rye bread consumption. Certain regularities have been found analyzing bread and cereal products' consumption in Latvia's households with different income level where bread and cereal product consumption is conversely to inhabitants' income (Fig. 4). For instance, in households with low income (Quintile 1 and 2) the consumption of bread and cereal products is bigger

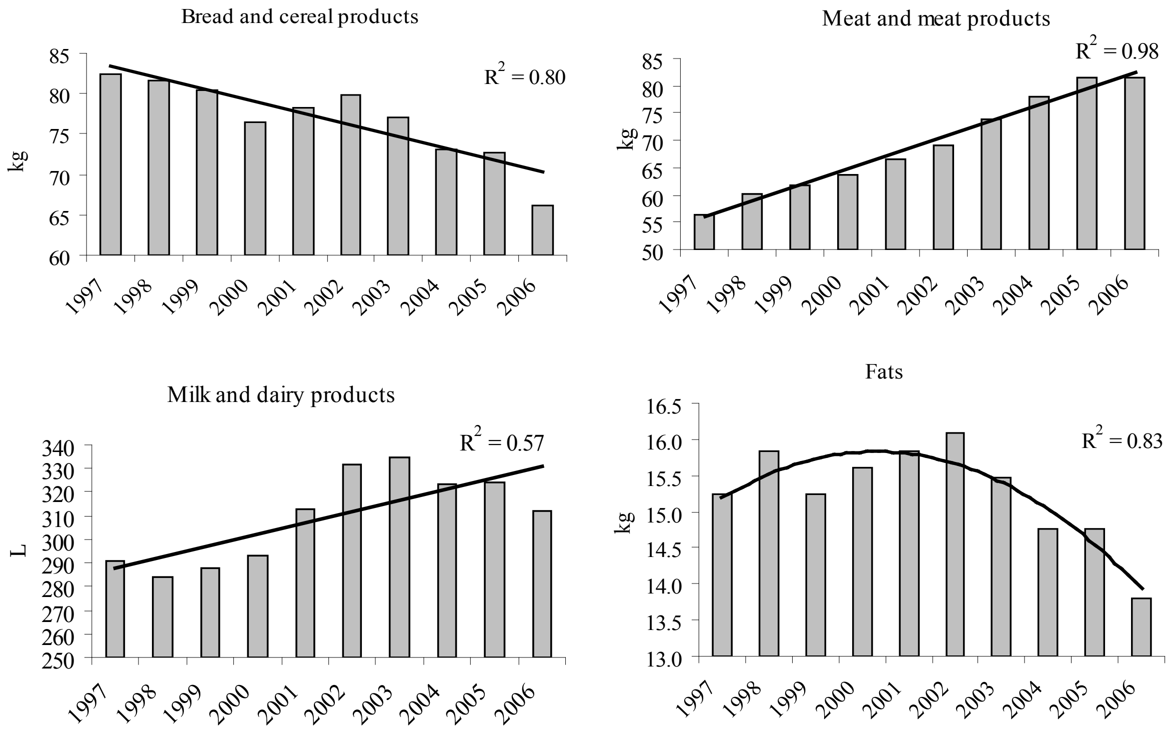

Fig. 3. The consumption of staple food groups in Latvian households between 1997 and 2006 (kg).

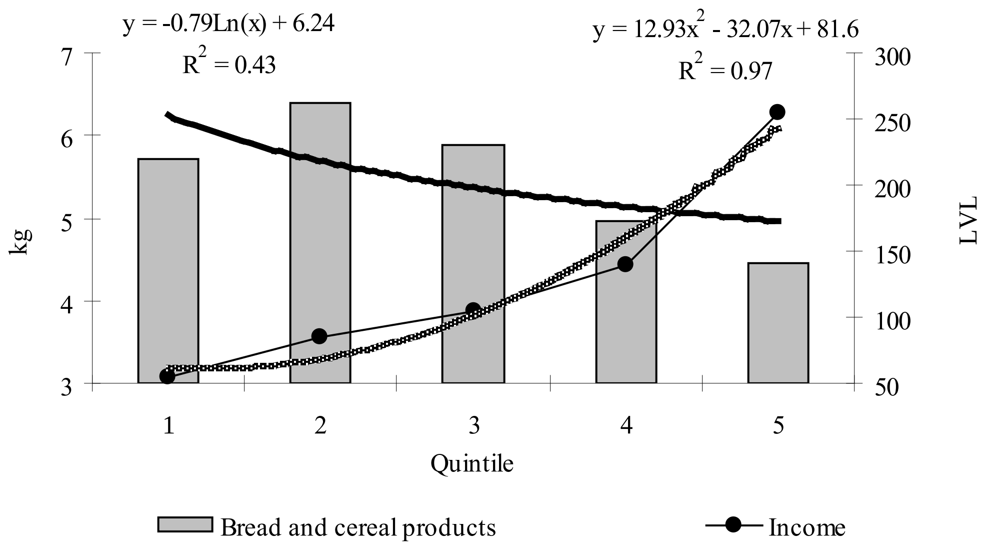

Fig. 4. The consumption of bread and cereal products (kg) in comparison with a household's disposable income (LVL) in quintile groups, 2005.

than in households with higher income (Quintile 4 and 5).

The consumption of milk and dairy products also shows a decline after the year 2003. It is interesting that health concerns have led to the downturn in consumption of some dairy products, particularly whole milk, while consumption of cheese, yoghurt and fermented dairy products has increased.

Higher consumer awareness of the nutritional benefits of a low-fat diet and a positive trend in the substitution of vegetable oils for animal fats in household diets has influenced decreasing of overall fat consumption. However, higher consumption of animal fats and margarine was observed only in households with low income (Quintile 1 and 2).

The consumption of fruits and berries has increased, largely driven by consumer health and nutritional

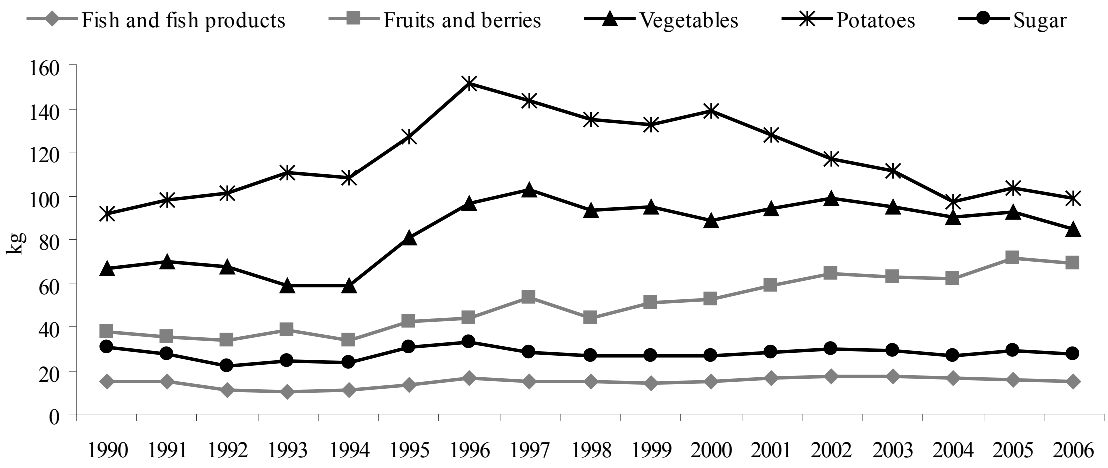

Fig. 5. The consumption of staple food groups in Latvian households between 1997 and 2006, (kg).

concerns. Since 1990 fruit and berries consumption has increased by 23% (Fig. 5).

Since 2002 the consumption of vegetables has decreased, and the study results show that members of Latvian households do not follow the World Health Organization (WHO) recommendations, which suggest an intake of more than 400 grams of vegetables (in addition to potatoes) and fruits per day. According to the WHO, only 60% of Latvian population report that they consume vegetables, excluding potatoes, (raw or cooked) daily (six to seven days per week). Besides in households with higher income level (Quintile 4 and 5) the consumption of frozen vegetables and those having low energy content (e.g., tomatoes, cucumbers) as well as semi-processed vegetables has increased (WHO, 1999).

The average consumption of fish and fish products, sugar, honey, chocolate, and other confectionery has not changed significantly. Some differences could be observed in the consumption structure between households with different income level. For example, households with higher income tend to consume more fresh and smoked fish, chocolates, honey, and ice-cream, while households with low income – cured fish, sugar, and jam.

Assessing the consumption of staple food products in households with the different income level it could be observed that better secured household diet is more diverse than diet of poorly secured households. The better-secured households consume by 69.5% more products (total number of analyzed products – n=95) than the poorest households. Therefore, the main factor affecting the diversity of consumed food is the income level of a household.

The ratio of product quantity and the ratio of price were other important characteristics calculated for comparing quantity and price that households with different income levels (Quintile 1 and Quintile 5) have paid for purchasing the same products. Logically, that households with higher income tend to purchase more diverse products – totally 70% of all analyzed products (n=84); and better secured households tend to purchase more expensive foodstuffs than poorly secured households. Yet, at the same time, households with low income have paid more than households with higher income for purchasing such products as beef, honey, mandarins, bean coffee, etc. (Table 2). In the authors' opinion this could be explained by the fact that consumers from the poorest households prefer shops closer to their place of residence instead of visiting supermarkets where the particular products cost cheaper than in small shops.

M. Schenkel with co-authors specifies that the rapid increase in purchasing power for food has been the most important (but not the only one) contributor to shifts in food consumption patterns (Schenkel et al., 2005). Also J. L. Martin reports that rising incomes and their impact on levels of food consumption has been one of the most important determinants in explaining shifts in global food demand and trade (Martin, 1999). At present in Latvia the income level of population exactly explains food consumptions trends in Latvia.

The forecast results of Latvian food consumption pattern for the planned seven year period (from 2007 to 2013) show the following food consumption tendencies within the household's income growth:

- consumption of bread and cereal products will decrease;
- consumption of meat and meat products on the whole will increase;
- regarding milk and dairy products, only the consumption of whole milk will decrease, whereas the consumption of other milk products will either rise or will remain at the same level (Fig. 6).

Table 2

The ratio of product quantity and ratio of price for certain food products between Quintile 5 and Quintile 1 in Latvia, 2006

Food products	Quintile 5/Quintile 1	
	ratio of product quantity	ratio of price
Beef	2.7	0.8
Semi-finished meat products	1.7	0.9
Mandarins	3.3	0.9
Coffee (bean)	2.9	0.9
Honey	4.0	0.9
Garlic	1.3	0.9
Semi-finished products	2.7	0.9

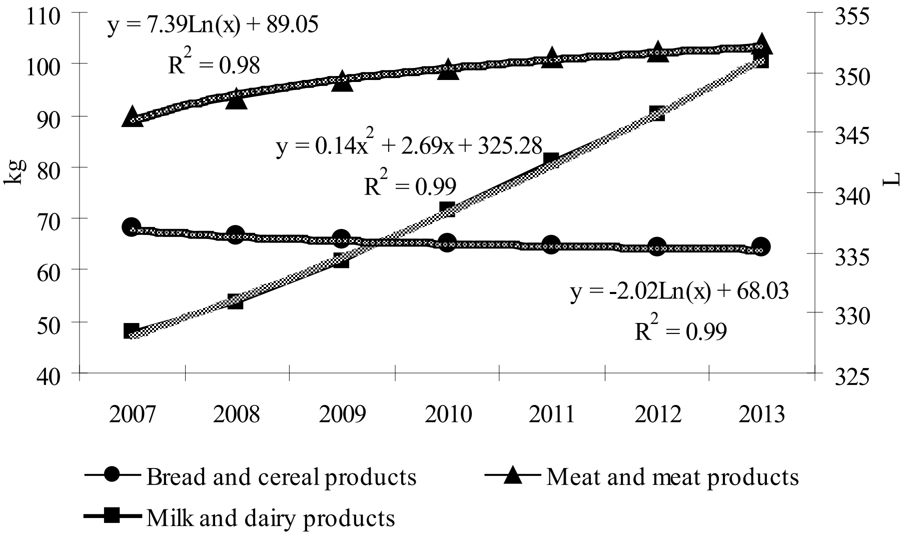

Fig. 6. Expected consumption of main foodstuffs (kg or L), forecast for 2007-2013.

In summary, food consumption trends of Latvian households tend to follow some worldwide tendencies (WHO, 2003; Wu, 2004) in terms of consumption of food and individual food items:

- food consumption budget falls as income rises;
- the budget shares of cereal, oil and fat products tend to decline as income increases;
- consumption of beverages, meat and fish appears to rise as income increases.

Nutritive Value of Consumed Food and its Trends

The economic development is normally accompanied by improvements in a country's food supply and the gradual elimination of dietary deficiencies, thus improving the overall nutritional status of the country's population (WHO, 2003). However, study results showed that in respect of food consumption, in the quantitative terms, Latvia is getting closer to the developed country's level, while qualitative changes in diet are still unsatisfactory.

Food consumption expressed in kilocalories (kcal) per capita per day is a key variable used for measuring and evaluating the global and regional food situation. Analysis of CSB data shows that dietary energy measured in kcal per capita per day has been fluctuating over the last few years, while globally it is steadily increasing. Average daily calorie consumption in Latvia in 2006 was 2570 kcal, which is 9%, or roughly 257 calories, below Latvian dieticians recommended calorie intake level (2827 kcal day^{-1}) (Table 3).

At the same time data shows that a relatively low proportion of food is derived from animal origin, but the tendency is positive, as annually this proportion increases. For instance, in 2002, daily calories consumed from animal products contributed 34% to total calorie intake, but in 2006 the consumption

Table 3

The nutritional value (kcal or g day-1) and origin of consumed food in Latvia, 2003-2006

	2002	2003	2004	2005	2006
Energy, kcal day-1					
Total	2663	2665	2611	2675	2570
Plant origin	1768	1730	1666	1712	1611
Animal origin	895	935	945	963	959
Carbohydrates, g day-1					
Total	345	336	322	331	312
Plant origin	331	322	308	317	298
Animal origin	14	14	14	14	14
Fats, g day-1					
Total	116	117	117	119	116
Plant origin	46	44	43	44	42
Animal origin	70	73	73	75	75

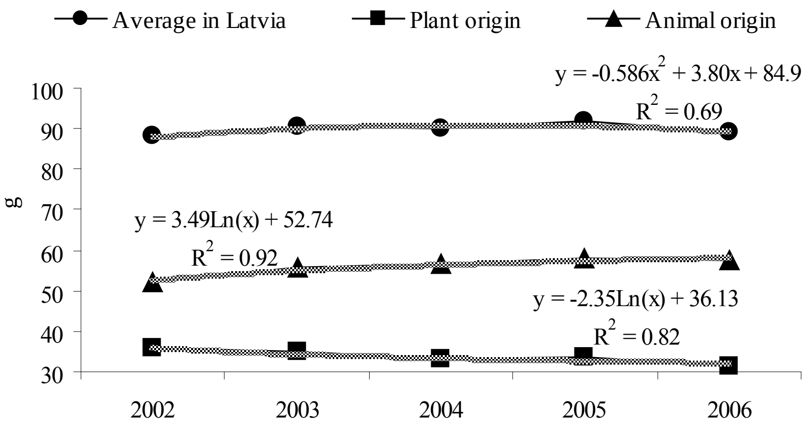

Fig. 7. Daily amount of protein taken with food in Latvia (g), 2002-2006.

of animal products amounted to a share of 37%. A similar increase can be observed for the protein intakes derived from animal products, although absolute protein intake has declined (Fig. 7).

Possible reasons, which have led to increase in the share of animal origin calories and thus to decline in the share of vegetable calories since 2002, are as follows:

- changes in relative prices between plant and animal products, particularly animal fat – speck, margarine, etc.;
- decrease in the consumption of bread and cereals.

However, according to K. Elsner and M. Hartman (Elsner, Hartman, 1998), in the OECD countries opposite tendency has been observed, which shows absolute fall in meat products consumption since 1980s, and it has been forecasted that this trend will continue in the future, as health consciousness is increasing.

The results of the study show that in the diet of Latvia's inhabitants 45.4% of total daily calories come from carbohydrates, 13.9% – from protein, and 40.7% – from fat. These indicators are inadequate to meet internationally recommended daily intake of energy and other macronutrients. WHO (WHO, 2003) stressed that, in general, the share of nutrients varies according to individual needs (age, gender, etc.), but the preferable average structure of macronutrients in the diet is the following[2]:

[2] http://www.healthydiningfinder.com/site/diners/getmore/healthylifestyles/calories.htm

- 45% to 65% of total daily calories should come from carbohydrates;
- 10% to 35% – from protein; and
- 20% to 35% – from fat.

WHO specifies that a diet, adequate to meet physiological requirements, containing sufficient amounts of fruit and vegetables and limited amounts of saturated fats and simple sugars combined with regular physical activity, is a cornerstone of good health (WHO, 2006).

Summarizing the results of the study, adverse changes in Latvian household dietary pattern can be observed, which include shifts in the structure of the diet towards:

- a higher energy density diet with a greater role for fat and added sugars in foods, and greater saturated fat intake (mostly from animal origin);
- reduced intakes of complex carbohydrates;
- reduced vegetable intakes.

Assessing the study results we can partly agree to M. Schenkel and co-authors (Schenkel et al., 2005) which argue that dietary changes are compounded by lifestyle changes. As the main consequences of unbalanced diet are sustained and acute increase in overweight and obesity of Latvia's citizens. According to WHO[3] data, among the population older than 15 years of age, 9.5% of the men and 17% of the women are clinically obese, while 41% of the men and 33% of the women are pre-obese. In all, 50% of the adult population is overweight. Moreover, the nutritional deficiencies are responsible for 1.2% of the disease burden in the Latvia's mortality group.

Conclusions

The structure of households' consumption expenditure has changed as a result of rapid economic development and employment growth. However, the share for food decreases annually; nevertheless the average share for food remains high comparing with other countries, and is one of the highest in all European Union member states.

Over the last decade Latvia food consumption pattern has changed significantly, particularly after accession to the European Union thus experiencing a similar tendency with other developed countries.

In general, there is a positive correlation between food consumption and income. For instance, the consumption of cereal, oil and fat products tend to decline, whereas consumption of beverages, meat and fish appears to rise as income increases. There are remarkable differences in food consumption (diversity and price of products, quantity of high nutrition value products, etc.) between the households with different income level; therefore income can be defined as the main factor influencing consumption.

Despite some positive qualitative changes in the dietary pattern of Latvian households, for example, increasing share of animal protein in the diet, the general situation is unsatisfactory due to high share of animal origin fat and sugar and low share of plant origin calories in nutritive value of Latvian population.

For more detailed estimation of trends and forecasts of Latvia food consumption and nutrition value it could be necessary to assess other consumption-influenced factors than income level, for instance, age, gender, education, socio-economical status, etc.

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Anotācija

Pēc 1990. gada, kad notika būtiskas izmaiņas Latvijas ekonomikā, mainījās iedzīvotāju labklājības līmenis, kas ieviesa izmaiņas pārtikas izdevumu un patēriņa struktūrā, apmierinot ne tikai kvantitatīvās, bet arī kvalitatīvās vajadzības pēc pārtikas. Raksta mērķis bija analizēt galvenās pārtikas izdevumu, patēriņa un uzturvērtības tendences Latvijas mājsaimniecībās pēdējo 10 gadu laikā. Galvenie pētījuma rezultāti ļāva secināt, ka iedzīvotāju izdevumu struktūra pēdējo gadu laikā ir mainījusies. Lielākās izdevumu grupas ir izdevumi pārtikai, transportam un izdevumi mājoklim, turklāt Latvijas iedzīvotāji arvien vairāk naudas līdzekļu atvēl izglītībai, atpūtai un kultūrai. Tomēr, neskatoties uz to, ka izdevumu īpatsvars pārtikai katru gadu samazinās, tas joprojām ir viens no augstākajiem Eiropas Savienībā. Vispārējās pārtikas patēriņa tendences ļauj salīdzināt Latviju ar citām attīstītām valstīm, kur novērojamas līdzīgas tendences. Secināts, ka pastāv pozitīva korelācija starp pārtikas patēriņu un ienākumiem. Piemēram, palielinoties iedzīvotāju ienākumu līmenim, graudaugu, eļļas un taukvielu produktu patēriņš samazinās, bet gaļas, zivju un bezalkoholisko dzērienu (sulu, minerālūdens, avotu ūdens) patēriņš palielinās. Neskatoties uz dažām pozitīvām izmaiņām Latvijas mājsaimniecību patērētās pārtikas uzturvērtības struktūrā, piemēram, dzīvnieku izcelsmes olbaltumvielu īpatsvara palielināšanos uzturā, kopējā situācija ir neapmierinoša, jo organismam nepieciešamā enerģija lielākoties tiek nodrošināta ar dzīvnieku izcelsmes taukiem un saldumiem, bet ievērojami mazāk ar augu izcelsmes produktiem.

Simulation-based Choice of Optimal Farming Strategies under Risks of Nature
Zemkopja optimālo stratēģiju izvēles modelēšana dabas risku apstākļos

Jurijs Merkurjevs, Vladimirs Bardačenko
Department of Modelling and Imitation, Riga Technical University
Rīgas Tehniskās universitātes Modelēšanas un imitācijas katedra
e-mail: merkur@itl.rtu.lv
Antons Ruža
Institute of Agrobiotechnology, LLU
LLU Agrobiotehnoloģijas institūts
e-mail: Antons.Ruza@llu.lv
Andrejs Solomennikovs
Institute of Ecology, Daugavpils University
Daugavpils universitātes Ekoloģijas institūts
e-mail: Andrey.Solomennikov@gmail.com

Abstract. The goal of simulation experiments with different input weather parameters is determining the farming strategies under conditions of nature inaccuracy due to global climate changes. The final goal would be suggesting most efficient farmer strategies subject to the given statistical uncertainty interval constraints. The application and analysis of decision-making theory methods in order to choose a farming strategy were performed to complete the set goal. It was illustrated that the choice of the optimal strategy depends on the farmer's subjective pessimism degree under conditions of no information on probabilities of the state of nature. The paper presents some results of the efficiency analysis of farming agricultural operations based on a specially developed discrete stochastic simulation model featuring the concept of agricultural function. The agricultural function value on a particular day of operation determines the expected crop gathered on the respective area. The atmospheric effect is modelled as random changes to agricultural function start time and duration of favourable period for performing an agricultural operation. According to the model farmer's strategies are described by two main parameters: agricultural operation start time and duration of the operation. The aim of the paper is to obtain quantitative estimation of a farmer's choice of agricultural operation strategy efficiency under unanticipated fluctuations of weather conditions.
Key words: risk, farming, strategy, optimisation, simulation.

Introduction

Climate changes affect durations of agricultural operations. Instability of weather parameters leads to lower accuracy of weather forecasts. As a consequence, there should be more emphasis put on the methodology of quantitative estimation of the expected crop depending both on the operation's start time as well as its intensity.

The traditional methodical approach for an estimation of influence of variable weather conditions on the crop lies in the adjustment of sufficiently accurate model parameters.

Most of the crop models known to the authors are based on the use of several groups of input parameters (Hoogenboom et al., 1992; Boote et al., 1998; Jamieson et al., 1998; Dadhwal et al., 2003; Jones et al., 2003; McMaster et al., 2003; Shaffer et al., 2004). One group of such variables represents weather factors, such as predictable marginal changes in the air and soil temperature, expected magnitude of solar radiation, deposits, and humidity, etc. Other groups of adjustable model parameters reflect both properties of soil as well as conventional farming practices for the given region.

The two approaches for crop estimation under uncertainty of weather conditions are portrayed in Figure 1.

Quantitative estimation of nature parameters on crop statistics is of special interest. For that purpose, the approach suggests creating special generators of random fluctuations of input parameters of crop models (Jones et al., 2003) which would simulate volatile weather parameters.

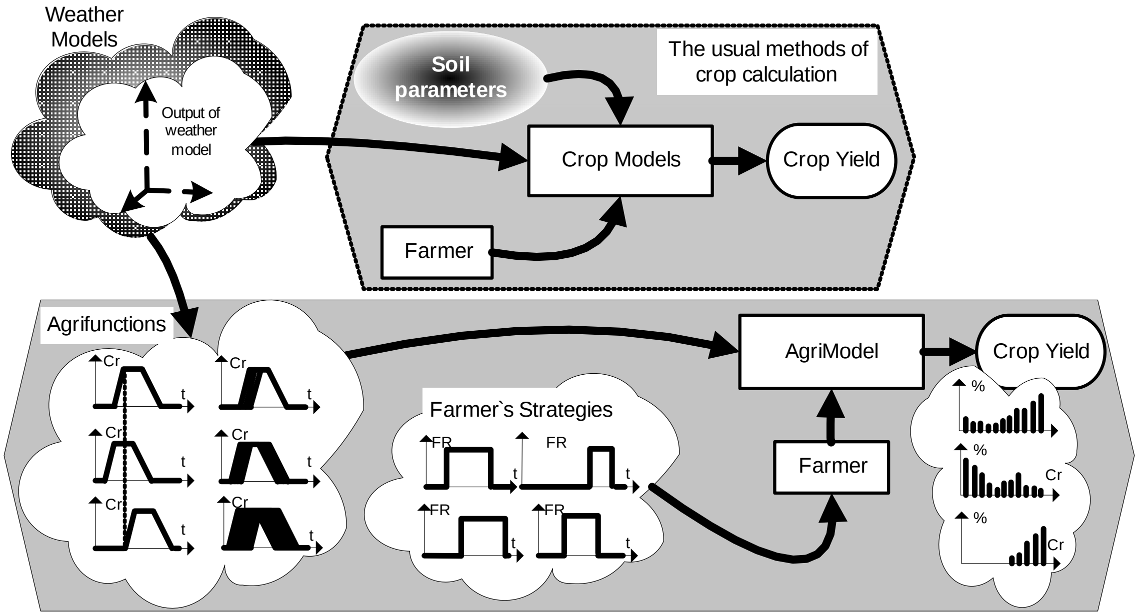

Fig. 1. Conventional approach to crop volume estimation (upper pane). The lower pane represents crop volume estimation using agricultural functions.

The conventional approach uses planting models. For example, Daisy is a Soil-Plant-Atmosphere system model (Willows, Connell, 2003) designed to simulate water balance, heat balance, solute balance, and crop production in agro-ecosystems subjected to various management strategies.

Should a crop model be realistic enough, such method can be used for the analysis of crop sensitivity to changes in nature parameters, and for choosing an optimal farming strategy. For the time being, however, such research has not been known to the authors of the present paper.

Recently there has been presented another methodical approach for finding an optimal farming strategy under conditions of uncertainty (Merkurjevs et al., 2002; Merkuryev et al., 2005; 2006). It is based on the introduction of agricultural functions. Agricultural function (agrifunction) in its simple form stands for the dependence of crop volume on agricultural operation time. It reflects farming experience in cultivation a specific crop in specific conditions (Merkuryev et al., 2006).

Following this approach any deviation in weather conditions affecting the crop will be reflected in space of parameters of agricultural function. This space has an essentially smaller number of variables, such as the parameters defining the function shape. The aggregate farming experience for various crops allows defining the typical agricultural function shape along a time scale, which is a trapezoid of unequal lateral sides and slightly oblique top which is mostly considered constant; this is the maximum efficiency area the farmer would be willing to achieve. It should be noted that the change of weather conditions might drastically affect duration of the efficiency spot and its start time.

Thus, in the considered aggregated approach, the variety of randomly variable parameters of weather conditions is reflected as change of a small number of essential function parameters. Such an approach allows quantitative estimation of influence of random fluctuations in functions' basic parameters both on an average crop, and on the histogram of crop distribution which gives essentially more information for decision-making when deciding for a best strategy.

Therefore the present paper concentrates on the analysis of farmer's decision-making when choosing the best strategy under conditions of weather uncertainty.

Agricultural Function-based Crop Model

Performing an agricultural operation too early would adversely affect the crop. Similarly, performed too late, would also reduce the expected crop; thus, agricultural function AF is trapezoid-shaped. Such 'altered' trapezoids are described in detail in the papers (Merkurjevs et al., 2002; 2005).

The present paper delimits itself to methodological assessment of the problem in focus; and therefore let us consider methodology of choice of an optimal strategy for a trapezoid-shaped agricultural function. Generally speaking, additional constraints can be imposed on the shape and duration of the agricultural function so that it is positive, convex, and limited both in duration and amplitude. There are also other restrictions on the shape of agricultural function AF which it is determined both by the specific crop species and the agricultural operation.

Let us introduce the following variables:

Taf – agricultural function start time which for conventional purposes is assumed Taf=10, though in reality this time is determined basing long-time repeating observations under comparable weather conditions characteristic of locality.

Ts – agricultural operation start time determined by the farmer basing on the weather forecasts and own experience which is the basic element of a farmer's strategy

dFR – duration of the agricultural operation which mainly depends on a farmer's readiness and technological limitations.

AF start time uncertainty is modelled as the sum of Taf value (constant under the current conditions) and random variable u_1. In a similar manner, uncertainty in AF duration dAF is modelled by the sum of fixed value dAF (dAF=2 for the subsequent calculations) and randomly distributed value u_2 stochastically independent of u_1.

Model Description

Let us measure agricultural operation efficiency relative to the value of crop obtained. Let us also observe that financials associated with the operations – cost structure of agricultural operations and crop revenue depend on factors lying beyond the scope of this paper, thus limiting the task to estimation of the crop volume in non-monetary terms.

Let us next consider the methodology of efficiency estimation understood as the crop volume CF (Fig. 2):

$$CF = \int_{Ts}^{Ts+dFR} AF(T_{af} + u_1, dAF + u_2, p_a, t) \times FR(dFR, T_s, t)dt \qquad (1)$$

Trapezoid agricultural function allows depicting the main features of harvesting and may be put as a simply calculable mathematical formula:

AF(T_{af} + u_1, durAF, t) =
(UnitStep[t-Taf+d1AF] - UnitStep[t-Taf])/
(d1AF)×(t-Taf+d1AF) + (UnitStep[t-Taf] -
UnitStep[t-Taf-d2AF]) + (UnitStep[t-Taf-d2AF]
-UnitStep[t-Taf-d2AF-d3AF]) /
(d3AF)×(Taf+d2AF+d3AF-t). (2)

The parameters of the expression will be considered in more detail below. At this point let us just observe that UnitStep(x) represents a unit step function, which equals zero at x<0 and equals one at x>=0, where x represents the argument of the function.

Should farmer activity be regular over time, the function is represented as:

FR(t, Ts, dFR)=(UnitStep(t-Ts) -
UnitStep(t-Ts-dFR))/dFR. (3)

Thus, the average intensity of farmer operations is inversely proportional to the duration dFR of his agricultural operation.

Agricultural operation start time Ts is determined by the farmer. In simulation experiments the deviation of optimal time durations d2AF and agricultural function start time Taf varied significantly.

Methodology of Research

Uncertainty in agricultural function start time is modelled through time scale shifts of 1, 2, 3, etc.

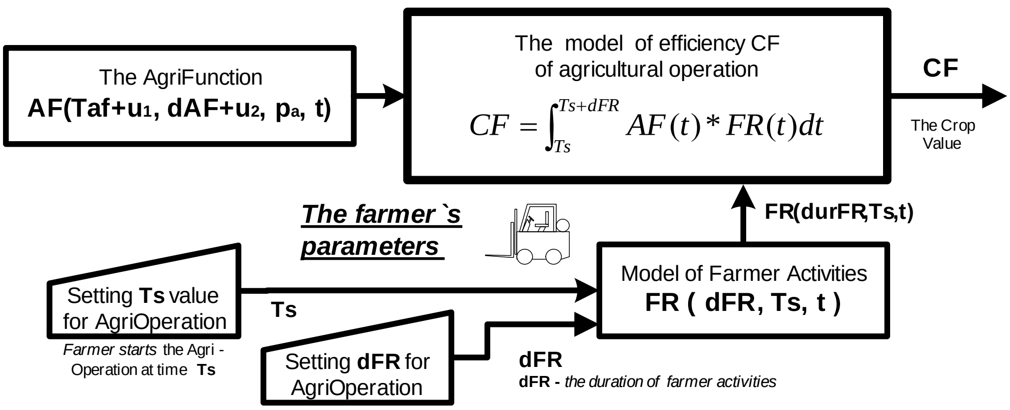

Fig. 2. Structural scheme of estimating expected yield volume CF depending on the states of nature Taf, wTaf and farmer strategies dFR, Ts. The figure presents yielding CF crop volume by integration of agricultural function AF product and farmer strategy model FR over the whole time interval of operation dFR with the start time Ts.

number of days. This shift however remains unknown to the farmer, and therefore the state of nature is modelled in this manner.

According to the conventional terminology, risks arise when probabilities of approach specific states of nature are known in advance. However, under circumstances when the states of nature remain unknown to the farmer, we have an uncertainty context.

Uncertainty of agricultural duration start time Taf is modelled as randomly distributed value u1 such as: (-wTaf)<=u1<=(+wTaf). The beginning of agricultural function now is unified distributed within the flexible interval (Taf–wTaf)<=Taf<=(Taf+wTaf). Thus, the higher value of wTaf, the less definite is the beginning of agricultural function Taf.

For instance, if Taf=10 and wTaf=+/-1 day, the real start of AF might be equally expected at any moment of the time interval Taf $\in$ [9, 11] with duration of 2 days with the average value of Taf=10. In case of Taf=9 and wTaf=+/-3 days, the start of AF might eventually fall equally expected at any moment of Taf $\in$ [6, 12] which is 6 long.

The variables of simulation experiment comprise two groups of parameters: the first group is parameters of the states of nature Taf, wTaf, wdAF, where the notions stand for:

Taf – agricultural function start time on the calendar scale

wTaf – uncertainty of the date

wdAF – variability of agrifunction duration.

The second group includes farming strategy parameters Ts, dFR also determined in the calendar time units, where the notions stand for:

Ts – operation calendar start time and

dFR – duration of completing operation AF.

Criteria and Choice of Optimal Strategy

Thus, the influence of farming strategies X*i* (T**s*i*,** dFR*i*) parameters on the average crop volume MCF with diverse combinations of parameters (Taf*i*, wTaf*i*, wdAF*i*) states of nature **S***j* has been researched.

The higher the average value MCFij=MCF**(**X*i*,S*j***)** the more efficient Xi strategy at the given state of nature S*j*. On conditions of probability risk P(S*j*)>0 the probabilities of states of nature j=1,…, Ns are known in advance. This information is used in order to pick the optimal strategy using probability-weighted criteria of efficiency. On uncertainty conditions we do not know anything on probability of either state of nature S*j*.

However, even on uncertainty conditions it might be assumed that if the probability of either state of nature is very low, such condition would not be considered as a state of nature S. On contrary, should probabilities of other states of nature be high enough, these would be considered as a state of nature S, since any analysis of hardly probable states would not be satisfactory even for a pessimistic farmer.

Consequently, even on conditions of complete uncertainty there is a probability proportion comprising variety of states of nature S, namely, all states of nature are approximately equally probable at a rational level, i.e.,

$$P(S1) \sim P(S2) \sim \ldots \sim P(Sj) \sim \ldots \sim P(S_{Ns}),\ P(Sj)>0;\quad j=1,\ldots,Ns.$$

Let us form the XS matrix, where rows X*i* correspond to farmer strategies with specific combinations of parameters (dFR, Ts) and columns S*j* featuring states of nature with respective combinations of parameters (Taf, wTaf). Thus, if possible farmer strategy is arranged in the rows and parameters of the nature arranged in columns, the intersection of ***i***th row and jth column will contain the average value of crop MCF*ij*, obtained through the application of *i*th strategy at *j*th state of nature.

So, now we have a standard initial matrix ready for application of some techniques of decision-making theory and the theory of operations research (De Groot, 1971). A part of the resulting matrix is presented in a contour graph in Figure 3. The shaded shapes correspond to greater crop values. Along the X-axis there is plotted farming strategies, the Y-axis reflects states of nature.

As it follows from the graph, the farming strategies lead to approximately equal results with no evidence of a clearly better strategy for all states of nature.

The same is also illustrated in Figure 4. This graph illustrates resulting effect of three strategies at various states of nature. The peak efficiency shifts from one farming strategy to another even at light changes in the states of nature. Choosing an optimal strategy becomes even more challenging.

The choice of the best farming strategy basically depends on farmer preferences which can be mathematically expressed by means of a suitable optimality criterion.

Optimal Choice Algorithm: Laplace Criterion

Let us consider what kind of strategies will be considered optimal if the farmer adheres to Laplace optimality criterion.

The Laplace criterion (Fig. 5) applies all the available information on the XS strategy-state of nature matrix and explicitly uses probabilities of states of nature which are assumed being equal P(S*j*)=1/Ns, j =1,…, Ns.

At the same time, the criterion Laplace criterion assumes application of probability theory in order to deal with uncertainty. This implies that for each state of nature S*j* in S, the farmer as the decision maker should assess the probability of P(S*j*) that S*j* state will occur.

The Laplace criterion relies on the Principle of Insufficient Reason which states that if no probabilities had been assigned by the farmer (who is assumed to be rational and capable of handling basic probability theory), it follows that there was insufficient reason for the farmer to evaluate that any state S*j* was more or less likely to occur than any other state.

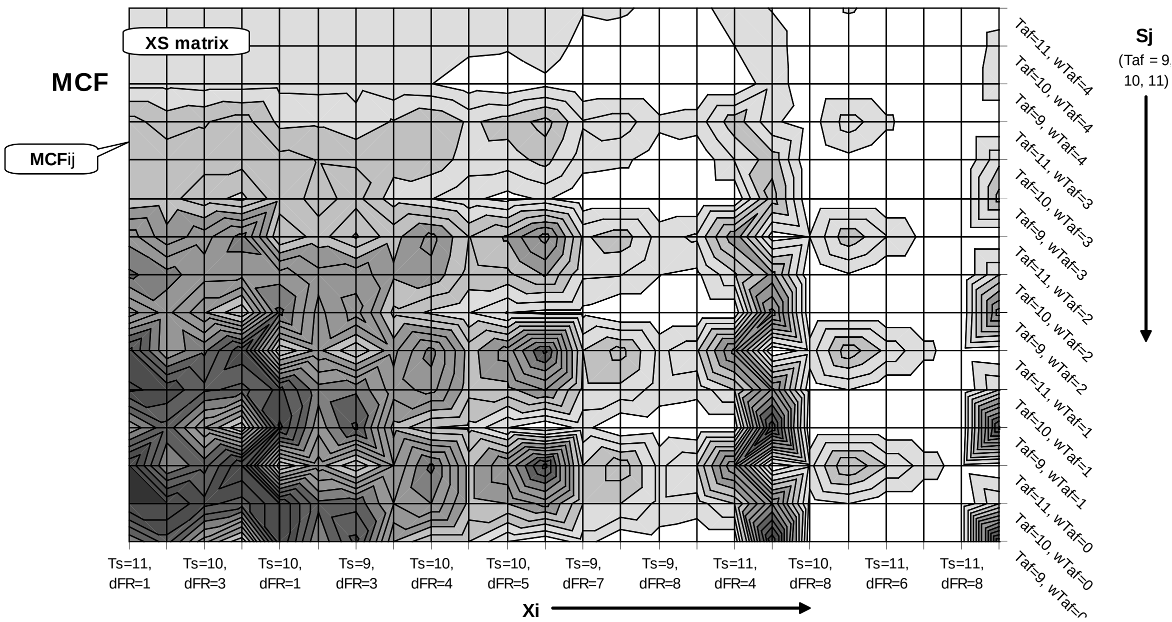

Fig. 3. The right-hand side graph shows 3D visualization of XS matrix. Axes X and Y correspond to farming strategy and the state of nature. The Z-scale corresponds to the average crop values MCF*ij*, i.e., elements of XS matrix. It might be noted that all strategies are equally efficient, there is no clear leader.

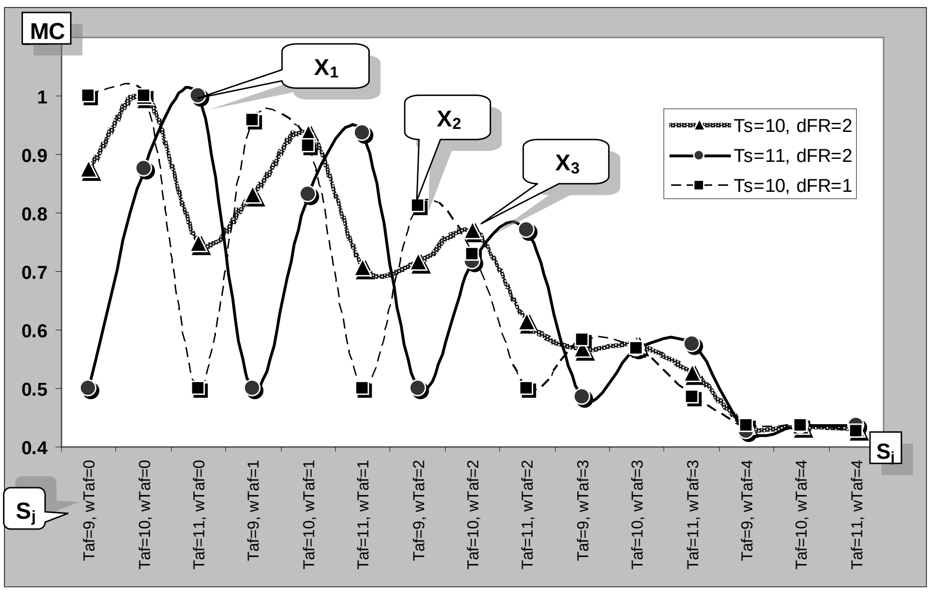

Fig. 4. The left-hand side graph shows dependence of crop volume MCF (Y-scale) on the states of nature (X-scale) for several well-performing strategies. There is no clear leader strategy for all conditions of nature.

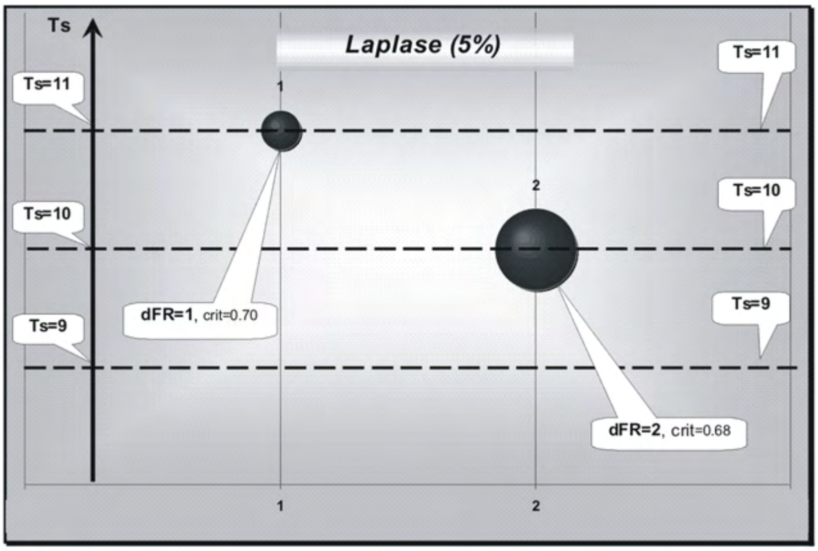

Fig. 5. The graph presents two strategies considered optimal in accordance with the Laplace criterion. The Y-scale features agricultural operation start time Ts. The bubble sizes are proportional to farming operation durations dFR. The X-scale denotes the ordinal number of the strategy which grows in value as the criterion diminishes; consequently, the strategies with lower ordinal numbers are better performing (at 5% significance level).

So, it is considered that a rational farmer would be capable of assigning probability distributions P(S*j*). Since it is not the case, all the states of nature **S***j* must be considered equally probable. Therefore, the probability P(S*j*) for each S*j* must equal 1/Ns, where **N**s is the number of states of nature in **S**.

It is a fairly straightforward logic which tries to compensate for the lack of empirical knowledge on real distribution of probabilities through the principle of insufficient reason.

Thus, the Laplace criterion does not rely on any additional information on distribution of probabilities of states of nature, but it integrates this information through "rational" assumptions basing on the principle of the insufficient reason.

The optimisation algorithm might be formalised as follows:

1) assign the probability P(S*j*)=1/Ns for each state of nature S*j* in S, for j=1,…, Ns;
2) for each i^{th} row of matrix MCFi*j*, it is necessary to calculate the efficiency measure of i^{th} strategy for all states of nature $E(X_i)=\Sigma_j P(Sj)\times MCFij$;
3) choose an action yielding the maximum $E(X_i)$, i.e., choose strategy X*opt*, for which $\max_i E(X_i)$.

It would be worthwhile to consider strengths and weaknesses of the Laplace criterion. By assuming uniform distribution of *states of nature* S, under this criterion it is assumed that all the elements MCF*ij* of the strategy-state of nature matrix XS have equal weights of 1/Ns.

There is a chance for improper use of the Laplace criterion which lies in the fact that the states of nature are not equally probable in most cases.

The weakness of the principle of insufficient reason lies in an implicit assumption that all decision makers who had not assigned a probability distribution to S had not done so because there is no reason to assume states of nature equally probable. However, in the real world human eventually deviate from the idealised decision maker: in a practical real world situation they will be unable to quantitatively estimate probabilities.

Since the farmer cannot assess probabilities, all states of nature are assumed equally probable. Thus, absence or ignorance of the reasons is enough to assume equal distribution of nature states probabilities.

Let us consider different farmers' expectations. An overly optimistic would be the maximax criterion (Fig. 6) when one expects a good situation and the obtained crop will be the highest.

The maximax rule recommends to accept such a strategy, for which the condition $\max_i[\max_j(MCFij)]$ holds. Obviously, the maximax strategy is the most efficient at two equally probable states of nature, and as the number of states grows its average efficiency drops in direct proportion to the number of states of nature.

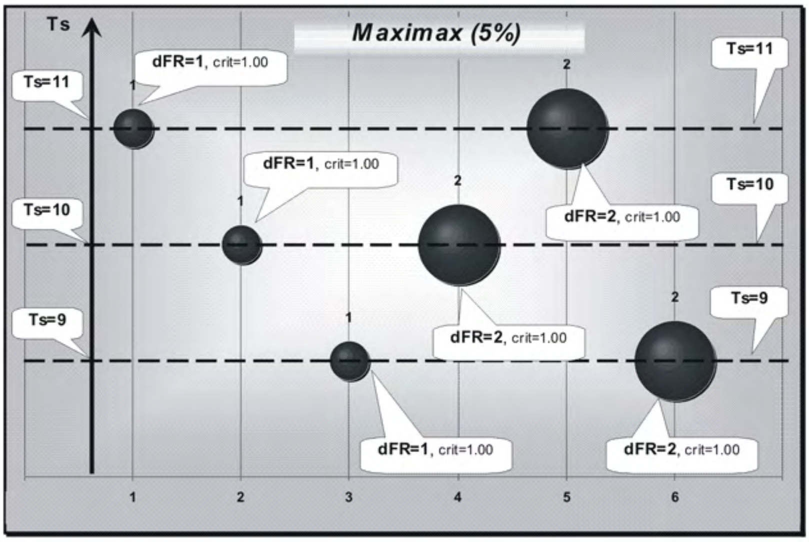

Fig. 6. The graph shows six strategies optimal according to the *maximax* criterion.

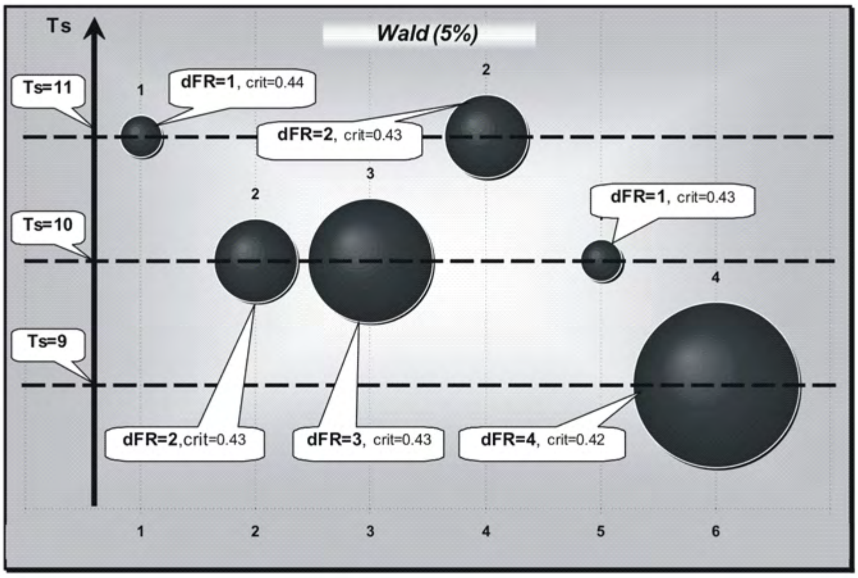

Fig. 7. The graph features six strategies considered optimal in accordance with the Wald criterion at 5% significance level.

Optimal Choice Algorithm: Wald Criterion

The Wald (or maximin) criterion (Fig. 7), which might be considered as a criterion of an extreme degree of pessimism would be the next criterion to consider. According to the Wald criterion, the least risky strategy is chosen, allowing no playing around with the nature.

Technically, this means that the farmer cannot end up in a situation worse than the one chosen as per the Wald criterion. This fundamental property of the criterion makes it attractive for cautious decision makers and is applied in situations allowing zero riskiness. However, in practical situations excessive pessimism of the criterion might appear unprofitable.

The step sequence for the Wald criterion-based optimisation would be as follows:

1) for each strategy (rows in strategy-state of nature XS matrix) determine the minimum possible crop value. This represents the worst possible outcome for the given strategy. Should this strategy be pursued, no worse result at any state of nature would be possible;

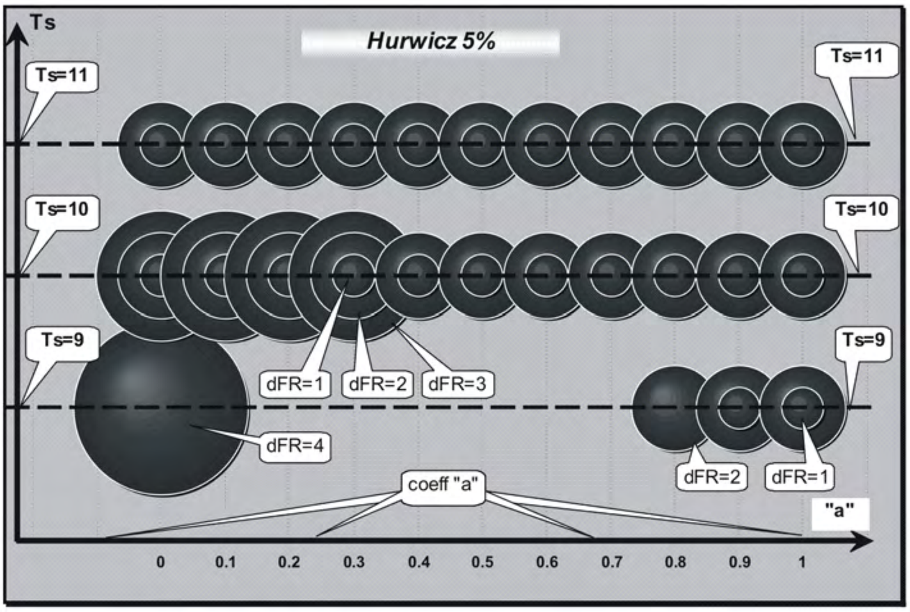

Fig. 8. The left-hand side of the graph portrays six strategies considered optimal as per the Wald criterion, whereas the right-hand side presents strategies optimal according to the Hurwicz criterion. The optimism coefficient "a" will be on the X-scale. The significance level equals 5% of criterion value for the best-performing strategy.

2) the crop volume for the given strategy will not lie below the minimum possible. The highest crop has to be chosen from among low-yield outcomes for each of the farming strategies. In order to arrive at such a solution one additional column is needed, the one that would contain the minimum values across rows. The maximum element in this column would represent the required solution.

The maximin/Wald criterion cannot be considered a rational approach for many cases as it ignores most of the information available in the strategy-state of nature matrix. The solution is searched only among cells of XS matrix that have extreme values. Information contained in other cells of XS matrix is absolutely ignored.

Optimal Choice Algorithm: Hurwicz Criterion

The Hurwicz criterion (Fig. 8) is trying to arrive at a rational compromise between the two above mentioned criteria of extreme optimism and pessimism. Instead of taking either side, the Hurwicz criterion assigns certain weight to the optimism/pessimism expectations.

The calculable expression reads as follows:

$$H(Xi)=a\times(\text{maximum of "}i\text{" row})+(1-a)\times(\text{minimum of "}i\text{" row}).$$

Introducing the weight of *a* in this context means that a complete maximax optimism of maximax (a=1) is replaced by an altered optimism level decreased through the optimism coefficient *a*, with *a* belonging to the interval of $0 \leq a \leq 1$. Thus, for a=1, there is complete optimism prevailing (turning to maximax), whereas a=0 would result in a risk-averse maximin. Under these notions, risk-averseness degree of the decision-maker would be expressed as $(1–a)$**.** Now, the weighted average of H for each strategy X*i* might be calculated as presented in the following paragraph.

The step-by-step application algorithm of the Hurwicz criterion would be as follows:

1) choosing coefficient of optimism degree (risk-averseness) value *a*;
2) weighted average H (X*i*) is calculated for each strategy X*i*;
3) choose the strategy with the maximum Hurwicz weighted average H (X*i*) with the given coefficient of *a*.

A critical analysis of the Hurwicz criterion reveals that the choice of a has no sufficient logic argument, or is simply trivial (usually, within the interval of 0.3-0.5). Besides that, the optimal strategy is searched only across extreme elements of the XS matrix, and information contained in other cells of the XS matrix is not considered.

Optimal Choice Algorithm: Savage Criterion

The Savage Criterion yields results such as to minimize possible regrets arising from making a non-optimal decision. Strictly speaking, a regret is a subjective emotional condition, whose proper estimation is a rather problematic issue. Nevertheless, it is possible to assume that regret is measurable for all the elements of the strategy-state of nature matrix.

The regret R_{ij} is defined as a possible loss of a part of a crop when X*i* strategy is chosen at a S_j state of nature (De Groot, 1971). Possible loss is a deviation between the highest crop attainable in a state of nature Sj and the actual result following from choosing the X*i* strategy. This can be formalised as follows:

R_{ij}=MCF*ij* -(maximum *j*-th column of XS matrix),

where

R_{ij} – regret for row *i* and column *j* of regrets matrix R={R*ij*}.

It should be noted that losses of opportunities are defined as negative numbers. The best outcome would be zero (absence of regrets), and the higher the absolute value of R_{ij} , the higher is total regret.

The algorithm of application is presented below:

1) transform XS matrix consisting of average crop values MCF*ij,* into regrets matrix R={R*ij*} using the expression R*ij*=MCF*ij*-maxi (MCF*ij*);
2) apply minimax rule to the R matrix.

A closer look at the Savage criterion reveals that regret linearly depends on the magnitude of the possible loss, whereas it is not the only one and not always a possible way of assessing regret (De Groot, 1971). Nevertheless, the Savage criterion is considered to be a better criterion compared to maximax, maximin or, probably, Hurwicz since the Savage criterion relies on more information among available on the problem. However, the Savage criterion is not able to take advantage of all the available information and it does not provide the ultimate solution to the problem of choosing the best farming strategy.

Let us compare the results obtained through using different criteria for the best-performing strategies at 5% level of significance (Figures 9 and 10).

Let us take a higher significance level by shifting the mark to <=0.05% of maximum value of the corresponding criterion. The lower number of optimal strategies available at the new significance level illustrates sensitivity of the criteria to the empirical set of data. For example, sensitivity of maximax and Savage criteria has not changed, whereas the number of the best-performing strategies for other criteria has decreased more than twice (Figures 11 and 12).

Comparing the results we might arrive at a conclusion that the optimal farming strategy is the one with parameters of dFR=1, Ts=11. The start time

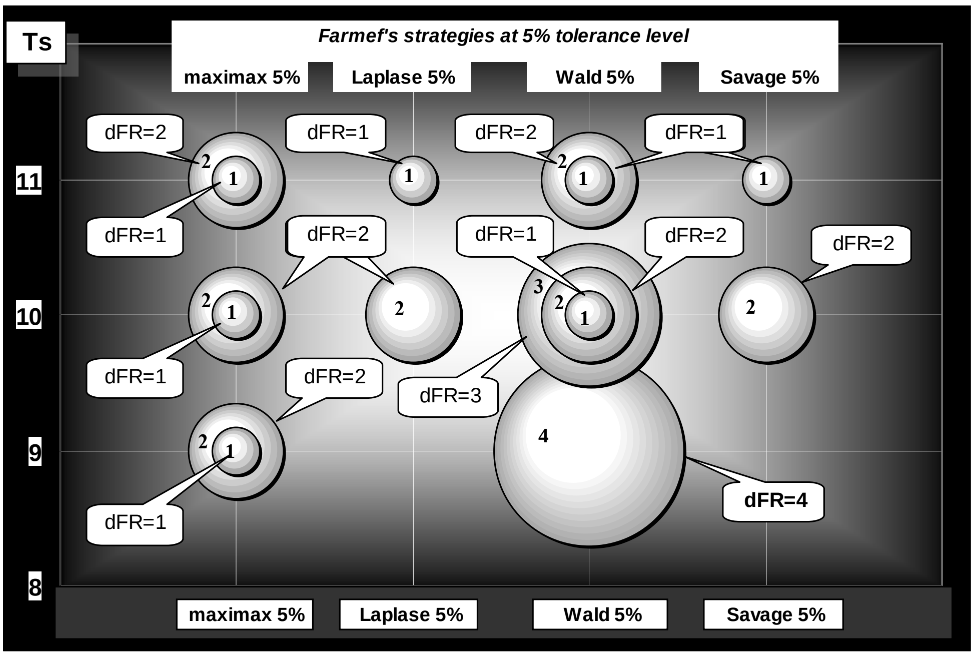

Fig. 9. The number and parameters of farming strategies found for maximax, Laplace, Wald, and Savage criteria with the significance level of 5% of corresponding criterion's maximum value.

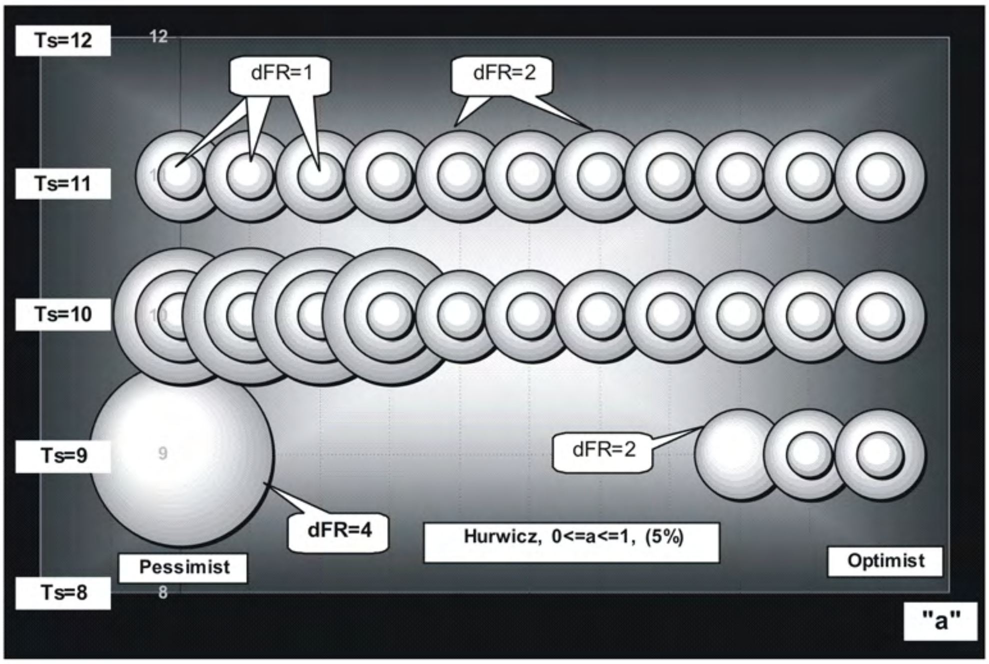

Fig. 10. The number and parameters of farming strategies found for the Hurwicz criterion with the significance level of 5% of corresponding criterion's maximum value.

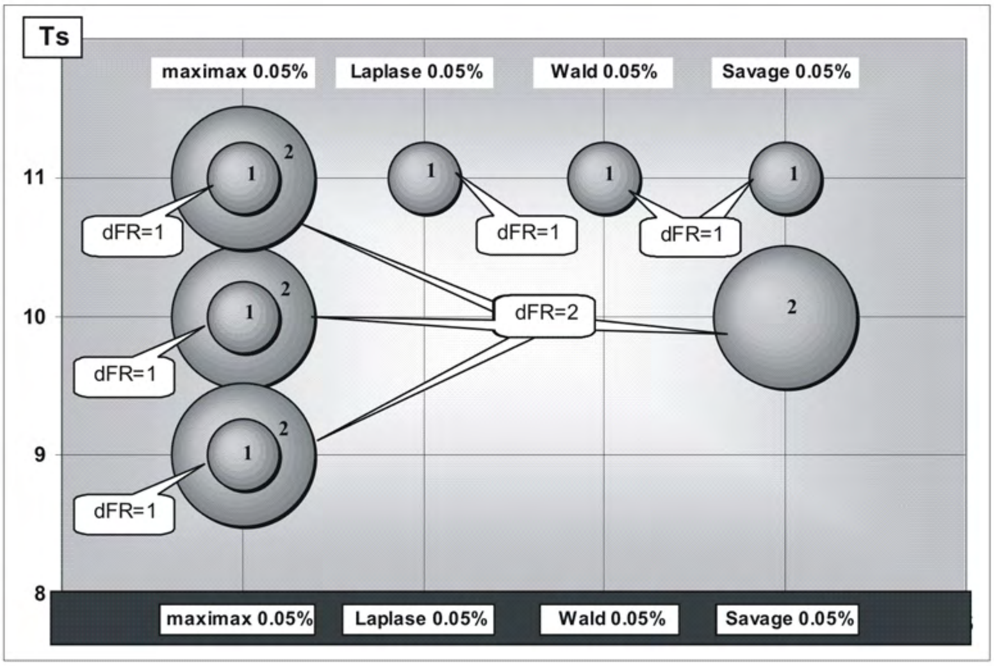

Fig. 11. The number and parameters of farming strategies found for maximax, Laplace, Wald, and Savage criteria within the significance interval of 0.05% of corresponding criterion's maximum value.

of this strategy is one day later than beginning of the agricultural function Taf=10.

We might arrive at an interesting general conclusion. In order to achieve the maximum average efficiency under climate uncertainty simulated in the present work, the operations must be performed with a slight delay (one day in the case studied) from the expected start of agricultural function. Once started, the operations must be completed with least time costs (one day in the case studied).

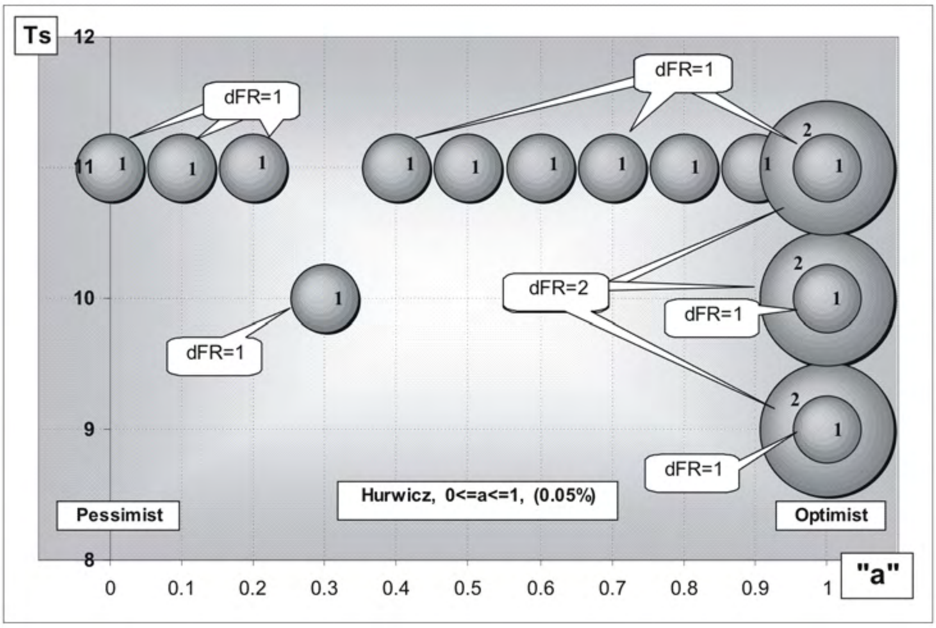

Fig. 12. The number and parameters of farmer strategies found for the Hurwicz criterion within the significance interval of 0.05% of corresponding criterion's maximum value.

Conclusions

The paper presents a simulation-based methodology of quantitative estimation and choice of optimal farming strategy on conditions of nature uncertainty.

Uncertainty of nature states is modelled as alterations in values of respective parameters of the trapezoid agricultural function. In the context of the research, a farming strategy is defined by two major parameters, namely, the time to start performing agricultural operation and its duration. In the current paper, the average crop values are presented in the form of a farming strategies–state nature matrix which had undergone application of several methods of decision-making theory.

Some sets of optimal farming strategies have been assessed using various optimality criteria. The resulting sets of optimal farming strategies based on the maximax, Laplace, Wald, Hurwicz, and Savage criteria are compared in the paper.

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Anotācija

Imitācijas eksperimentu ar dažādiem laika apstākļu parametriem mērķis ir zemkopja stratēģiju novērtēšana nenoteiktos meteoroloģiskās situācijas apstākļos, ko izraisa globālās klimatiskās izmaiņas. Gala uzdevums ir efektīvāko lauksaimnieka stratēģiju izvēles modelēšana ievadīto laika apstākļu nenoteiktības parametru robežās. Izvirzītā mērķa sasniegšanai tika izmantotas lauksaimnieka optimālo stratēģiju lēmumu pieņemšanas teorētiskās metodes. Par pētījumu pamatu tika izmantoti ražas kvantitatīvie rādītāji dažādām lauksaimnieka stratēģijām ar dažādām laika apstākļu fluktācijām, kas iegūtas, balstoties uz agrofunkciju koncepciju. Ilustratīvi parādīts, ka optimālo stratēģiju izvēle informācijas trūkuma dēļ attiecībā uz iespējamo meteoroloģisko situāciju perspektīvā lielā mērā ir atkarīga no lauksaimnieka pesimisma pakāpes. Lauksaimnieka stratēģijas galvenokārt ir atkarīgas no diviem nozīmīgākajiem parametriem – no agrooperācijas sākuma laika un tās izpildes perioda ilguma. Lauksaimnieka optimālo stratēģiju aprēķini tika veikti kritērijiem maximax, Laplace, Wald, Hurwicz un Savage.

Requirements for the Development of Latvian Agricultural Risk Management System
Prasības Latvijas lauksaimniecības riska vadības sistēmas attīstībai

Irina Arhipova, Daiga Dumpe, Aleksejs Zacepins, Sergejs Arhipovs
Faculty of Information Technologies, LLU
LLU Informācijas tehnoloģiju fakultāte
e-mail: Irina.Arhipova@llu.lv

Abstract. In conformity with Paragraph 5, Subparagraph 131 of the European Community guidelines regarding the state aid for the agricultural and forestry sectors for the years 2007-2013 each European Union Member State shall introduce the agricultural risk management system by the year 2010. Under Article 12, Paragraph 1 of the law "On Agriculture and Rural Development" agricultural risk management assures the efficient system for the compensation for losses caused by agricultural production risks. The goal of the concept of Latvian agricultural risk management policy is to develop the agricultural risk management system which in future would envisage specific actions performed by both the state and farmers under the emergency situations. The article deals with the analysis of the experience of the EU member states concerning the introduction of agricultural risk management systems as well as the research on the possible variants for introduction of risk management system in Latvia. The variant is to be supported as the agricultural risk management policy concept envisages supporting the payments of insurance premium and the establishment of compensation fund. This solution is characterised by the ensured state basic responsibility and participation using the compensation fund, the funds which consist of the state and farmers' annual payments. The systems analysis has been performed for this variant regarding the information system introduction in order to find out the information system integration possibilities necessary for the risk management policy implementation.
Key words: agricultural risk management system, information system, systems analysis.

Introduction

Since 1998, the elements of producers' risk management system have become an integral part of the practical structure of Latvian agricultural state policy. Initially they were the instruments of compensation for losses caused by market crisis, and they were in a form of market intervention and compensation payments. Later they were followed by the promotion of preventive elimination (lessening) of possible risks and losses through the purchase of production insurance policy in a form of subsidies, thus hoping for the development of production insurance system. In addition to the above mentioned measures, since 2002 the Cabinet of Ministers has repeatedly granted funds from the national budget for the compensation for losses caused by adverse weather conditions. Since the accession of Latvia to the European Union Common Agricultural Policy, combating of losses caused by possible market crisis has become the competence of the Common policy instruments. In conformity with Paragraph 5, Subparagraph 131 of the European Community guidelines regarding the state aid for the agricultural and forestry sectors for the years 2007-2013 each European Union Member State must introduce the agricultural risk management system by the year 2010.

During the last years – since 2004, the government has implemented into practice and institutionally strengthened the risk management policy with three main state participation measures paid to the farmers for the compensation for losses caused by risks. They envisage:

1) the subsidisation of the purchase of insurance policies as a possible regular state aid to every concerned producer;
2) the compensatory payments from the funds of national budget, guaranteed by the state, under the epizootic conditions of certain animals. Such funds are envisaged for emergency cases;
3) the compensatory payments for losses caused by adverse weather conditions, natural calamities and animal diseases and similar reasons. These compensatory payments are disbursed in conformity with certain political decisions.

Annually the co-financing of the purchase of insurance policies is included in the state subsidisation programmes for agriculture. While the financial resources for the compensatory payments in case of losses are not really planned. In case of losses the Ministry of Agriculture considers the farmers' applications, and makes decisions on the granting of funds, redistributing the existing budgetary resources or demanding additional financing from the national budget. Therefore the present approach has several considerable disadvantages:

a) public expenditure cannot be forecasted, and it is unbalanced within a period of time;
b) the system does not motivate farmers to perform the risk management activities on their farms, and thus lessen the risks and potentially possible losses;
c) the system does not solve the problem of prevention and lessening of losses – it only diminishes the consequences, and their financial manifestation;
d) the system distorts the competitiveness in the market of risks and compensatory measures for losses, hindering the development of privately financed service – the insurance of agricultural risks;
e) it does not precisely define the principles of co-operation between the state and farmers, the limits of the responsibilities of parties, their obligations, and accountability;
f) the present system is more based on the political decisions, and it cannot be considered as durable and sustainable policy, which is observed by producers, when working out the strategy of their business development.

The result of the above mentioned disadvantages is a situation when both the political management of the sector and the authorised representatives of agricultural sector, being aware of the threat the situation causes, have agreed on the necessity to develop new Agricultural risk management policy (Fīrere, 2008).

The aim of the article is to find out the development tendencies and the principles for introduction of Latvian agricultural risk management system. In order to achieve the aim, the following objectives are set:

– to analyse the experience of the EU member states regarding the introduction of agricultural risk management system;
– to analyse the possible variants of risk management system to be introduced in Latvia;
– to analyse the variants of the concept of Latvian agricultural risk management policy;
– to perform the systems analysis regarding the information system introduction necessary for the implementation of risk management policy.

Latvian Agricultural Risk Management Policy

Risk management is based on the identification and assessment of risks (Arhipova, Arhipovs, 2005; Riski lauksaimniecībā …, 2005), studying their possible influence on the farm, and choosing one of four strategies:

1) to leave the risk zone – to reprofile the farm by choosing specialisation with less risk;
2) to perform no particular activities regarding the risk lessening – the farmer takes upon himself all the consequences that might occur in case of such risk;
3) to take risk lessening measures – choosing safe farming, undertaking the preventive measures – vaccination of livestock, spraying of cultivated plants, establishment of rational rotation of crops, and other measures;
4) to transfer risks or hand them over to the third party – insurers, funds, and other financial institutions.

Under the present conditions the farmers do not observe the risk management principles concerning the issues related to the agricultural risk management. In most cases the farmers prefer not to transfer the risk to the insurers, considering that these risks had been taken by the state. Such point of view exists irrespective the fact that there had been no agreements signed regarding the transfer of risk to the state, and there had been no binding payments made, which contradicts to the normal practice. Although after several years of work, the Ministry of Agriculture provided for hope in spring of 2008 that from May, the fund of agricultural risk insurance in Latvia might start functioning; the introduction of the system is delayed. Besides, the insurance system has become more complex at the stage of inter-ministerial harmonization, and thus it is less attractive for the farmers (Fīrere, 2008). According to Aivars Lapins the deputy state secretary of the Ministry of Agriculture, the rules for the operation of agricultural risk insurance fund, most probably, would be submitted to the government in July. Risk Management Fund will be introduced within the Agricultural Risk Management System. It will deal with the problems related to the agricultural production risks, and it will consist of the state and farmers' payments. Thus there will be savings accumulated, and only in clearly defined cases there would be compensatory payments made from the Fund. The State Treasury will be the holder of the finances of the fund, but Rural Support Service will administer the payments made in the fund and the compensatory payments made from the fund. The payments in the fund will be made annually by both the farmers and the state (Par lauksaimniecības risku …, 2008).

Latvian Agricultural policy regarding risk management issues is defined only partially. There is a procedure worked out, how farmers can apply for receiving subsidies to cover partially insurance premium. But the terms for receiving insurance compensatory payments are provided in the insurance contract. Thus there had been a stable system established which is legally grounded and provides for the liabilities, obligations and rights of all parties involved.

However, the procedure for the compensation of losses is not developed. There are no main elements:

a) applicant's definition;
b) the definition for the losses to be compensated;
c) the terms and volume for the compensation for losses;
d) the form and procedure of application submission;
e) the procedure for the consideration of application and prevention of losses;
f) decision-making and granting of financing.

Thus the present system is more grounded on the political decisions, which are based on the experts' evaluations regarding the topicality and importance of separate cases as well as the validity of applications concerning losses, instead of figures. As a result in some cases the received compensatory payments do not correspond to the volume of losses, and are unreasonably small or too large. Although, within the framework of present policy, the state uses two instruments (direct compensations and subsidisation of insurance premium) for the compensation for agricultural losses, they are not mutually balanced. Farmers prefer not to insure their risks at the insurance joint-stock companies, relying on the state that would cover their losses in case of any risks (Pamatojuma izstrāde …, 2006).

Under Article 12, Paragraph 1 of the law "On Agriculture and Rural Development", agricultural risk management assures the efficient system for the compensation for losses caused by agricultural production risks (Lauksaimniecības un lauku …, 2004). The Ministry of Agriculture has started to develop the agricultural risk management system. By participating in the insurance system a farmer would have a guarantee that he would receive the compensatory payments for the losses. The state would also benefit from the system, because it would clearly determine the criteria according to which the farmers could be granted the compensatory payments. Thus the state would not need to compensate single losses. The Ministry of Agriculture plans to submit to the government the conceptual project of the agricultural risk management system by September 1, 2008 (Krastiņa, Klints, 2008).

Each European Union Member State shall introduce the agricultural risk management system by the year 2010. The necessity for the insurance of agricultural risks is provided not only by the EU rules, but also forced by situation, when every year the farms are exposed to the danger of cataclysms. The research was performed on the experience in other countries in order to develop the agricultural risk management system (Iespējas un risinājumi …, 2005).

The Experience of the EU Member States Regarding the Introduction of Agricultural Risk Management System

The EU member states have developed different systems that are used to manage the agricultural risks. On the whole the systems could be grouped according to the degree the state is involved in the risk management.

In Greece, the agricultural risks are mainly managed by active state participation. The state involves farmers in the insurance system, administrates it and guarantees the covering of losses. Thus the activities of private sector are limited and are related to the products and risks the state does not cover, or it provides additional covering for the insurance offered by the state.

Spain has rich experience regarding agricultural insurance. Within the agricultural insurance system in Spain there are no risks divided, which should be insured in the private sector, from the risks, which are the objects of the aid for the national agricultural policy. All insured agricultural risks are covered, using the private sector, but the state provides the subsidisation of all types of insurance policies. Spain and Portugal have established the co-operation between the private insurance and state, where the state dominates. The state provides both subsidisation of premium and reinsurance. Private insurance companies are involved in the system, administrating programmes and partially taking upon them risks and covering losses.

Italy, France, Austria, Germany and the Netherlands have the agricultural insurance systems, which are mostly private. However, there are also differences among these countries, and they are related to the amount of premium subsidised. For example, in Italy the state is involved in the agricultural risk management and the covering of losses with the compensation system the subsidisation of insurance premium as well as the private insurance companies are also involved. The state partially participates in the agricultural risk insurance system, subsidising the premium in certain regions, which are particularly exposed to the danger of disasters and adverse weather conditions.

In the Netherlands, the participation of state in the agricultural risk management is relatively limited. In relation to the covering of losses the Ministry of Agriculture and farmers have agreed on the system, within which there is a co-operation among the farmers, the Ministry and credit institutions. Within this system the state can receive capital from a private bank for financing or co-financing of actual losses. In Germany, like in the Netherlands, there is a voluntary, private insurance system, which is based on the offer provided by insurers, instead of the governmental agencies (Risk Management Tools …, 2001).

In Latvia there had been several attempts to encourage the farmers to insure their planted fields against the losses caused by adverse weather conditions. However, the farmers do not prefer insurance. Already for several years the farmers blame the insurers that they are not interested in this type of business – it does not provide them profit. In their turn, the insurers think that the farmers are not interested themselves in the solution of their own problems (Krastiņa, Klints, 2008).

The Concept of Latvian Agricultural Risk Management System

Since 2004, the state has implemented into practice and institutionally strengthened the risk management policy with three main state participation measures paid to the farmers for the compensation for losses caused by risks. They envisage:

1) the partial subsidisation of the purchase of insurance policies from the private insurance companies as a possible regular state aid to every concerned producer;
2) the compensatory payments from the funds of national budget, guaranteed by the state, under the epizootic conditions of certain animals. Such funds are envisaged for emergency cases;
3) the compensatory payments for losses caused by adverse weather conditions, natural calamities and animal diseases and similar reasons. These compensatory payments are disbursed in conformity with separate decisions, if it is admitted that a natural calamity has taken place in the country.

This concept is based on the basic principles that the state responsibility and co-responsibility should be related only to the risks caused by adverse weather conditions, epizootic conditions, and natural calamities. According to the spheres and types of risks, the levels of state responsibility, the forms of their implementation within the framework of agricultural risk management policy are grouped as follows:

a) the state basic responsibility in case of large volume risks – natural calamities, emergencies, infectious diseases of animals or plants under the state monitoring and epizootic cases;
b) the state co-responsibility in case of average volume risks – adverse weather conditions;
c) farmer's responsibility in case of the rest of risks (spheres for which the state is neither responsible nor co-responsible).

The aim of the concept is to develop the agricultural risk management system, which would provide for specific activities of both the state and farmers in case of emergency in future. The developed solution variants are based on a single goal and basic principles, but the difference between the variants exists at the level of institutional ensuring by means of which the problem is being solved (Par koncepciju …, 2007). In order to evaluate the possible variants of risk management system introduction, it is necessary to define clearly the state participation in particular cases. When introducing any of offered variants, it, like any other type of state aid, will be submitted for the approval of the European Commission.

The concept offers the variants of solution.

The Concept of Latvian Agricultural Risk Management System: Variant 1 – only the payments of private insurance premium are supported

The aid is granted for covering insurance policy purchase costs to insure cultivated plants and animals used for the production of agricultural products. The aid covers up to 50% of the costs of insurance premium. The aid can be increased up to 80% of the costs of insurance premium, if the insurance policy indicates that it covers only the losses caused by adverse weather conditions, which should be considered as natural calamities (frost, hail, ice, rain or drought, which destroy more than 30% of the average annual production of one farm, taking into consideration the production of three previous years).

This variant also offers an opportunity for the organizations or enterprises founded by farmers to establish, on the basis of their own initiative, private funds for compensating for losses caused to farmers. According to the premium calculations performed by the private fund and conditions set by this fund, the state covers 50% of the insurance premium costs, but not more than the price of a single unit (area ha or cattle unit) provided by the laws and regulations. The private fund accumulates these financial means and, in case of emergency, decides on the granting of compensatory payments to the farmers for the losses.

The aid payments are administrated by Rural Support Service (hereinafter – RSS) in conformity with the laws and regulations on the state aid for the agricultural development. On the basis of farmers' applications (in case of a fund – on the request of each fund (data aggregation)), RSS settles the accounts with the insurance companies within 30 workdays after it has received the application (in case of a fund, the accounts are settled with the holders of the fund within 30 workdays after RSS has received the application).

The financing for ensuring of payments is envisaged in conformity with the laws and regulations on the state aid for the agricultural development. The state aid for the agricultural development may not be less than 2.5% of the total expenditure of annual base budget.

Every year, within the framework of measures, the financing in the amount of LVL 200 000 is used, and the last evaluation of data shows that year by year the farmers have become more and more active concerning the purchase of insurance policies. Thus there is no need for additional financing of insurance premium payment aid from the budget.

In case of a private fund, the co-financing for the insurance premium payments is envisaged in conformity with the laws and regulations on the state aid for the agricultural development on the basis of experience gathered during previous years (every year there are regulations worked out on the state aid for the agricultural development and the procedure for granting such aid. During the last three years, LVL 100 000-200 000 have been allocated for the partial aid of insurance premium). The total financing for these measures is determined in compliance with Article 5, Paragraph 3 of the law "On Agriculture and Rural Development" providing that the state aid for agricultural development is 2.5% of the total expenditures of the annual base budget, which are covered from grants from general revenues, deducting the contributions to the budget of the European Union. Additional financing for the implementation of this variant will not be requested – it will be implemented within the financial resources of the national budget sub-programme 21.01.00 "Subsidies for the Producers of Agricultural Products".

The benefits from the introduction of the solution:

a) the commensurability of the payments of state finance with the benefit from the functioning of programme;
b) the involvement of private insurance companies in the system in order to facilitate the offer of additional services;
c) lessening of market distortion;
d) the compensatory payment granted to the policy holder is proportional to the caused losses;
e) there is no need for changing the present administration system;
f) there is a possibility to provide regular state aid to every concerned producer of agricultural products regarding the purchase of insurance policy.

The problems related to the introduction of the solution:

a) insurance joint-stock companies do not offer the variety of insurance opportunities corresponding to the farmers' needs;
b) the provisions, offered by insurance companies, are not attractive enough, because their aim is gaining profit and providing for all expenses, related to risks, in the cost of policy;
c) lack of the initiative of non-governmental organizations concerning the establishment of funds;
d) problems in relation to the attraction of financing for maintaining of operational activities of private funds.

In order to implement the offered variant, it is necessary to evaluate the laws and regulations, providing for the procedure of the establishment of private funds and the principles of their functioning. When preparing the draft regulatory enactment on the state aid for agriculture in 2008 and the procedure of its granting, there should be regulations provided for the covering of insurance premium costs in the private funds.

The Concept of Latvian Agricultural Risk Management System: Variant 2 – payments of insurance premium are supported and the establishment of compensation funds

The essence of the solution regarding the compensation fund is characterised by the fact that, in order to prevent the co-responsibility risks, the state uses the compensation fund, the financing of which consists of annual payments made in the fund by subjects – both the state and farmers.

A farmer and the state make determined, equal payments in the compensation fund. These payments accumulate, and in clearly defined cases the compensatory payments are made from the fund. The basic principles of the compensation fund are as follows:

1) risks to be insured: drought (heat), incessant rain, frost and black frost, storm;
2) insurance against the farmer's not obtained harvest;

3) the minimum area to be insured is 1 ha; if the farmer participates in the fund, all the territory of the farm is insured;
4) the payment to be made in the fund is determined on the basis of risk occurrence probability;
5) in case of risk occurrence, the compensatory payments are granted only to those farmers, who have made payments in the fund on voluntary basis;
6) the compensatory payments from the fund are granted only if there are the respective meteorological data on the deviation of weather from the norm, and the adverse weather conditions have caused damage to the area of cultivated plants (including those of fruit-trees and bushes as well as forage crops) of at least 30% of the total area of the respective crop in a particular region (the region is considered to be RSS regional offices), but the compensatory payments are calculated for each farm individually;
7) the compensatory payments are calculated and granted for the actual losses. If there is insufficient financing in the fund, the amount of compensatory payments are determined according to the financial resources available in the fund or by scaling down the amount of compensatory payments;
8) there should be at 10% reserve left in the fund from the payments in the fund; the rest of the fund resources are available for the compensatory payments;
9) the deadline for the introduction of compensation fund is the year 2008.

The State Treasury which ensures the liquidity and profitability of the fund is the holder of the finances of the fund, but the payments made in the fund and the compensatory payments made from the fund are administrated by RSS in conformity with the procedure provided by the laws and regulations. The payments in the fund are made by both farmers and the state on an annual basis.

The payments in the fund are made on the basis of the application submitted by the applicant for the aid on receiving the aid regarding the single area payment. When the applicant receives the aid payment, RSS deducts from it the payment in the compensation fund (specially established non-budgetary account), if the applicant has agreed to make such payments and to participate in the fund. When the applications from the national budget sub-programme 21.01.00 "Subsidies for the Producers of Agricultural Products" had been aggregated, part of the state co-financing is being transferred to the compensation fund. This part is proportional to the payments made in the fund by farmers.

Then all the payments made in the fund are directed to the holder of the financial resources of the fund, which ensures the management of financial resources and maintaining of financial rate of return and liquidity.

When, in conformity with the laws and regulations, emergency occurs (EC Regulation No. 1857/2006, Article 2, Paragraph 8), the applicant for the aid submits an application to RSS on the losses caused to his farm, and the report of inspection issued by the parish consultant. On the basis of submitted application and the report of inspection issued by the parish consultant, RSS performs inspection on their farms for a part of applicants, calculates the caused losses, submits the application for the financing to the holder of the compensation fund and settles the accounts with the applicants for the aid.

Since the state participation in the fund is a state aid and the financial resources will be taken from the national budget sub-programme 21.01.00 "Subsidies for the Producers of Agricultural Products", the fund is a subject to the provisions defined in Sub-paragraph 4.5 of the Regulations No. 78 "Regulations on the State Aid for Agriculture in 2007 and Procedure for the State Aid Granting", issued by the Cabinet of Ministers on January 23, 2007 that Rural Support Service performs selective inspection of at least 5% of decisions made regarding every case.

In case of a local risk (for instance, hail, etc., or infectious diseases) RSS compulsory performs inspection regarding each application.

In order to ensure the functioning of such fund, it is necessary to plan about LVL 1,000,000 as the financing from the national budget for the first year of the functioning of fund. This financing would ensure the functioning of the administrative institution and the execution of its functions in conformity with the procedure provided by the laws and regulations. In future, the current administrative costs of fund are covered from the payments made in the fund.

The part of state co-financing for the ensuring of payments in the fund is envisaged annually in compliance with the laws and regulations on the state aid for agricultural development. The total financing for these measures is determined in compliance with Article 5, Paragraph 3 of the law "On Agriculture and Rural Development" providing the state aid for agricultural development in the amount of 2.5% of the total expenditures of the annual base budget, which are covered from grants from general revenues, deducting the contributions to the budget of the European Union. Additional financing for the implementation of this variant will not be requested – it will be implemented within the financial resources of the national budget sub-programme 21.01.00 "Subsidies for the Producers of Agricultural Products".

The benefits from the introduction of solution:

a) clearly defined institutional structure of risk management system, which determines the co-operation principles of all concerned parties, their obligations and responsibility;
b) in case of emergency there is a possibility of immediate decision making and use of necessary financial resources for the compensatory payments;
c) the farmers are involved in the solution of problems, and the psychological factors play a significant role: if one participates with his/her payment in the fund, s/he is granted a compensatory payment in case the risk occurs;
d) the regulations are clearly defined, therefore political decisions are not necessary in case the risk occurs.

The problems related to the introduction of the solution:

a) the establishment of the fund and ensuring of its efficient functioning may take several years;
b) the functioning of the fund is based on the principle of voluntary participation, which may not be supported by farmers. Thus the administrative costs of the fund may be higher than the payments made in the fund;
c) in comparison to Variant 1, there is a need for additional expenses regarding provision and maintenance of the administrative capacity.

In order to implement the offered variant, it is necessary to prepare proposals for the needed amendments of the laws and regulations on the state aid for agricultural development. It is necessary to amend the law on RSS and the law "On Agriculture and Rural Development". It is necessary to work out the regulations on the administration and monitoring of the fund as well as the amount of payments to be made in the fund.

The Concept of Latvian Agricultural Risk Management System: Variant 3 – the state aid is provided for the losses caused by adverse weather conditions and for the insurance premium payments

This variant offers to maintain the present system of compensation for losses in case of emergency. If adverse weather conditions have caused significant losses to the agricultural producers, and emergency occurs at the state level, then, on the basis of informative report submitted to the government, the decision is made on granting compensatory payments for the partial covering of losses.

The report contains data on the meteorological deviation of weather from the norm as well as the data analysis on the actual caused losses and their comparison to the period of time of previous three years. The evaluation and determination of compensatory payments shall be performed in conformity with the provisions of the European Commission Regulation (EC) No. 1857/2006 on the application of Articles 87 and 88 of the Treaty in relation to the small and medium enterprises involved in the production of agricultural products, and the amendments to the Regulation (EC) No.70/2001.

The aid payments are administrated by RSS in conformity with the laws and regulations on the state aid for agricultural development. The compensatory payments are granted only to the farmers, who have declared their farming area at RSS for the single area payment, and registered their animals at the Agricultural Data Centre.

Within the framework of this variant it is not possible to forecast the amount of necessary financing, because it can vary depending on the locality of emergency and the volume of caused losses. On the basis of informative report approved and the decision made by the government, the proposals for the amendments to the law "On the National Budget" and the allocation of the necessary additional financing to the national budget sub-programme 21.01.00 "Subsidies for the Producers of Agricultural Products" for the compensatory payments for losses.

In order to ensure the conformity with the provisions of the European Commission Regulation (EC) No. 1857/2006 on the application of Articles 87 and 88 of the Treaty in relation to the small and medium enterprises involved in the production of agricultural products, and with the amendments to the Regulation (EC) No.70/2001, there is a need for additional financing for the establishment and maintaining of agricultural production accounting data base.

There is no need for additional financing to cover the administrative costs, because it is ensured from the existing budgetary funds.

The benefits from the introduction of the solution:

1) clearly defined provisions for the compensations guaranteed by the state;
2) the present system is preserved, and there is no need for additional financing to establish new administrative institutions.

The problems related to the introduction of the solution:

a) it is impossible to forecast the financial resources, and they are unbalanced;
b) the system distorts the competitiveness in the market, hindering the development of privately financed service – the insurance of agricultural risks;

c) the system is more based on the political decisions, and it cannot be considered as durable and sustainable policy, which is observed by producers, when working out the strategy of their business development.

In order to implement this variant, presently it is not necessary to make any amendments to the laws and regulations in force. The developed solution variants have one common goal and basic principles. The difference between the variants is the institutional ensuring.

The Comparative Analysis of the Possible Variants of Risk Management System to be Introduced

Variant 1 envisages the state aid only to the payments of private insurance premium. This variant also allows for the establishment of private funds by the farmers' non-governmental organizations in order to compensate the losses caused to the farmers. The benefit for the state, when ensuring the implementation of purposeful risk management policy, is defining of political responsibility, ensuring and managing the transition from the present system to the privately financed risk management system. There is no compensation guaranteed to the farmers from the state for the losses, except the risks within the state basic responsibility. This variant does not distort the private insurance market.

Variant 2 envisages the aid for the payments of insurance premium and the establishment of compensation fund. This solution is characteristic by the fact that the state basic responsibility and co-responsibility are ensured, using the compensation fund, the financing of which consists of annual payments made in the fund by both the state and farmers. The benefit for the state, when ensuring the implementation of purposeful risk management policy, is defining of political responsibility.

Variant 3 envisages the state aid for the compensation for the losses caused by adverse weather conditions as well as aid for the payments of insurance premium. This variant offers to maintain the present system of compensation for losses in case of emergency. If adverse weather conditions have caused significant losses to the agricultural producers, and emergency occurs at the state level, then, on the basis of informative report submitted to the government, the decision is made on granting compensatory payments for the partial covering of losses.

On November 22, 2007, the Cabinet of Ministers of the Republic of Latvia issued Regulations No. 729 "On the Concept of Agricultural Risk Management Policy in Latvia", which provides for the support of Variant 2, included in the summary of concept. These regulations also provide that by September 1, 2008, the Ministry of Agriculture should develop and the Minister for Agriculture should submit to the government, in compliance with the procedure, the draft regulations on the agricultural risk fund administration and monitoring as well as the amount of payments that should be made in the fund.

The Systems Analysis of Agricultural Risk Management System Introduction

In the digital era the progress of information technologies provide not only opportunities, but also cause the necessity for simple and efficient means, how to ensure the receiving, processing, storage and exchange of information. Internet gradually, yet more and more becomes one of the main means for the provision and receiving of information and services. The era of technologies has changed the lifestyle and working habits of people, the way the farmers carry out their business and the way the governments serve their electorate. As a result, e-government has emerged towards which are moving the governments of almost all countries. The introduction of e-government is considered by the government not only at the state level, but also by the management level of enterprises for meeting their needs. Recently the electronic government or e-government has become an often mentioned concept both in Latvian society, in mass media and during the governmental discussions. E-government means the inclusion and application of IT for more efficient and modern ensuring of the functioning of the state, local governments and the enterprises related to them as well as for the establishment of mutual links between the population and organizations. E-government is a form in which the state and local government can use the new technologies for their advantage in order to ensure more comfortable availability of information and services for the population and enterprises, to improve the quality of rendered services and provide more opportunities to participate in the government (Ceļvedis e-pārvaldē, 2006).

In Latvia, the decision on the implementation of Variant 2 of the introduction of risk management system concept has been made – the aid for the payments of insurance premium and the establishment of compensation fund. The second variant of introduction envisages the establishment of compensation fund. We will view this variant in relation to the information technologies or the system. Designing of models is one of the forms to describe a system. Nowadays, when designing models, the visual modelling language UML (Unified Modelling Language) is used. UML is a special instrument by means of which several diagrams are designed that help describe the essence of the system. On the basis of requirements set by a client and the developed subject metamodel, it is possible to work out the requirements of information system and its general description. The general description of HACCP (Hazard Analysis and Critical Control Point) information system and the requirements set for it as well as the development of risk management system technologies in the private forestry was incorporated within the framework of the sub-project “Latvian Agricultural Information Technologies System” of the co-operation project “Latvian Agricultural Risk and Crisis Management Systems” (Lauksaimniecības un pārtikas …, 2007).

All the information obtained from the diagrams will be used to help preparing the documentation for the information system as well as for the development of information system itself. The system is described, grouping three types of diagrams: the diagrams of classes, activities, and the possibilities to use the system, because they are most often used within the process of diagram modelling.

The diagram of classes shows classes (Fig. 1), interfaces and their interaction. When modelling the object-oriented systems, the diagrams of classes are used more often, because they show the systems static model. The static model, firstly, is the identification and defining of the basic concepts of system under the research. Secondly, it is the identification of relations that might exist between these concepts. It is called a static model, as it does not describe dynamics, and changes, which take place within the system. On the whole, the systems static model can be considered as the main, because, while designing such model, the view on the system to be modelled is formed.

The subjects – a farmer and the state – make determined, equal payments, supplementing the compensation fund. The compensation fund is necessary for the prevention of several risks, or the compensation fund insures against the following risks: drought, incessant rain, frost and black frost, storm as well as insures against the farmer’s not obtained harvest. The compensation fund is supported by the State Treasury, but it is administrated by RSS.

The diagram of activities (Fig. 2) describes the dynamics, or the sequence of activities, which should be performed in order to achieve certain goal. This diagram is important, as it shows specific activities, which should be carried out in a particular case. The reference point could be the beginning of a year, but there could be also a different reference point. At the reference point there are payments made in the compensation fund by both a farmer and the state. When the fund is established or supplemented, it is administrated by Rural Support Service, but the State Treasury ensures the liquidity and profitability of the fund. If during the year or accounting period a risk occurs, and the farmer has losses, he is paid the compensatory payment. If during the year or accounting period no risk occurs, the process of the fund supplementation is repeated from the beginning.

The diagram of use (Fig. 3) opportunities describes the functioning of system from the external

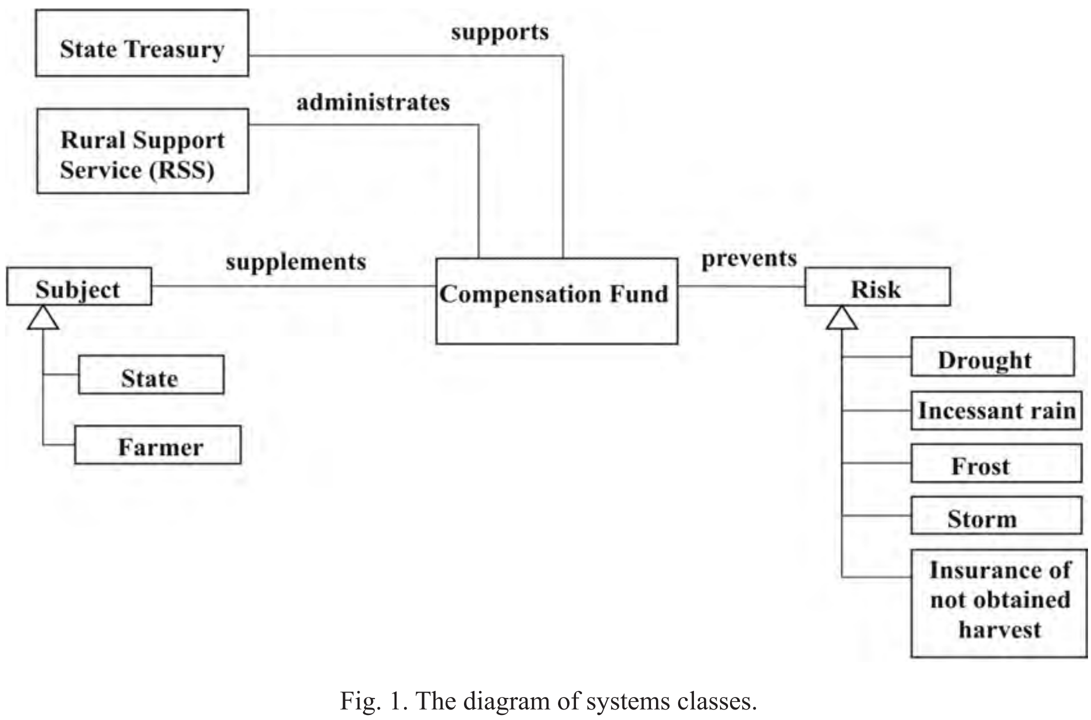

Fig. 1. The diagram of systems classes.

agents' view that are called the actors within the process of modelling, but, in fact, they are the users of the system. The diagram is important, since it shows the functionality of the system. It shows the functions performed by the described system or the object.

Risk management systems could consist of three sub-systems: Farmers' Register, System of Payment Calculation, and Compensation Fund.

Farmers' Register is necessary for the registration of all farmers who would like to establish and supplement the compensation fund with the aim of self-insurance against several risks and losses. This system could be implemented as a data base, where all data about the farmers would be stored.

The System of Payment Calculation could help calculate the amount of payments to be made in the compensation fund, as the payment to be made in the fund is determined on the basis of risk occurrence probability, taking into consideration the average income from the particular crop during the last three years.

The system, called Compensation Fund, could store all the information regarding the fund, its value as well as it could register all participants' payments and compensatory payments.

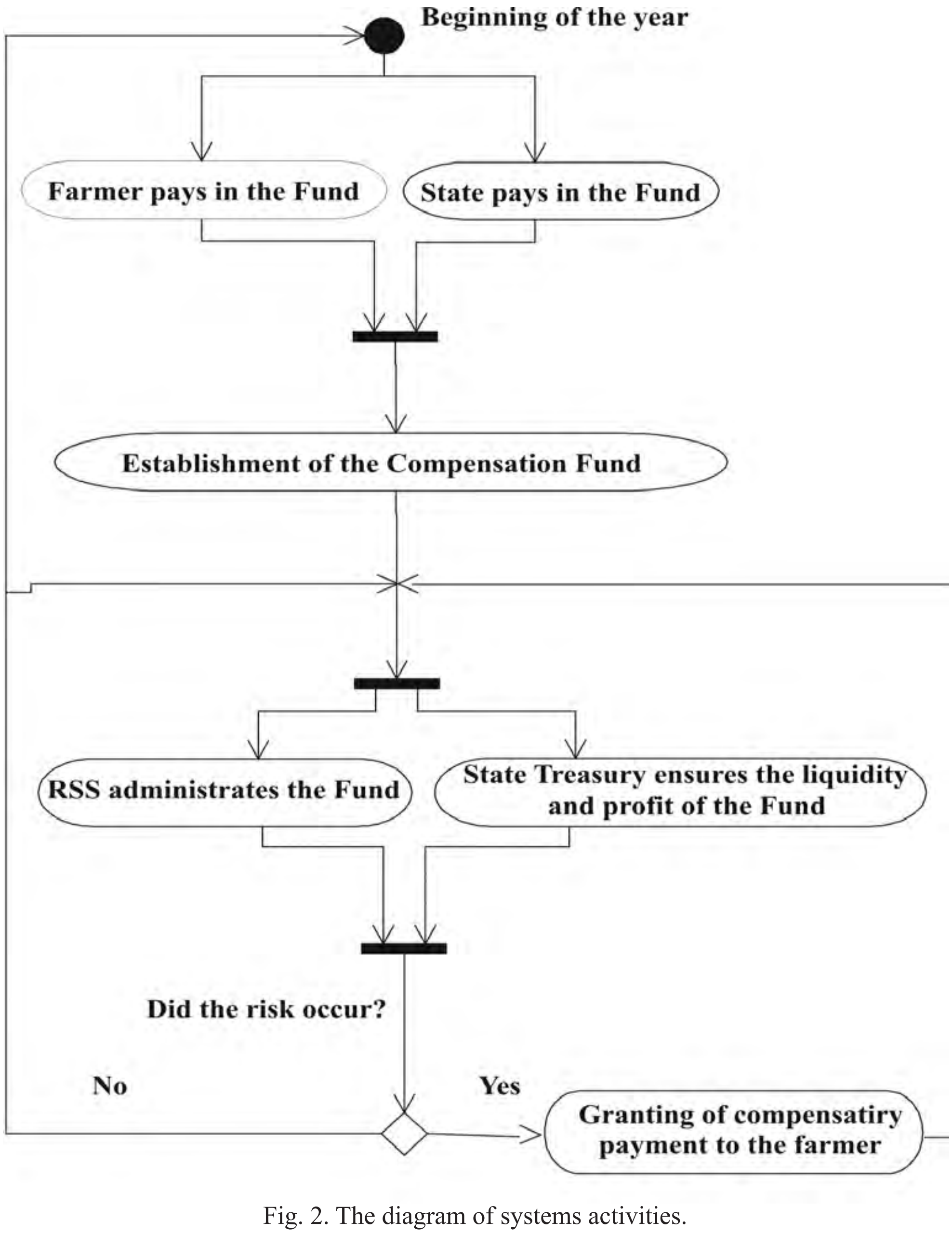

Fig. 2. The diagram of systems activities.

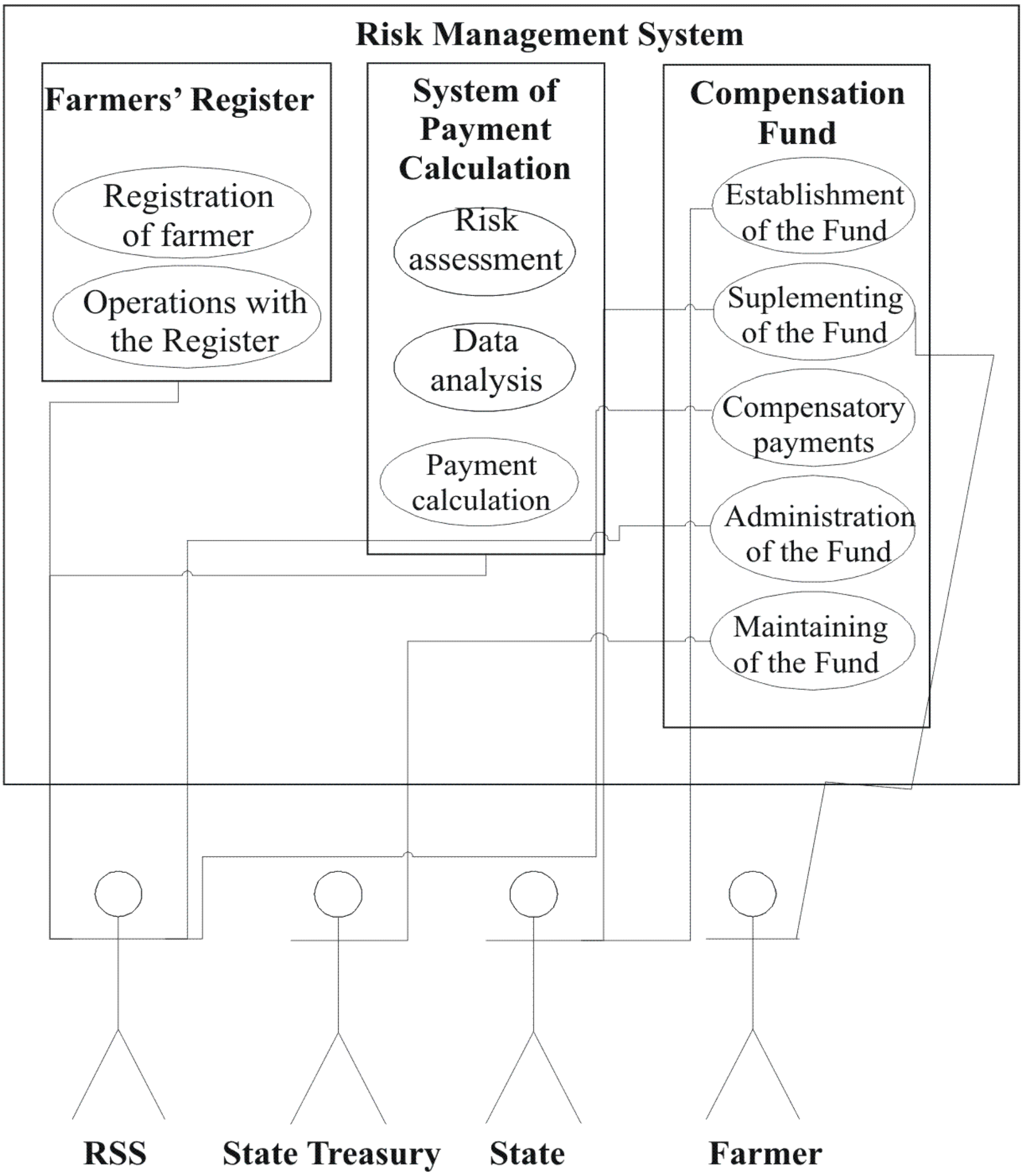

Fig. 3. The diagram of the possibilities to use the system.

Conclusions

The present situation in Latvia does not provide an opportunity for the population and entrepreneurs to aggregate the information in the entirety at the administrative institutions, since the information is transferred from one institution to another. The introduction of agricultural risk management system would provide benefit not only for its user-client who would receive qualitative service, necessary just for him. The administration would also benefit as e-management is an instrument for the fundamental modernisation of management: the new processes and services are oriented towards the end-user; the existing services and solutions are revised and adjusted to the new situation or eliminated at all.

The introduction of agricultural and forestry risk management information system will ensure efficient system for the compensation for losses caused by agricultural production risks. It will help determine the actions of both the state and farmers in case of emergency.

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Anotācija

Atsaucoties uz Eiropas Kopienas pamatnostādnēm attiecībā uz valsts atbalstu lauksaimniecības un mežsaimniecības nozarē 2007.–2013. gadā 5. punkta 131. apakšpunktu, katrai Eiropas Savienības dalībvalstij līdz 2010. gadam ir jāievieš lauksaimniecības risku vadības sistēma. Saskaņā ar Lauksaimniecības un lauku attīstības likuma 12. panta 1. punktu „ .. lauksaimniecības risku vadība nodrošina efektīvu sistēmu lauksaimniecības ražošanas risku radīto zaudējumu kompensēšanai”. Latvijas lauksaimniecības risku vadības politikas koncepcijas mērķis ir izstrādāt lauksaimniecības risku vadības sistēmu, kas nākotnē paredzētu noteiktu rīcību gan no valsts, gan no lauksaimnieku puses ārkārtas situācijas gadījumos. Rakstā analizēta ES valstu pieredze lauksaimniecības riska vadības sistēmu ieviešanā, kā arī pētīti risku vadības sistēmas iespējamie ieviešanas varianti Latvijā. Lauksaimniecības risku vadības politikas koncepcijas atbalstāms risinājuma variants paredz atbalstu apdrošināšanas prēmiju maksājumiem un kompensācijas fonda izveidei. Šo risinājumu raksturo tas, ka tiek nodrošināta valsts pamatatbildība un līdzdalība, izmantojot kompensāciju fondu, kura līdzekļus veido ikgadējas valsts un lauksaimnieku iemaksas. Šim risinājuma variantam ir veikta informācijas sistēmas ieviešanas sistēmanalīze, lai noskaidrotu riska vadības politikas īstenošanai nepieciešamās informācijas sistēmas integrēšanas iespējas.

Insurance Problems and Prospects in Latvian Agriculture
Apdrošināšanas problēmas un perspektīvas Latvijas lauksaimniecībā

Aija Graudiņa
BA School of Business and Finance
Banku Augstskola
e-mail: Aija.Graudina@ba.lv

Abstract. Agriculture is subject to the impact of natural risks, which results in annual losses suffered by agricultural producers. The State, at its own expense, compensates agricultural producers for losses, with the subsidies amounting to LVL 2.1 million on average. Since 2000, the insurance scheme for insuring risks in crop farming sector established by the Ministry of Agriculture has provided for subsidizing persons involved in growing of crops, in the amount of 50% of the insurance premium payments. The necessity of the involvement of the State in the agricultural risks (systematic risk) management has been historically proven in EU Member States and other counties. In the European Union, cereal crop risk management is effected on two levels: governmental emergency funds *(ad hoc)* and private insurance. The experience of the EU and other countries shows that the public and private partnerships are possible on both levels and in different proportions as far as compensated losses are concerned. Procedures and requirements for the formation of emergency funds are set and defined on the European Union level. This paper is based on monographs of agricultural risk insurance specialists and EU documents on agricultural risk insurance, such as Commission Regulations, the research summarizing the experience of Latvia and other countries. These publications do not contain methodological or other solutions for agricultural risks and their insurance. An important factor of the relevancy of the theme is the necessity of a special original model for the crop risk insurance service, defining the methods for calculating coverage, premiums and compensations by using average crop indicators in Latvia's countryside, when a systematic database of statistics of crop loss is not available.
Key words: crop risk, insurance service model.

Introduction

Agriculture is subjected to the impact of natural risks resulting in annual losses suffered by agricultural producers. The State, at its own expense, compensates agricultural producers for losses by means of the subsidies amounting to LVL 2.1 million on average. Since 2000 the insurance scheme for insuring risks in the crop-farming sector established by the Ministry of Agriculture has provided for the subsidy of persons involved in growing of crops in the amount of 50% of the insurance premium payments. However, there is no express demand for cereal crop insurance services, since losses are compensated for from the state funds without any obligation or financial input on the farmers' part. Moreover, there is no supply of cereal crop insurance services on the part of insurance companies.

According to the theory of insurance, agricultural risks typical of climatic conditions (systematic risks) are ranged in the group of risks between pure and speculative risks, which are difficult to insure. The essence of risk and individual attitude to risk have been defined by the following authors of risk management theory (Williams, Smith, Young, 1998; Jaunzems, Vasermanis, 2001; Graudiņa, 2002, 2003; Rejda, 2003; Willet, 1951; Tversky, Kahneman, 1992; Зубец, 2001; Machina, Schmeidler, 1992).

The necessity of the State involvement in the systematic risk management has been historically proven in the EU member states and other countries.

In the European Union, cereal crop risk management is effected on two levels: governmental emergency funds *(ad hoc)* and private insurance. The experience of the EU and other countries shows that public and private partnerships are possible on both levels and in different proportions as far as compensated losses are concerned. Procedures and requirements for the formation of emergency funds are set and defined on the European Union level.

This paper is based on monographs of agricultural risk insurance specialists and the EU documents on agricultural risk insurance, such as Commission Regulations (EC) No. 1/2004, and No. 1857/2006 and amendments to the Commission Regulation (EC) No. 70/2001 as well as on the research summarizing the experience of other countries

(Ray, 1998; Meuwissen, Huirne, Hardaker, Black, Hanf, Skees, 1999; Williams, Smith, Young, 1998; Skipper, 1998; Harrington, Niehaus, 2003; Rejda, 2003; Graudiņa, Jansons, 2006; Manitoba Crop Insurance..., 2005). The results of extensive research regarding agricultural risks and possibilities for their management have been recently published in Latvia (Pelāne, 2001; Šķeptere, 2003; Ercmane, 2003, 2004; Arhipova, Arhipovs, 2005; Merkurjevs, Bardačenko, Arhipova, Rudusa, 2004; Rivža, Špoģis, 2005; Turka, Mihejeva, Bankina, Bimšteina, 2005; Špoģis, Radžele, Jance, 2005; Bardačenko, Merkurjevs, Rudusa, Solomenikova, 2005; Špoģis, Dobele, 2005; Rivža, Rivža, Šantere, 2007; Ruža, Solomenikova, Merkurjevs, 2007). However, these publications do not contain methodological or other solutions for agricultural risks and their insurance.

An important factor of the relevancy of the theme is the necessity of a special original model for the crop risk insurance service, defining the methods for calculating coverage, premiums and compensations by using average crop indicators in Latvia's agriculture, when a systematic database of statistics of crop loss is not available.

Novelty of research: model of insurance service for the needs of Latvia cereal crop insurance development when a systematic database of statistics of crop loss is not available.

The research methods envisaged for solving the set tasks: the monographic descriptive method as well as the methods of analysis and synthesis are widely used in the paper to study the problem elements and synthesize coherencies; scientific induction method is used for summarizing individual facts in general statements and coherencies; deduction method is used for theoretical explanations and logical synthesis of the empirical study; the dynamic analysis method, data grouping method, constructive calculation method and statistical-graphical method are used for the analysis of statistical data; in the event that statistically significant data regarding the insurance product creation process are not available, actuarial mathematics elements are applied, using the insurance premium calculation method of the US Federal Crop Insurance Corporation (FCIC):

1) the size of the insurance coverage in cereal crop insurance is calculated:

$$\text{Insurance coverage} = \text{Crop}_{avg.} \times \text{Price, LVL t}^{-1}, \quad (1)$$

where (Ray, 1998; Manitoba crop insurance ..., 2005)

Crop$_{avg.}$ – the average cereal crop yield in 2000–2004 in the country, according to categories, t ha^{-1};

Price – the assumed average cereal price LVL 66.90 t^{-1} in the country in total and according to categories; it is constant in all examples offered LVL;

2) the expected value is calculated using the folloving formula (Pettere, Voronova, 2004; Skipper, 1998):

$$EV = \sum_{i=1} p_i x_i , \quad (2)$$

where

p_i – probability of the occurrance of event "i";

x_i – amount of losses; in cereal crop insurance x_i – probability of any possible yield loss p_i;

3) actuary insurance premium should completely cover the potential loss (Pettere, Voronova, 2004; Skipper, 1998):

$$P = Z, \quad (3)$$

where

P – insurance premium;

Z – potential loss;

4) loss arrays x_i are created separately for each category and calculated using the formula (Ray, 1998):

$$x_i \begin{cases} \text{Actual Yield} - \text{Coverage, if } \langle 0 \\ 0, \text{ if } \rangle 0 \end{cases}, \quad (4)$$

where

x_i – potential loss;

5) the indicators of cereal crop yield loss calculated for every unit characterising risks are used when calculating the probability of the occurrence of yield loss p_i (Ray, 1998):

$$\text{Probability } p_i = \frac{N_{loss}}{N}, \quad (5)$$

where

N_{loss} – is the number of events when loss x_i occurs;

N – is the number of units characterising insured risks in all categories;

6) to calculate the actuarial premium per hectare for Category 1, we use the criterion of statistical indicator of "expected value":

$$EV = 0.024\ \left(t\ ha^{-1}\right) \times 66.9\ \left(LVL\ t^{-1}\right) \times 0.139 = 0.223\ \left(LVL\ ha^{-1}\right); \quad (6)$$

7) assuming that loss records are precise, we can calculate the actuary calculation using the following equation (Ray, 1998; Manitoba crop insurance..., 2005):

$$\left(\text{Average yield}\ \left(t\ ha^{-1}\right) \times\ 80\% - \text{Actual yield}\right) \times\ \text{Price} = \text{Compensation for loss}. \quad (7)$$

Results and Discussion

Insurance Market in Latvia between 1992 and 2006. In the mid 1990's, further stabilization of Latvia's insurance market was promoted due to the implementation of the European Union legal framework, thus improving the supervision and legislation system of the insurance market. In 1994, life insurance commercial activities were separated from non-life insurance commercial activities.

Article 12 of the Law "On Insurance Companies and Supervision" sets forth which types of insurance in Latvia issue 19 sector licences (Apdrošināšanas sabiedrību ..., 1998).

Cereal crop insurance product/service is included in the subdivision of movable property insurance of property insurance (Fig. 1). Agricultural risks, particularly grain cultivation risks, are a specific phenomenon in the group of risks. In the aggregate of risks, grain cultivation risks are placed between the "pure" risks, i.e., completely independent, mutually uncorrelated risks, such as those related to property insurance, vehicle insurance, health insurance and "speculative", i.e., systematic, dependent, mutually correlated risks, such as risks characteristic of the market of contracts on future financial transactions (Pettere, Voronova, 2004; Crop insurance ..., 2009).

Several objects of potential loss with risks pertaining thereto are characteristic of agricultural sector – risks typical of insurance object of loss of a private person: injuries, diseases, death, risks typical of property insurance object: fire, storm, flood, theft, burglary (Īpašuma apdrošināšanas ..., 2005; Homeowners Insurance, 2009). Risks typical of insurance object of loss of yield (crop yield and livestock): natural risks, damage by third persons, plant diseases (Lauksaimniecības risku …, 2002). Risks typical of insurance object of loss of price: fluctuations of sales prices, fluctuations of purchase prices. Risks typical of insurance object of institutional (political) loss: legislative changes in the country, legislative changes in the EU (priorities in agricultural policy).

Risks typical of insurance object of financial loss: changes in credit interest rates, loan or credit management, financial solvency (Jakušonoka, 2005; Risk Management Tools ..., 2001; Income Insurance ..., 1999).

The author of the paper analyses specific grain cultivation insurance risks.

Experience of cereal crop insurance in other countries and in Latvia. In the European Union, cereal crop risk management is effected on two levels: public/governmental – special funds compensating for loss (*ad hoc* payments) with the average annual amount of compensations paid being EUR 904.3 million. The risks most often compensated for are: drought, frost and flood. Private insurance where the risks most often compensated for are as follows: hail and fire, with the average total amount of compensations paid being EUR 1061.0 million: insurance premiums are subsidised by the State.

Every EU country has risk management systems of governmental level as well as risk management systems of private insurance, which are established in each country depending on economic or historical traditions of agricultural risk insurance, such insurance against hail or fire risks, and compensation for loss is defined by the law.

1. In Italy, Spain, Austria, Portugal, Greece and Sweden, the government does not compensate for loss from special public funds if a relevant insurance service is available for the risk having caused the loss. In other EU countries, including Latvia, the law does not provide for restrictions regarding compensation

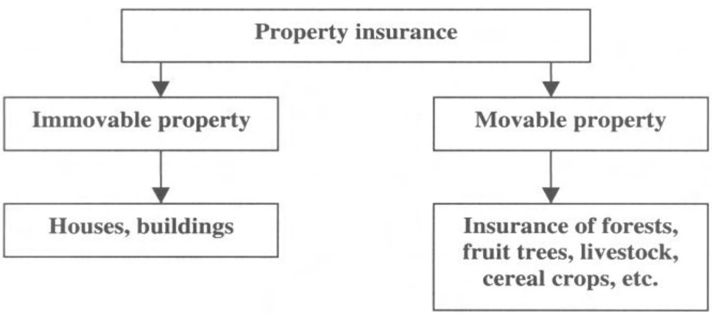

Fig. 1. Place of cereal crop insurance product/service in the package of non-life insurance services.

for loss.The largest compensations for loss from special public funds are in France (1996–2005), with compensations from public funds amounting to EUR 155.6 million per year. Only EUR 5.0 million comes from private insurance as compensation for loss in grain cultivation. In Spain (2000–2005), EUR 3.7 million on average come from public funds as compensations per year, and EUR 388.3 million on average come from private insurance, where the State subsidises 41% of insurance premiums. In Latvia (2000–2005), annual compensations for loss in grain cultivation coming from special public funds amount to EUR 3.2 million on average. The amount of compensations for loss in private insurance is not specified. The government of Latvia subsidises 50% of insurance premiums (Agricultural Insurance Schemes, 2006; Risk Management Tools ..., 2001; Meuwissen et al., 1999).

2. When the government is involved in support of private insurance services, private insurance offers coverage not only for hail and fire risks, but also for other agricultural risks related to climatic factors. Spanish private insurance, in close cooperation with the government of Spain and farmer's union, offers insurance coverage for virtually any possible agricultural risk related to climate. In Austria, France, Italy and Luxembourg, private insurance of grain cultivation, in collaboration with the government, offers insurance coverage not only for hail risk, but also for other climatic risks with the exception of drought risk.

In Bulgaria, Poland, the Czech Republic, Hungary, Portugal, Slovakia, Slovenia, and Sweden, private insurance offers insurance of hail risk in grain cultivation as well as insurance coverage of other risks depending on the insurance policy. In Belgium, Germany, the Netherlands and England, private insurance offers insurance of hail risk. The governments are not involved in subsidisation of insurance premiums (Agricultural Insurance Schemes, 2006; Risk Management Tools ..., 2001).

3. Insurance premium rates in the EU market range from 1% in England to 6-8% in Spain, Portugal and Italy. The main factors affecting rate range in the EU: risk frequency in time and space, insured risks (hail, drought) and their number in one policy, crop sensitivity to natural risks, deductible amount, number of insured households,

4. Deductible amount in insurance in the EU market ranges from 0% to 40% or more. Factors affecting the deductible amount: the bigger risk frequency in time and space, the higher deductible %, may appear as an individual approach to each separate farming household – the higher the deductible amount, the lower the insurance premium, new insurance product – bigger deductible amount (Agricultural Insurance Schemes, 2006; Risk Management Tools …, 2001).

On 25 April 2002, on behalf of the European Community, the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments there under the Council Decision (2002/358/EC) was passed concerning the approval. This attention should be brought to the so-called ''green box'', which describes the United Nations guidelines regarding subsidies for agriculture (Padomes 2002. gada 25. aprīļa lēmums (2002/358/EK) ..., 2006).

In the ''Communication from the Commission to the Council on risk and crisis management in agriculture'', European Community Commission (2005) suggests that the potential of three options should be assessed, from the point of view of individually or jointly, completely or partially replacing Community and Member States' *ad hoc* emergency measures (Komisijas paziņojums Padomei ..., 2005): Option 1: Insurance against natural disasters – financial participation in farmers' premium payments. Insurance provides an alternative to public ex-post compensation payments for losses caused by natural disasters at the EU and national or regional level. Option 2: Mutual fund support. Mutual funds represent a way of sharing risk among groups of producers who want to take their own responsibility for risk management. Option 3: Providing basic coverage against income crises. A more general coverage against crises that result in severe income losses would allow existing safety net provisions to be further simplified and improves the balance between different agricultural sectors.

Apart from the aforementioned three options, the EU offers creating a public emergency fund in grain cultivation for the compensation of crop loss and fixed assets of agricultural production, where in addition to classical systematic risks also unfavourable weather conditions are the defined losses. For example, risks of frost, hail, ice, rain or drought are set equal to natural disasters as soon as the scope of damage has reached a specified threshold of normal production.

Commission Regulation (EC) No. 1857/2006 of 15 December 2006 on the application of Articles 87 and 88 of the EC Treaty to State aid for small and medium-sized enterprises active in the production of agricultural products and amending Regulation (EC) No 70/2001. The Regulation allows Member-States to award different kind of State aid without prior permission of the Commission (Komisijas Regula (EK) Nr. 1857/2006 …, 2007). The Community guidelines for state aid in the agriculture and forestry sector 2007 to 2013 (2006/C 319/01) (Kopienas pamatnostādnes ..., 2006).

The information defines the level of State responsibility in the agricultural sector on the whole, including primary producers:
1) Section V of the document discusses issues related to risk and crisis management;
2) the common minimum threshold of damages is 30% of normal production for all areas; farmers always cover part of the losses; therefore, when creating a service, deductible amount should be applied;
3) compensation is not applicable if there is no insurance.

The management of demand and supply of agricultural risk insurance service in grain cultivation in Latvia, similar to other world and the EU countries, is effected on two levels. Public insurance – compensation for loss related to agricultural risks from the national budget, with total compensations paid in the period between 2000 and 2005 amounting to LVL 12.3 million (Table 1). The risks most often compensated for are: drought, frost and flood (Koncepcija "Par lauksaimniecības …", 2006). Private insurance – where aid for agricultural risk insurance in the form of subsidies has been determined every year since 2000 (Table 2). The Cabinet defines the annual amount of state aid for each supported programme of agricultural subsidies within a month from the date of passing the annual law on the national budget. The Minister for Agriculture sets forth the procedure for receiving such aid (Lauksaimniecības un lauku …, 2004).

During these years, the State has compensated the farmers for 50-70% of the amount of premium determined by the insurance company. For example, premiums for crops have ranged from LVL 5 to LVL 10 ha^{-1}. The regulations on subsidies have not been changed essentially during these years. In 2005, the aid for farmers was set forth under the Cabinet Regulations No. 70 ''Regulations on State Aid for Agriculture in 2005 and the Procedure of Allocation'' which were issued pursuant to Parts 4 and 6, Section 5 of the Law ''On Agriculture and Rural Development'' (Noteikumi par valsts atbalstu …, 2005).

The concept ''On Agricultural Risk Management Policy in Latvia'' developed by the Ministry of Agriculture in 2007 offers the following solutions: variant 1: Aid only for private insurance premium payments, variant 2: Aid for private insurance premium payments and establishment of compensation funds, variant 3: State aid for loss caused by unfavourable climatic conditions and for insurance premium payments (Koncepcija ''Par lauksaimniecības risku …'', 2007).

These solutions reflect the potential administrative models; however, in order to create an actuarially reasonable insurance fund, it is necessary to define the following irrespective of the administrative model – the object of insurance and insurable

Table 1

Compensations for loss caused by climatic fluctuations paid from the state funds in Latvia between 2000 and 2005, LVL

Ref. No.	Compensations for loss caused by climatic fluctuations	2000	2001	2002	2003	2004	2005	Total
1	Loss caused by frost	0.63						0.63
2	Loss caused by floods		0.09					0.09
3	Loss caused by dryness			5.90				5.90
4	Loss caused by excessive rainfall				5.00			5.00
5	Damage due to frost					0.22		0.22
6	Loss of livestock due to midge bites and loss caused by floods						0.44	0.44
	Total:	0.63	0.093	5.90	5.00	0.22	0.44	12.28

Table 2

Number of households–recipients of insurance premium subsidies in grain cultivation and livestock breeding in Latvia between 2002 and 2005 (units)

Ref. No.	Number of recipients of subsidies	2002	2003	2004	2005
1	Grain cultivation	41	2	0	no data
2	Livestock breeding	no data	no data	no data	138

risks, insurance coverage and deductible, method of premium calculation if historical data are not available, loss record keeping system and method of claim calculation.

Model of insurance service for cereal crop yield. The choice of administration of the insurance scheme determines the nature of insurance, for instance, personal insurance, state insurance – public sector, combined insurance – private and public sectors.

The combined model of administrative insurance is the optimum choice for systematic risk management from both a theoretical and practical point of view. Communication between participants of the insurance scheme is formed (Fig. 2) (Collin, Hansson, 2000).

Insurance legal base determines the nature of insurance: optional personal insurance, mandatory service of optional insurance (such as *OCTA* – Mandatory insurance of civil liability of vehicle owners in Latvian insurance market), mandatory state level insurance, and mandatory municipal insurance.

Risk management capacity is affected by the number of units characterising risk – the bigger the number of units characterising risk (farming households), the bigger risk management capacity.

The following steps to be taken to ensure the biggest possible risk management capacity: to set forth by the law mandatory crop insurance service, to set administratively a long-term insurance contract for cereal crop insurance service, for example, for 5 years.

The risks affecting the potential loss of cereal crop yield: risks caused by natural disasters: drought, hot wind, excessive humidity, storms, frost, flood, earthquake, and landslide, other risks: plant diseases and pests, damage caused by animals, risks related to damage by third persons. The elements describing the administration of cereal crop insurance: property right to the land under crop (the owner's property, joint property or leased land is managed); classification of areas under cereal crop according to their productivity, flow data of cereal crop productivity in years: in households, in regions or in the whole country. The minimum period for summarizing data is five years; setting of economically sound insurance coverage; setting of insurance rate pursuant to the size of the loss ratio if actual loss indicators are available; if actual loss indicators are not available, the rate can be calculated pursuant to the indicators of cereal crop productivity, alignment methods for the potential consequences of moral hazards and asymmetrical market, such as deductible; cereal crop insurance compensation.

Setting stages of the insurance service, the basic administration element of cereal crop insurance:
1) insurance coverage assessment;
2) insurance rate calculation and insurance premium determination;
3) loss identification and compensation (Blends, 1995; Skipper, 1998).

Calculations of cereal crop insurance service are based on the data regarding the average cereal crop productivity in the country in total between 2000 and 2004. The data are classified into three relevant categories.

Category 1 characterises areas of the country with the lowest average cereal crop yield during the last five years against the total cereal crop yield indicator in the whole country (1.68 t ha^{-1}). Category 1 represents 467 80 households with the total area of 151 724 ha.

Category 2 characterises areas of the country with the medium-sized average cereal crop yield during the last five years against the total cereal crop yield indicator in the whole country (2.20 t ha^{-1}). Category 2 represents 4 735 households with the total area of 210 024 ha.

Category 3 characterises areas of the country with the highest average cereal crop yield during the last five years against the total cereal crop yield indicator in the whole country (3.16 t ha^{-1}). Category 3 represents 220 households with the total area of 74 900 ha (Lauku saimniecības Latvijā ..., 2005). In insurance, property insurance coverage and potential loss scope are defined before the occurrence of the insured risk. In case of cereal crop insurance, the potential loss and insurance coverage can be established only at the time of harvesting.

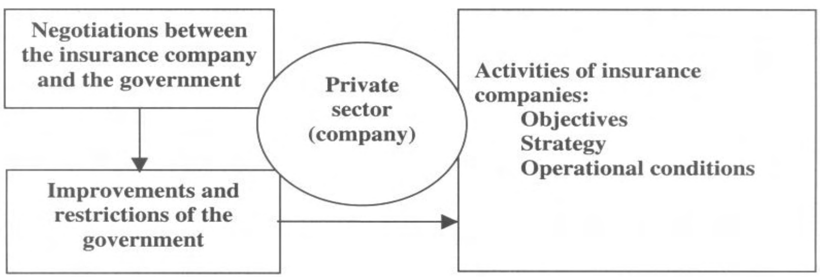

Fig. 2. Communication between the public and private sectors in creation of insurance schemes.

To reduce the impact of adverse selection and moral hazard on the insurance market, we will use the classical insurance mechanism for alignment of adverse selection and moral hazard: deductible where the amount of deduction is fixed, coinsurance where a set percentage is fixed. The size of the insurance coverage in cereal crop insurance is calculated depending on the indicators of the average cereal crop yield in a year, during a period of at least five years, unless significant loss of cereal crop yield has occurred within these five years (formula 1). Insurance coverage amount for instance, if insurance coverage is 100%, borders of categories differ by LVL 99.34 ha^{-1}; if insurance coverage is 90%, borders of categories differ by LVL 89.41 ha^{-1}; if insurance coverage is 80%, borders of categories differ by LVL 79.41 ha^{-1} (Table 3) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005).

The statistical equation of ''expected value'' formula (2), on which the insurance premium calculation is based, can be simplified according to the classical insurance theory stating that the actuary insurance premium should completely cover the potential loss formula (3).

We will use the formula (4) for estimation of the premium, calculating insurance compensations paid (potential loss) x_i and probability p_i, with which such losses may occur. Loss arrays x_i are created separately for each category and calculated using the formula (4).

To calculate potential loss x_i we calculate the average yield in the regions for the period of five years, observing the classification of the regions into categories, apply the calculated average yield to the relevant insurance coverage of 80%, 90% and 100%, observing the classification of the regions into categories (Table 4) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons 2006; Ray, 1998). We calculate the average yield loss of each year, observing the classification of the regions into categories and coverage types. For example, flow data of the average yield of Category 1 for units characterising risks and the average cereal crop yield with the insurance coverage of 80% are 1.34 t ha^{-1}. We define the units characterising risks (regions) where the average cereal crop yield is lower than the set cereal crop yield, i.e., lower than 1.34 t ha^{-1}. The average level of cereal crop yield of units characterising risks of Category 1 is lower than the set cereal crop yield level, i.e., 1.34 t ha^{-1} in nine regions. Pursuant to these indicators, we establish the average scope of loss of the average cereal crop yield of Category 1, if the level of loss is below the average indicator for the loss 1.34 t ha^{-1} (Table 4) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998). We calculate the potential average cereal crop loss x_i for insurance coverage of 80%, 90% and 100%, according to categories (Table 4) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998).

The lowest cereal crop losses are for the units characterising risks of Category 3 with the insurance coverage of 80%. The highest cereal crop losses are

Table 3

Insurance coverage amount by categories if insurance coverage is 80%, 90%, and 100%

Category Ref. No	Average crop yield, t ha^{-1}	Insurance coverage 80%, LVL ha^{-1}	Insurance coverage 90%, LVL ha^{-1}	Insurance coverage 100%, LVL ha^{-1}
1	1.68	89.65	100.85	112.06
2	2.20	117.13	132.22	146.91
3	3.16	169.12	190.26	211.40

Table 4

Average dynamic cereal crop yield loss by categories for all units characterizing risks in Latvia between 2000 and 2004 with the insurance coverage of 80%, 90%, and 100% (t ha^{-1})

Category	Average crop yield	80% coverage	Crop loss	90% coverage	Crop loss	100% coverage	Crop loss
Category 1	1.68	1.64	0.024	1.51	0.055	1.68	0.104
Category 2	2.20	1.75	0.007	1.98	0.042	2.20	0.142
Category 3	3.16	2.53	0.000	2.84	0.010	3.16	0.113

for the units characterising risks of Category 2 with insurance coverage of 100%. We create a joint base of indicators of the average dynamic cereal crop yield loss according to categories for all units characterising risks with the insurance coverage of 80%, 90%, 100% (t ha^{-1}) (Table 4) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998).

The indicators of cereal crop yield loss calculated for every unit characterising risks (Table 4) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998) are used when calculating the probability of the occurrence of yield loss p_i (formula 5).

For each category we calculate the average loss from the probability of loss. To determine the average arithmetic value for the yield every year, the annual assessment of probability of loss should be made, for instance: value 0.1385 is the assessment of probability where in 13.85% of cases a loss of 0.024 t ha^{-1} occurs.

Loss for Category 1 (the first group of households) with the average cereal crop yield of 1.68 t ha^{-1} is 0.024 t ha^{-1}. To calculate the actuarial premium per hectare for Category 1, we use the criterion of statistical indicator of ‘‘expected value’’ (formula 6). It means that the actuarial premium of cereal crop yield for Category 1 with the insurance coverage of 80% is LVL 0.22 ha^{-1} (Table 5) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998). For the actuarial cereal crop insurance premium according to categories with the insurance coverage of 80%, 90%, 100% calculated for three categories.

Applying the insurance coverage of 80%, 90% and 100% for the calculations of cereal crop insurance premiums, we obtain the following results: cereal crop insurance premium with the insurance coverage of 80% for Category 1 is LVL 0.233 ha^{-1}, and cereal crop insurance premium with the insurance coverage of 100% is LVL 2.783 ha^{-1}. The amount of loss according to categories (Fig. 3) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998) varies depending on the insurance coverage and average indicators of cereal crop yield. We may conclude that Category 2 is the category most exposed to risk, i.e., farming households with medium-sized areas under cereal

Table 5

Actuarial cereal crop insurance premium, LVL ha^{-1}, by categories with the insurance coverage of 80%, 90%, and 100%

Insurance coverage according to categories	Actuarial cereal crop insurance premium, LVL ha^{-1}, with insurance coverage of 80%	Actuarial cereal crop insurance premium, LVL ha^{-1}, with insurance coverage of 90%	Actuarial cereal crop insurance premium, LVL ha^{-1}, with insurance coverage of 100%
Category 1	0.223	0.849	2.783
Category 2	0.026	0.868	6.222
Category 3	0.000	0.134	3.779
Actuarial cereal crop insurance premium, LVL ha^{-1}	0.201	0.843	3.104

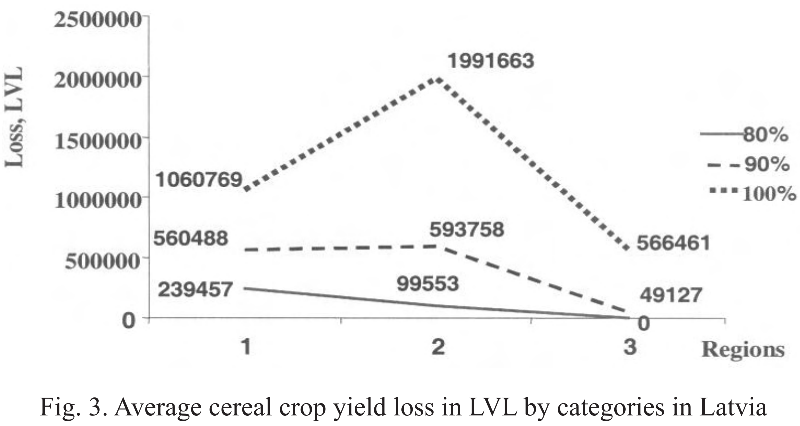

Fig. 3. Average cereal crop yield loss in LVL by categories in Latvia between 2000 and 2004 with the insurance coverage of 80%, 90%, and 100%.

Table 6

Average indicators of compensation for cereal crop yield loss in Latvia between 2000 and 2004, LVL ha^{-1}

Insurance coverage according to categories	Insurance compensation		
	80% coverage	90% coverage	100% coverage
Category 1	8.69	10.09	11.20
Category 2	11.77	13.21	14.69
Category 3	16.93	19.03	21.14
Average insurance compensation for yield loss	12.46	14.11	15.68

crop and medium-sized cereal crop productivity, as cereal crop productivity is affected not only by climate conditions, but also intellectual, social, economic, disposition, professional, commercial, financial, crediting, investment and other risks. Potentially, it is a group of producers who would be most willing to purchase insurance. If the insurance coverage of cereal crop of the cereal producers of this category is 90%, the actuarial cereal crop insurance premium is LVL 0.868 ha^{-1} (Table 5) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998). The result is dramatically different if the insurance coverage is 100%. In this case, the actuarial insurance premium for Category 2 is LVL 6.222 ha^{-1}. When creating an insurance service, it is necessary to offer such a service with various amount of insurance coverage: 100%, 95%, 90%, 85%, 80% depending on the level of cereal crop yield. Pursuant to the calculated example, the most profitable insurance coverage is 90%, where the actuarial insurance premium for cereal crop is:

– Category 1: LVL 0.849 ha^{-1};
– Category 2: LVL 0.868 ha^{-1};
– Category 3: LVL 0.134 ha^{-1}.

The dramatic differences of the calculated insurance premiums according to categories can be mainly explained by the fact that 10% of crop loss occurs much rarer in households with high cereal crop productivity than in households where the average cereal crop productivity is lower.

The actuarial insurance premium for cereal crop of Category 3 with the coverage of 100% is 3.779 which is 28 times bigger (Table 5) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998) than the actuarial insurance premium for cereal crop with the insurance coverage of 90%.

The most difficult task is to determine the actual loss, as there exist many factors affecting yield loss in nature that are not discussed and analysed in the present paper. Assuming that loss records are precise, we can calculate the actual calculation using the following equation (formula 7). Let us assume that the actual cereal crop yield is by 10% smaller than the average cereal crop yield in all categories with the insurance coverage of 80% is

$$\left[1.34\ \left(\mathrm{t\ ha^{-1}}\right) - 1.21\ \left(\mathrm{t\ ha^{-1}}\right) \times 66.9\ \left(\mathrm{LVL\ t^{-1}}\right)\right] = 0.13\ \left(\mathrm{t\ ha^{-1}}\right) \times 66.9\ \left(\mathrm{LVL\ t^{-1}}\right) = 8.69\ \mathrm{LVL\ ha^{-1}}.$$

In this case the scope of compensation for cereal crop yield loss within Category 1 is equal to LVL 8.69 ha^{-1}, if insurance coverage is 80% (Table 6) (Lauku saimniecības Latvijā ..., 2001, 2002, 2004, 2005; Graudiņa, Jansons, 2006; Ray, 1998).

Conclusions

1. Latvia's insurance market is developing pursuant to EU legislation and according to historical experience and regularities of EU Member States and other countries. The general development trends of the insurance market are positive – the insurance market size is increasing.
2. In the European Union, cereal crop risk management is effected on two levels: governmental emergency funds *(ad hoc)* and private insurance. The experience of the EU and other countries shows that the public and private partnerships is possible on both levels and in different proportions as far as compensated losses are concerned.
3. In Latvia, risk management related to cereal crop yield is effected on two levels: on public level by compensating for loss from the national budget and subsidizing insurance premiums and on the level of the so far underdeveloped private insurance.
4. Mathematical model of crop insurance service has been developed establishing:
   1) method of calculating the insurance coverage;
   2) method of calculating the insurance premium;

3) method of calculating the insurance compensation in a situation in Latvia's countryside when a systematic database of statistics of crop loss is not available.

The amount of loss according to categories varies depending on the insurance coverage and average indicators of cereal crop yield. The optimum level of deductible is 10%, with the insurance coverage of 90%, where the actuarial insurance premium for cereal crop is:

1) Category 1: LVL 0.849 ha^{-1};
2) Category 2: LVL 0.868 ha^{-1};
3) Category 3: LVL 0.134 ha^{-1}.

The actuarial insurance premium for cereal crop of Category 3 with the coverage of 100% is 3.779, which is 28 times bigger than the actuarial insurance premium for cereal crop with the insurance coverage of 90%. Representatives of Category 2 are most exposed to risk. This is a group of producers, who would be most willing to purchase insurance. If the insurance coverage of cereal crop of the cereal producers of this category is 90%, the actuarial cereal crop insurance premium is 0.868 LVL ha^{-1}. The result is dramatically different if the insurance coverage is 100%. In this case, the actuarial insurance premium for Category 2 is 6.222 LVL ha^{-1}.

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Anotācija

Lauksaimnieciskā ražošana pakļauta dabas risku ietekmei, kā rezultātā katru gadu lauksaimniecības produkcijas ražotāji cieš zaudējumus. Valsts no saviem līdzekļiem lauksaimniecības produkcijas ražotājiem subsīdijās atlīdzina zaudējumus vidēji gadā 2.1 milj. latu apmērā. Kopš 2000. gada valsts Zemkopības ministrijas iedibinātās augkopības nozaru riska apdrošināšanas shēmas ietvaros subsidē personas, kuras nodarbojas ar kultūraugu audzēšanu, 50% apmērā no apdrošināšanas prēmijas izmaksām. Taču nav izteikta pieprasījuma pēc graudaugu apdrošināšanas pakalpojuma, jo zaudējumi tiek kompensēti no valsts līdzekļiem bez jebkādām saistībām un iemaksām no zemnieku puses un nav arī graudaugu sējumu apdrošināšanas pakalpojuma piedāvājuma no apdrošināšanas sabiedrību puses. Lauksaimnieciskās ražošanas (sistemātisko) risku vadībā valsts līdzdalības nepieciešamība vēsturiski apstiprinājusies gan ES dalībvalstīs, gan arī citās valstīs. Eiropas Savienībā graudaugu ražas risku vadība notiek divos līmeņos: valdības ārkārtas fondi (*ad hoc*) un privātā apdrošināšana. ES un citu valstu pieredze rāda, ka valsts un privātā sadarbība iespējama abos līmeņos un dažādās proporcijās attiecībā uz atlīdzinātiem zaudējumiem. Eiropas Savienības līmenī ir noteiktas konsekvences un izteiktas prasības valdības ārkārtas fondu veidošanai.

Lauksaimniecības risku apdrošināšanas problēmu risinājumus piedāvā Eiropas Komisijas regulas. Izmantoti arī Latvijas un citu valstu pēdējo gadu lauksaimniecības risku vadības pieredzes pētījumu publicēto materiālu rezultāti. Taču šajās publikācijās nav atrodami lauksaimniecības risku un to apdrošināšanas metodiskie vai citādi risinājumi. Pētījuma aktualitāte saistīta ar to, ka nav pieejama ražas zaudējumu sistemātiska statistikas datu bāze, līdz ar to ir izveidots nepieciešamais jaunais modelis ražas risku apdrošināšanas pakalpojumam.

Hordein Diversity in Spring Barley Genotypes Related to Crude Protein Content
Hordeīna daudzveidības izvērtējums vasaras miežu genotipiem saistībā ar kopproteīna saturu graudos

Mara Bleidere, Ilze Grunte
State Stende Cereal Breeding Institute
Valsts Stendes Graudaugu selekcijas institūts
email: Maara.Bleidere@stendeselekcija.lv

Abstract. The aim of the study was to assess the diversity of hordein banding patterns in different spring barley genotypes (covered, hulless, two-row, and six-row) and to identify the relation of hordein patterns and hordein polypeptide bands with total protein content. The study was carried out at the State Stende Cereal Breeding Institute from 2004 to 2006. On the basis of sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), 5 D hordein, 16 C hordein, and 28 B hordein banding patterns were detected. In total, 26 hordein polypeptide bands were recognized. Cluster analysis based on hordein patterns classified spring barley genotypes into three groups, and two of them significantly differed in crude protein content. Association was found between definite hordein patterns and crude protein content. There were found five covered varieties with identical hordein banding patterns but with varied crude protein content (111.9 to 154.3 g kg^{-1}). The patterns for these genotypes were distinctly different in the intensity and density of the color of hordein polypeptide bands, especially in C hordein. Among all the genotypes screened, 10 hordein polypeptide bands revealed significance in identifying of genotypes with definite crude protein.
Key words: *Hordeum vulgare,* electrophoresis, hordein diversity, crude protein.

Introduction

The research on new resources of variability and a better knowledge of genetic diversity existing within the available material is of particular interest in different types of barley.

Usually about 40% of the total nitrogen of mature grain is present in the storage protein fraction, termed hordein (Shewry, 1995). In barley, this alcohols-soluble protein, or prolamin, is of poor nutritional quality, notably deficient in the essential amino acid lysine, and is responsible for the poor quality of the whole grain when used as a diet for monogastric animals (Molina-Cano et al., 2000).

Hordein can be classified into three groups of polypeptides called B, C, and D hordeins based on their electrophoretic mobility (Shewry, Tatham, 1990). The B and C fractions account for 70-80% and 10-12%, respectively, of the total hordein, while the D fractions are a minor component (about 5%). Each group of hordein is synthesized from a family of structural genes. These different hordeins differ in molecular weight and amino acid composition (Shewry, 1995). The major B hordeins and C hordeins are encoded by the multigenic loci *Hor2* and *Hor1*, respectively, both located on the short arm of chromosome 5. The D hordein is characterized by high glycine, proline and glutamine content. Their synthesis is encoded by the *Hor3* locus located on the long arm of chromosome 5 (Shewry, Tatham, 1990).

The regulation of grain storage protein synthesis is available for study because these proteins are generally specific to endosperm tissues, the expression of their genes is developmentally regulated, and the proteins have been extensively characterized. Hordeins are largely tolerant to mutations and are selected neutrally. Hordeins show high intergenotypic variation and have been used as a genetic marker (Shewry, 1995).

Any complete study of protein will require methods for protein separation. Diversity in the hordein family has made the analysis of these fractions very useful in evolutionary studies (Yin et al., 2003), for variety identification, and for analyzing the genetic diversity in collections (Shewry et al., 1978). Among biochemical techniques, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) is a system which is most widely used for separating proteins and for studying the biochemistry and genetics of hordein to describe genetic structure of crop germplazm. This diversity can be explained through differences within the B and C hordeins that occur between varieties, as well as grain protein levels and environments (Molina-Cano et al., 2001). SDS-PAGE of hordein has been used to characterize covered barley varieties from Brazil (Echart-Almeida, Cavali-Molina, 2000), Tibet (Yin et al., 2003), United Kingdom (Shewry et al., 1978), Yugoslavia (Radovic, Vapa, 1996), and Lithuania (Leistrumaite, Paplauskiene, 2007). Hordein polymorphism in relation to agromorphological traits was also analyzed for hulless barley collection (Atanassov et al., 2001). In these studies several hordein patterns have been fractionated.

Great effort has been made to clarify the relationship between hordein fractions and malting quality (Shewry et al., 1980; Riggs et al., 1983). Peltonen et al. (1994) studied the effect of B, C, and D hordeins on malting quality of northern European barleys and found that the B fraction had some effect on malting quality through changing adjusting diastatic power. Molina-Cano et al. (2000) suggested that both B hordeins and β-glucans were relevant to water uptake. The B and C hordeins have been shown to be associated also with milling energy where increase in C hordein along with a decrease in β-glucan corresponded to a decrease in milling energy, which characterizes such a trait as grain hardness (Molina-Cano et al., 1995).

In the present study, SDS-PAGE analyses of hordein polypeptide patterns were used to analyze genetic diversity of the material of different origin characterized with a wide range of variability in crude protein content. The aim of the study is to assess the diversity of hordein banding patterns in the different spring barley genotypes and to identify the relation of hordein patterns and hordein polypeptide bands with total protein content.

Materials and Methods

There were chosen 52 barley genotypes that represent a broad range of germplazm (two-row, six-row, covered, and hulless) of different origin. Thirty-eight genotypes of covered spring barley, from which 28 with two-row and 10 with six-row ear types, and 15 hulless genotypes were used in this study. Only two-row hulless genotypes were included in this investigation (Table 1).

The barley genotypes were grown at the State Stende Cereal Breeding Institute from 2004 to 2006. The soil at the site was sod-podzolic sandy loam, humus content – 12-15 mg kg^{-1}, soil pH – 6.0-6.7, pre-crop – potatoes, content of available phosphorus P_2O_5 – 201-215 mg kg^{-1}, and available potassium K_2O – 124-147 mg kg^{-1}. Plot size was 2 m^2, two replicates, seeding rate – 400 germinated seeds per m^2. The plots were fertilized with $N_{60}P_{35}K_{50}$ + S_{42} kg ha^{-1}.

Crude protein content (N × 6.25) was determined by the Kjeldahl method (LVS 277/Latvian State Standard). According to results of the previous investigation, all types of barley genotypes included in this study cover a wide range of variation in crude protein content (Bleidere, Grunte, 2008). Analysis of variance suggested that crude protein in this material was more strongly ($p<0.01$) affected

Table 1

Spring barley genotypes used in the study

Barley type	n	Country of origin: No. of genotype
Two-row, covered	27	Latvia: (1)’Abava’, (2)’Ansis’, (3)’Balga’, (4)’Gate’, (5)’Idumeja’, (6)’Klinta’, (7)’Kristaps’, (8)’Linga’, (9)’Malva’, (10)’Rasa’, (11)’Ruja’, (12)’Sencis’; Australia: (13)’Grimmet’; Austria: (14)’Austrian early’, (15)’Landsorte Aus Tirol’; Chile: (16)’379’; Denmark: (17)’Lysimax’; Germany: (18)’Annabell’, (19)’Danuta’, (20)’Hanka’, (21)’Justina’, (22)’Polygena’; Great Britain: (23)’Century’, (24)’Cork’; Hungary: (25)’Hatvani 45/25’; Portugal: (26)’Lechtaler’; Sweden: (27)’Primus II’
Six-row, covered	10	Latvia: (28)’Druvis’; Bolivia: (29)’Valluno’; Denmark: (30)’Colsess IV’, (31)’July’; FIR Macedonia: (32)’IV/192’; Mexico: (33)’Puebla’, (34)’Zoapila’; Nepal: (35)’B90A’, (36)’RNB-367’; North Korea: (37)’Chosen’
Two-row, hulless	15	Latvia: (38)’L 302’; Canada: (39)’CD Candle’, (40)’Gainer’, (41)’McGwire’; the Czech Republic: (42)’KM 2084’; Guatemala: (43)’2474’, (44)’Clho 7799’; Italy: (45)’Orzo Nudo di Altamura’; Japan: (46)’Sumire Mochi’, (47)’Wanubet’; Lithuania: (48)’X-4’; Russia: (49)’C.P.I. 22817’; Sweden: (50)’SW 1291’; Turkistan: (51)’10250’; USA: (52)’Merlin’

by the genotype (Bleidere, 2008). Three-year mean values of crude protein are used in the results of this investigation.

Hordein analysis for each genotype was done from the grain harvest of 2006 in two replications. Barley flour sample for each replication was obtained by crushing grains from one single ear and sieving them through a 0.5 mm sieve. Barley hordein was extracted 1 h at 60 °C by shaking 0.5 g of barley flour with 1.5 mL of extraction buffer 3 times (55% (v/v) propan-2-ol, 2% (v/v) β-mercaptoethanol, 1% acetic-acid). After centrifugation (10’ at 14000 rpm), 90 μL of gel-loading buffer (50 mM Tris × Cl (pH 6.8); 100 mM dithiothreitol; 2% SDS; 0.1% bromophenol blue; 10% glycerol) were added to 10 μL of supernatant. Hordeins were separated by vertical sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). The stacking gel layer contained 5% of acrylamide, but separating gels contained 10% of acrylamide. The gels were run for 2 h at a 100 mA constant current, then fixed in 50% methanol and 12% acetic acid solution, stained with Coommassie Brilliant Blue G-250, washed in 17% methanol and 3% glycerol solution, and photographed by digital imaging system DigiGenius (*Syngene*). Apparent molecular weights of single polypeptide bands of B, C, and D hordeins were studied by determining their molecular weight (MW) in kilodaltons (kDa) by *GeneTools* gel analysis software (*Syngene*) according to marker proteins β-galaktosidase (MW 116.0 kDa), albumin (66.2 kDa), ovalbumin (45.0 kDa), and lactate dehidrogenase (35.0 kDa) (*Fermentas*). The varieties ‘Sulky’, ‘Atem’, ‘Nathalie’, and ‘Iris’ were used as checks that correspond to the patterns of the D hordeins group. The variety ‘Igri’ was run as a control in all gels.

The results of SDS-PAGE for D, C, and B hordeins are shown in diagrammatic manner (Leistrumaite and Paplauskiene, 2007). The hordein banding patterns were determined by scoring the presence and absence of all examined bands. The bands were numbered according to their electrophoretic mobility. The scores were given as 1 for the presence, and 0 for the absence of a band. The presence and absence of bands were entered in the binary data matrix. The crude protein and SDS-PAGE data were analyzed for the comparison of means for quantitative traits using t-test of two samples assuming unequal variance. By elaborating a pairwise similarity matrix using the presence (1) or absence (0) of B, C, and D hordein banding patterns, the dendrogram was constructed by cluster analysis obtained from Euclideant distance and clustered by Neighbor-joining method using software STATISTICA. Coefficient of variation (V%) was calculated to characterize the variation in crude protein for genotypes belonging to a definite hordein banding pattern.

Results and Discussion

Hordein polypeptides have been separated by SDS-PAGE in three fractions which were D, C, and B. Different analysis have indicated that C hordein can be separated into polypeptides with molecular weight ranging between 67 and 86 kDa, B hordein – between 30 and 60 kDa, and D hordein – with molecular weight of about 105 kDa (Shewry et al., 1978; Heisel et al., 1986). Electrophoretic data showed that in this study the molecular weight of the analyzed polypeptides ranged from 35 to 94 kDa. Molecular weight for D hordein polypeptides ranged from 82 to 94 kDa, for C hordein polypeptides – from 49 to 66 kDa, and for B hordein polypeptides – from 35 to 46 kDa. Hordein fractions separated from a range of varieties using SDS-PAGE showed extensive variation in banding patterns within each hordein groups.

There were 5 different banding patterns consisting of 4 bands for D hordein group (Fig. 1). In other studies it was found that the D hordein of European barley varieties consists of single component of polypeptide, but two or three components have been reported in other varieties (Leistrumaite, Paplauskiene, 2007).

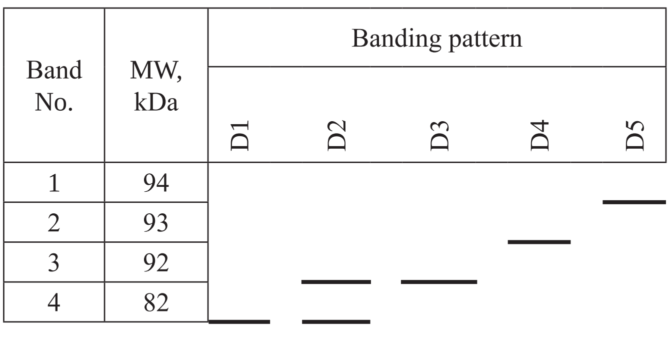

Fig. 1. Diagrammatic representation of SDS-PAGE patterns of D hordein in spring barley genotypes.

Distribution of different types of barley genotypes in each group of D banding patterns is presented in Table 2. Only three six-row barley genotypes (29) 'Valluno', (30) 'Colsess IV' and (35) 'RNB-367' had banding pattern D1 consisting of a single band with molecular weight of 82 kDa.

The D hordein pattern 2 formed from two bands had one covered and three hulless two-row varieties. Most of the varieties from different types of barley belong to hordein banding pattern D3. There were differences in crude protein content between varieties characterized by different banding patterns of D hordein. The lowest crude protein content was for genotypes belonging to the D hordein banding pattern 4 (131.6 g kg^{-1}; V%=4). The highest average crude protein (160.9 g kg^{-1}) was for genotypes with D5 hordein pattern. To D1, D2, and D3 patterns belonged varieties with a wide range of crude protein content, which was indicated by the coefficient of variation – 13, 23, and 14%, respectively. Covered two-row genotypes had 4 bands of D hordein, six-row genotypes had 3 bands, but hulless genotypes – 4 bands of D hordein.

The C hordein group had more polypeptide bands and patterns than D hordeins had. There were determined 16 banding patterns that totally consisted of 11 bands in the C hordein group for different types of barley (Fig. 2).

These 16 banding patterns were formed from 2 to 5 bands. In the C hordein group, 10 different bands and 7 banding patterns were found for 27 covered two-row varieties, 7 bands and 7 banding patterns were found for 10 six-row barley genotypes, and 8 different bands and 7 banding patterns – for 15 hulless genotypes (Table 3). Majority of the varieties

Table 2

D hordein patterns in different types of barley genotypes in relation to crude protein content

Banding pattern*	Barley genotypes, No.			Crude protein, g kg^{-1}	V, %
	covered, two-row	covered, six-row	hulless, two-row		
D1	–	–	38; 40; 48	154.4	13
D2	17	29; 30; 35	–	151.1	23
D3	1; 2; 4; 6; 7; 9; 10; 11; 12; 14; 15; 16; 18; 19; 20; 21; 22; 23; 24; 25; 26; 27	28; 31; 34	39; 41; 43; 44; 45; 50; 51; 52	135.8	14
D4	3; 5; 8	–	42; 47	131.6	4
D5	13	32; 33; 36; 37	46; 49	160.9	11

* banding pattern according to Fig. 1.

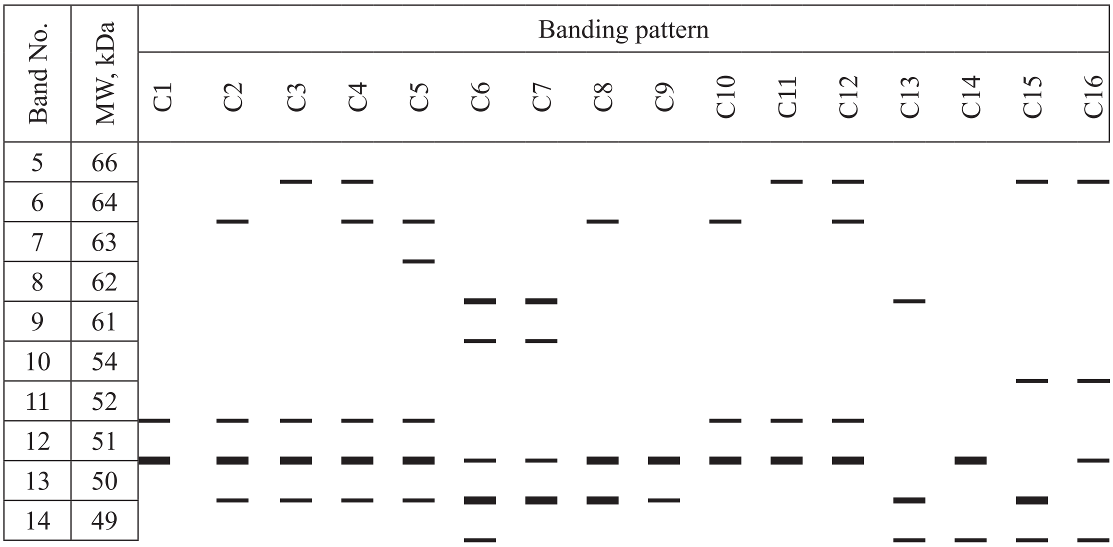

Fig. 2. Diagrammatic representation of SDS-PAGE patterns of C hordein in spring barley genotypes.

from all types of barley were characterized by the C2 and C4 hordein patterns.

Within C hordein, the C2 and C4 hordein patterns were diverse regarding the protein content which was demonstrated by the coefficient of variation (11% and 12%, respectively). Covered two-row genotypes with a comparatively lower average crude protein content (114.0 to 121.7 g kg^{-1}) belong to C11, C12, and C13 hordein banding patterns. Other 7 six-row barley varieties were characterized by different C hordein banding patterns. Six of them had heightened protein content (149.3 to 196.2 g kg^{-1}). C hordein patterns C8 and C16 were specific only for particular hulless genotypes. All hulless genotypes with hordein patterns C5 and C16 had a comparatively high crude protein content – with mean values of 166.2 and 164.4 g kg^{-1} (coefficient of variation – 3% and 5%, respectively).

In total, in B hordein group, 28 hordein banding patterns with 12 polypeptide bands were discriminated. The tested covered two-row barley genotypes were found to possess 12 hordein banding patterns formed from 12 hordein polypeptide bands (Fig. 3, Table 4).

Nine varieties from this type of barley were characterized by B3 hordein banding pattern. All these varieties had low crude protein content (mean value – 122.4 g kg^{-1}; coefficient of variation – 5%). Five covered varieties belonging to B13 hordein banding pattern were diverse regarding crude protein content. The rest of covered varieties had different B hordein banding patterns. For covered six-row and hulless two-row genotypes there was a wide range of diversity regarding B hordein banding patterns that totally differed from each other and also from the covered two-row ones. There were 10 hordein banding patterns which consisted of 9 polypeptide bands found within 15 hulless barley. Only B10 and B24 hordein banding patterns were the same for two two-row and six-row varieties. This result shows that barley varieties included in this study and demonstrating a wide range of variability in crude protein content had high polymorphism of B hordein banding patterns.

The results of polymorphism of different barley genotypes regarding hordein banding patterns are summarized in a dendrogram (Fig. 4).

There were several genotypes with an identical hordein banding pattern (linkage distance 0) eliminating nine similarity groups from 2 to 5 varieties in each group. This was observed not only

Table 3

C hordein patterns in different types of barley genotypes related to crude protein content

Banding pattern*	Barley genotypes, No.			Crude protein, g kg^{-1}	V, %
	covered, two-row	covered, six-row	hulless, two-row		
C1	–	–	46	173.0	–
C2	1; 6; 13; 14; 17; 25	29; 31; 34	47; 49; 50	142.7	11
C3	–	32; 35	–	150.7	12
C4	3; 8; 9; 11; 16; 18; 21; 23; 26; 27	–	40; 42	130.1	12
C5	15	–	38; 45; 48	166.2	3
C6	–	37	–	155.1	–
C7	–	36	–	196.2	–
C8	–	–	39; 41	127.9	5
C9	24	–	52	123.4	8
C10	–	30	–	151.9	–
C11	2; 4; 12; 20	–	–	121.7	4
C12	5; 19	–	–	132.7	–
C13	22	28	–	114.3	3
C14	–	33	–	149.3	–
C15	7; 10	–	–	120.2	4
C16	–	–	43; 44; 51	164.4	5

*banding pattern according to Fig. 2.

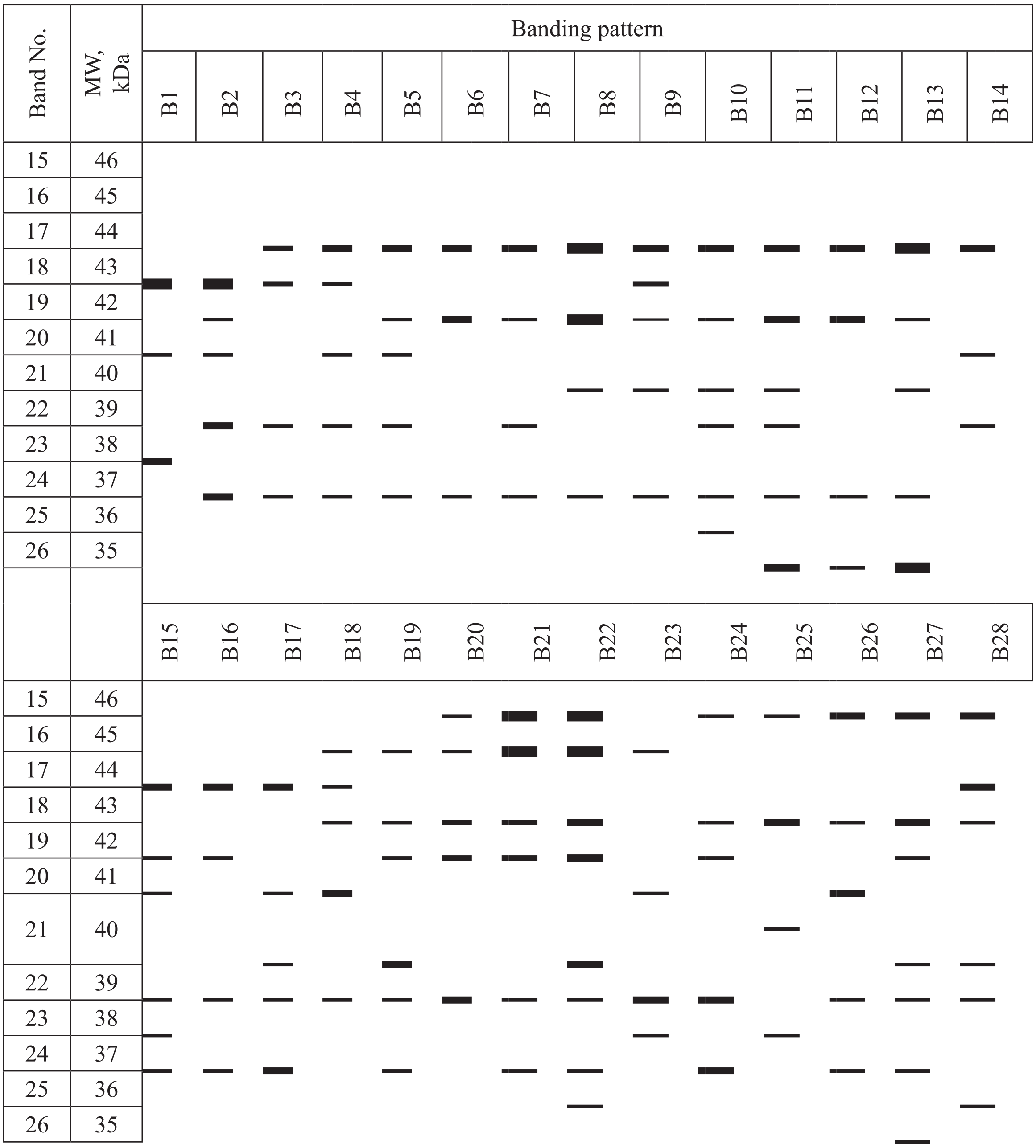

Fig. 3. Diagrammatic representation of SDS-PAGE patterns of B hordein in spring barley genotypes.

between the same types of barley but also between different types of barley (two-row, six-row, and hulless). For example, the covered barley variety (3) 'Balga' had the same hordein banding pattern as the hulless line (42) 'KM 2084', six-row variety (28) 'Druvis' had the same hordein banding pattern as the two-row variety (22) 'Poligena', and covered two-row barley variety (1) 'Abava' had identical hordein pattern with hulless genotype (50) 'SW 1291'. In general, these varieties exhibited also similar crude protein content. Also G. Liu et al. (2000) in his study could not distinctly separate spring and winter barley varieties, as well as 2-row and 6-row barley varieties into two groups by using protein electrophoresis. The hordein polymorphism described in hulless collection was quite similar to that generally observed in covered barley (Atanassov et al., 2001). The created dendrogram allowed observing structuration of diversity. Relatedness between several varieties was found in hordein banding patterns.

Barley genotypes clustered on linkage distance 1.4 are genotypes which have similarity with one or two of the hordein banding pattern groups (D, C, or B). These genotypes are mainly of European origin,

Table 4

B hordein patterns in different types of barley genotypes related to crude protein content

Banding pattern*	Barley genotypes, No.			Crude protein, g kg^{-1}	V, %
	covered, two-row	covered, six-row	hulless, two-row		
B1	14	–	–	170.7	–
B2	–	–	46	173.0	–
B3	4; 7; 9; 10; 11; 12; 20; 23; 24	–	–	122.4	5
B4	–	–	45	164.1	–
B5	–	–	39	120.6	–
B6	1; 13	–	41; 50	137.2	8
B7	6	–	–	136.7	–
B8	–	35	–	159.3	–
B9	17	–	–	111.6	–
B10	22	28	–	114.3	4
B11	–	34	–	157.5	–
B12	5	–	–	132.7	–
B13	16; 18; 21; 26; 27	–	–	137.2	13
B14	–	–	40	133.0	–
B15	–	33	–	149.3	–
B16	–	–	47; 52	134.0	2
B17	–	–	49	155.9	–
B18	–	29	–	144.8	–
B19	–	37	–	155.1	–
B20	2; 3; 19	–	42	123.7	6
B21	25	–	–	165.7	–
B22	–	36	–	196.2	–
B23	8	–	–	129.8	–
B24	15	31	–	161.4	8
B25	–	32	–	142.1	–
B26	–	–	43; 44; 51	164.4	5
B27	–	–	38; 48	165.1	3
B28	–	30	–	151.9	–

*banding pattern according to Fig. 3.

which indicates genetic similarity between them. These genotypes originated two clusters according to hordein banding patterns. Cluster I combined only the covered two-row barley genotypes mainly with a comparatively lower crude protein content (127.3 g kg^{-1}). Cluster II grouped genotypes with a heightened crude protein content (145.1 g kg^{-1}). According to t-test, the difference of means between these two clusters regarding crude protein was significant ($p<0.01$). Cluster III grouped genotypes with unique hordein banding patterns. These barley genotypes are more distant as to the origin of material. To cluster III mostly belong the hulless and six-row covered barley genotypes included in this investigation and they exhibited a heightened grain crude protein content. Also for high lysine barley variety (17) 'Lysimax' the hordein banding pattern differed from other genotypes.

Nevertheless, in cluster I there were found five covered varieties with identical hordein patterns (D3C3B13) but with different crude protein content. When analyzing SDS-PAGE of hordein fractions it was found that the patterns for these genotypes distinctly differed in color intensity and density of hordein polypeptide bands (Fig. 5). For barley genotypes (16) '379', (26) 'Lechtaler' and (27)

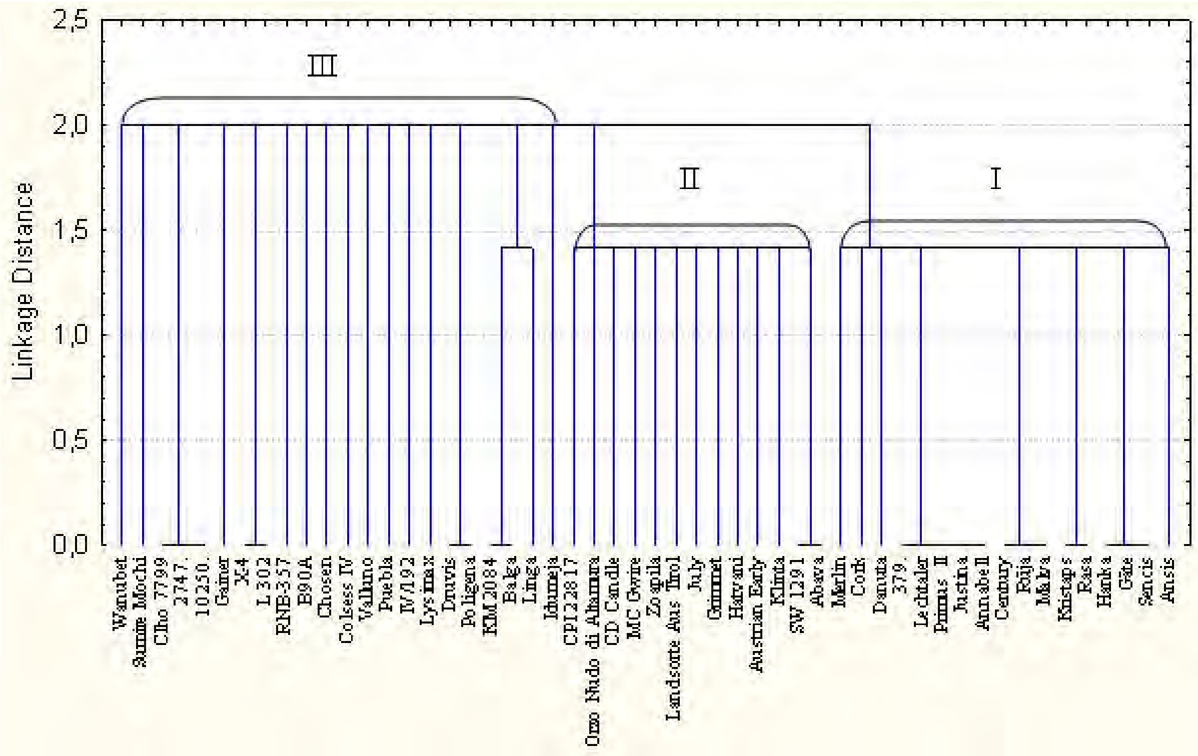

Fig. 4. Dendrogram of 52 different types of barley obtained from Euclideant distance, based on hordein banding patterns and clustered by the Neighbor-joining method.

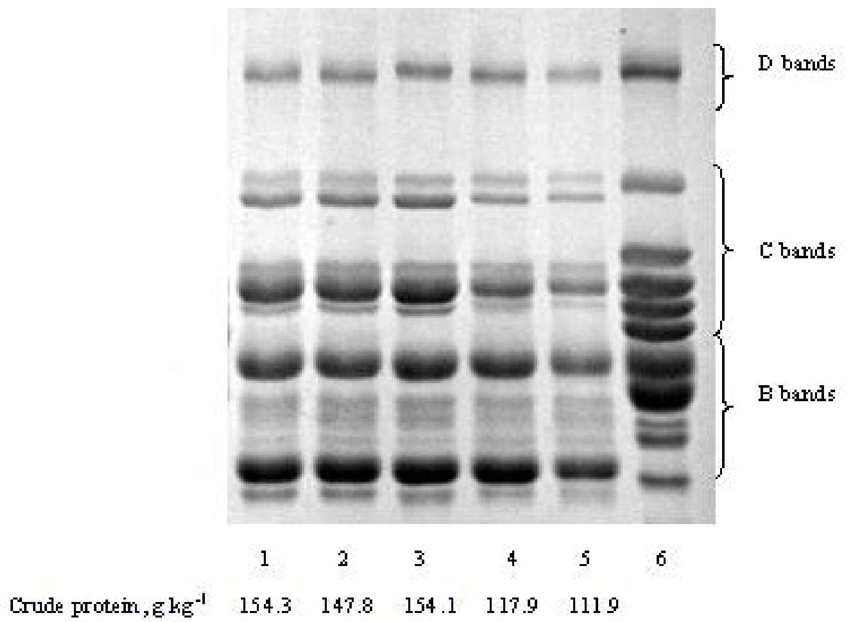

Fig. 5. Spring barley genotypes similar in hordein banding patterns and differing in crude protein content: (1) 'Primus II'; (2) 'Lechtaler'; (3) '379'; (4) 'Annabell'; (5) 'Justina'; (6) 'Igri' (control variety).

'Primus II' which crude protein content according to three-year average was 154.3, 147.8 and 154.1 g kg^{-1}, respectively, the bands were more dense and more intensively colored than for the varieties (18) 'Annabell' and (21) 'Justina' with a significantly lower crude protein content (117.9 and 119.9 g kg^{-1}, respectively). This was found for all hordein fractions but especially for C hordein. According to

Table 5

Associations between crude protein content and single hordein polypeptide bands

Band	Presence of band		Absence of band		Mean difference[1]
	number of genotypes	crude protein, g kg^{-1}	number of genotypes	crude protein, g kg^{-1}	
D hordein					
1	7	160.9	45	137.0	23.9**
2	5	131.7	47	141.1	9.4*
3	37	136.3	15	149.9	13.5*
4	7	147.3	45	139.1	8.2
C hordein					
5	21	128.5	31	148.2	19.7**
6	34	140.5	18	139.5	1.1
7	7	165.7	45	136.9	29.2**
8	4	144.9	48	139.8	5.2
9	2	175.6	50	138.8	36.8
10	5	146.7	47	139.5	7.2
11	40	140.4	12	139.7	0.7
12	48	142.1	4	117.2	24.9**
13	41	139.6	11	142.6	3.0
14	8	140.8	44	140.1	0.7
B hordein					
15	16	151.7	36	135.1	16.6**
16	9	142.9	43	139.7	3.3
17	36	135.2	16	151.5	16.3**
18	29	143.1	23	139.1	4.0
19	30	143.1	22	136.7	6.4
20	16	149.9	36	135.3	14.6**
21	17	145.6	35	137.6	7.9
22	38	149.3	14	137.5	11.8
23	5	139.2	47	140.3	1.2
24	41	141.9	11	133.7	8.2*
25	5	141.5	47	140.1	1.4
26	10	145.5	42	139.0	6.6

[1] *, ** – mean difference significant at the 0.05 and 0.01 level respectively.

the literature, changes in total grain protein content mainly determine the changes in hordein fraction (Shewry, 1995). The accumulation of hordein during grain development is genetically determined and depends on hordein genes expression during grain development stages (Kirkman et al., 1982), which means that for these high-protein genotypes heightened accumulation of grain nitrogen during grain filling is determined genetically.

As indicated by Dailey et al. (1988), the main differences in the increasing of the relative amount of hordein fractions are as visible changes in relative bands' intensity and loss of band sharpness in B hordein region, and replacement of the C polypeptide patterns with a single band. This changes the ratio of hordein B to C, which negatively correlates with the total protein content (Kirkman et al., 1982; Molina-Cano et al., 2001). Therefore analyzing the hordein profile types for different varieties grown under the same growing conditions, also the density of bands that could give information about differences in crude protein content of a definite genotype is important to be considered for genotypes with similar hordein banding patterns.

Summary of significance of protein subunits for detecting associations between crude protein content and single hordein polypeptide bands by comparison of means using t-test is given in Table 5.

On the basis of combination of various banding patterns, 26 hordein bands were recognized among all the genotypes screened. There was great genotypic variation in the bands of C and B polypeptides, which was determined also in other studies. Shewry et al. (1980) described 21 and 8 different bands of B and C hordein, respectively, in the collection of 183 barley varieties and landraces, whereas Nielsen and Johansen (1986) described 12 C hordein bands and 15 B hordein bands in the collection of 66 varieties commonly grown in Denmark. In the study of Liu et al. (2000), in total, 26 hordein polypeptide bands were observed. The hordein banding patterns of each genotype consisted of 7 to 14 bands. All the 26 bands were polymorphic and, out of these, 10 exhibited significant association with crude protein content in the t-test. The mean value of crude protein increased significantly at the presence of bands 1, 7, 12, 15, 20, and 24, and at the absence of bands 2, 3, 5, and 17. The present study revealed that these protein polypeptide bands could be used in the screening of barley breeding material according to the crude protein content.

As the hordein electrophoresis is possible to be performed also from a single seed, the information about hordein polymorphism and variation of traits of interest considered together would help the breeder obtain useful information not only about genetic diversity of material but also about variability of the crude protein content of genotype already in the early stage of breeding process when the amount of grain is not sufficient for deep evaluation of grain quality. The use of molecular markers to locate the genes controlling quantitative traits, also crude protein, has been considered important in the analysis of such traits. The amount of information provided by marker-based research will depend on the type and number of markers and their linkage relationships. The frequency of these markers based on protein polypeptides for quantitative traits are not commonly observed since these markers based on protein alleles would tend to be simply inherited, whereas grain quality traits such as crude protein are polygenic in nature.

The results of the present study are encouraging for locating the factors that influence expression of crude protein. Hordein polymorphism and variation of traits of interest considered together would indisputably help the breeder to diversify the sources of germplazm and optimize the choice of parents to be used in crossing programs. The breeders can be sure that hordein profile will remain unchanged through different environments. However, the conclusions drawn in this study could be specific to the samples investigated and the environment in which this trait was recorded. It is because of existence of possible variation of crude protein due to genotype and environment interaction. This condition could change associations between single hordein polypeptide band and definite protein level found in this investigation. It would be desirable to continue validation of the obtained results in the next investigations including more barley genotypes characterized with wider variation in grain crude protein.

Conclusions

1. On the basis of SDS-PAGE, 5 D hordein, 16 C hordein, and 28 B hordein banding patterns with 27 bands were discriminated.
2. Cluster analysis based on hordein banding patterns classified three groups of genotypes. Two of them significantly ($p<0.01$) differed in mean crude protein content. Association was found between definite hordein banding patterns and crude protein content.
3. There were found five covered two-row varieties with identical hordein patterns but with varied crude protein content (111.9 to 154.3 g kg^{-1}). The patterns of these genotypes distinctly differed in the intensity of hordein polypeptide, especially in C hordein.
4. On the basis of combination of various banding patterns, 26 hordein polypeptide bands were recognized among all the screened genotypes; out of these, 10 exhibited significant association with grain crude protein content. The present investigation showed that association between biochemical variation and crude protein content could be used for screening of the breeding material and for future exploitation in barley improvement.

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Anotācija

Pētījumu veica Valsts Stendes Graudaugu selekcijas institūtā no 2004. līdz 2006. gadam. Izmantojot nātrija dodecilsulfāta (SDS)-poliakrilamīda gela elektroforēzi, novērtēja rezerves proteīna (D, C un B hordeīna) daudzveidību 52 dažādas izcelsmes vasaras miežu genotipiem (divkanšu, daudzkanšu, plēkšņainajiem, kailgraudu) saistībā ar kopproteīna saturu graudos. Pētījumā iekļautajiem genotipiem konstatēja 26 hordeīna polipeptīdu joslas, kas veidoja 5 D hordeīna, 16 C hordeīna un 28 B hordeīna polipeptīdu joslu profilus. Atrastas būtiskas atšķirības pēc kopproteīna satura graudos starp noteiktiem D, C un B hordeīnu joslu profiliem. Pamatojoties uz datiem par hordeīna joslu profiliem, klāsteru analīzē genotipi sadalījās trīs grupās. Starp divām grupām konstatēta būtiska atšķirība pēc kopproteīna satura graudos. Daļai no pētījumā iekļautajām šķirnēm konstatēts identisks hordeīna joslu profils, bet atšķirīgs kopproteīna saturs graudos. Hordeīna polipeptīdu joslas šīm šķirnēm atšķiras pēc krāsas intensitātes un blīvuma, īpaši C hordeīnā. Pētījumā konstatēts, ka 6 hordeīna polipeptīdu joslu klātbūtne un 4 hordeīna polipeptīdu joslu trūkums būtiski ietekmē kopproteīna saturu graudos. Dati par hordeīna daudzveidību ir izmantojami selekcijas izejmateriāla ģenētiskās daudzveidības novērtēšanā, kā arī selekcijas līniju graudu kopproteīna satura izvērtēšanā selekcijas sākumposmā.

Raksturojošās kontaktleņķa vērtības un virsmas enerģijas noteikšana koksnei
Determination of the Characteristic Value of the Contact Angle and Surface Energy for Wood

Tatjana Rubina
LLU Matemātikas katedra
Department of Mathematics, LLU
e-mail: Tatjana.Zukova@inbox.lv
Egils Stalidzāns
LLU Datoru sistēmu katedra
Department of Computer Systems, LLU
e-mail: Egils.Stalidzans@llu.lv
Fredijs Dimiņš, Pēteris Kūka, Andris Morozovs
LLU Ķīmijas katedra
Department of Chemistry, LLU
e-mail: Andris.Morozovs@llu.lv

Abstract. The roughness and structural or compositional heterogeneity of wooden surface causes significant differences in the contact angle. Wooden surface does not correspond to all mentioned prerequisites to gain a stable value of the contact angle. Therefore during measurements one can observe exponential decrease in the contact angle value until the drop fully soaks into the wood. Assuming that rapid contact angle changes are consequences of hydrodynamic processes, a hypothesis can be advanced that the characteristic value of the contact angle is the extrapolation of the linear period of contact angle changes in time to the moment of drop forming. Modelling a drop with constant contact surface with wood and constant speed of the change in the volume suggests that at the starting period the changes have to be close to linearly decreasing ones. Thus it is assumed that characteristic value of the contact angle is the y-intercept of linear approximation of the linear period of contact angle dynamics excluding nonlinear changes in the contact angle. A methodology is developed to calculate the characteristic contact angle excluding the influence of nonlinear part that corresponds to transition processes. It is assumed that nonlinear part of measurements is the part that does not fit into the one standard deviation wide corridor around the linear approximation of all the set of measurements. The influence of nonlinear part on the contact angle using different test liquids decreases in the following sequence (from high to low): formamide>ethylene glycol>water≅diiodomethane. To simplify the measurement procedure it is proposed to start the measurements when nonlinear processes are finished. The measurements can be started (influence of non-linear part has ended) the soonest in case of formamide on non-sanded wood transversally to the fibre (after 4.4 s), and the latest in case of diiodomethane on sanded wood transversally to the fibre (after 40.0 s). Replacing linearly approximated values of the contact angle (θ) with the corrected ones (θ'), the surface tension (σ_{sb}) calculated after acid-base method increases by 1-2%, and in case of Owens-Wendt-Rabel and Kaelble method – by 2-6%.
Key words: wood, contact angle, sessile drop, surface energy.

Ievads

Mūsdienās būtiska ir koksnes resursu racionāla izmantošana, tāpēc praktiski visa kokapstrāde ir saistīta ar līmju un pārklājumu izmantošanu. Koksnes izstrādājuma lietošanas laikā pārklājumus nākas atjaunot to samērā īsā kalpošanas laika dēļ. Līmējuma vai pārklājuma noturība ir atkarīga no līmes vai pārklājuma kārtiņas uzklājuma vienmērīguma un no tās saistības ar koksni, ko nodrošina labas adhēzijas izveidošanās.

Koksne ir porains, caurlaidīgs, higroskopisks, anizotrops, bioloģisks materiāls ar ārkārtēji lielu ķīmisko dažādību un fizikālo īpašību mainīgumu. Līmējuma vai pārklājuma saistību ar koksni nodrošina ļoti daudzi mainīgie lielumi, no kuriem galvenie ir: a) līmes vai pārklājuma īpašības; b) koksnes īpašības;

c) ekspluatācijas apstākļi. Koksnes īpašību atšķirības starp vienas sugas atsevišķiem kokiem ir pietiekami nozīmīgas, lai visnotaļ izmainītu līmējuma vai pārklājuma izturību (Bowyer et al., 2003; Smith et al., 2003; Dinwoodie, 2000; Уголев, 2001).

Lai pētītu un prognozētu koksnes (Gérardin et al., 2007; Aydin, 2004; Gindl et al., 2004), kā arī sasmalcinātas koksnes vai tās šķiedras saturošu kompozītu (Qin, Holmbom, 2008; Gupta et al., 2007; Garcia et al., 2006) virsmas slapināšanos ar šķidrumiem, pēdējo desmit gadu laikā tiek izmantoti šķidruma un cietas virsmas veidotā kontaktleņķa (saukta arī par malas leņķi), ko veido pieskare piliena kontūrai saskares punktā ar cietu virsmu, mērījumi (1. att.). Kontaktleņķi galvenokārt nosaka ar divām metodēm: tieši mērot leņķi piliena kontūras pieskarei ar goniometru (piliena metode) (Qin, Holmbom, 2008; Gupta et al., 2007; Aydin, 2004; Gindl et al., 2004) vai mērot svara izmaiņu paraugam, to iegremdējot un izvelkot no šķidruma (Vilhelmī metode) (Gérardin et al., 2007; Garcia et al., 2006). Ar piliena metodi var noteikt gan statisko, gan dinamisko kontaktleņķi. Statisko kontaktleņķi mēra uz virsmas sēdošam, konstanta tilpuma pilienam. Dinamiskā kontaktleņķa mērīšanas laikā sēdoša piliena tilpumu palielina (augošais) vai samazina (dilstošais), vai arī ļaujot pilienam noripot pa slīpu virsmu un mērot kontaktleņķi piliena priekšā un aizmugurē. Sēdoša piliena un Vilhelmī metodei katrai ir savas priekšrocības un trūkumi. Kontaktleņķa mērījums ar piliena metodi raksturo slapināšanos ļoti mazam virsmas laukumam (2-10 mm^2), tādēļ, lai noskanētu visu virsmu, nepieciešams veikt daudz mērījumu. Savukārt Vilhelmī metodes trūkums ir tas, ka kontaktleņķa aprēķinam izmanto slapināšanas perimetru, kurš virsmas raupjuma dēļ ir lielāks par ģeometrisko un izmainās parauga iegremdēšanas un izcelšanas laikā koksnes uzbriešanas dēļ.

Neatkarīgi no lietotās metodes stabilas kontaktleņķa vērtības iegūšanai nepieciešams, lai pētāmā objekta virsma būtu līdzena, homogēna, necaurlaidīga un ķīmiski inerta attiecībā pret testa šķidrumu. Koksnes virsmas raupjums un strukturālā vai sastāva heterogenitāte izraisa ievērojamas kontaktleņķa atšķirības. Koksnes virsmai neīstenojas neviena no minētajām prasībām stabilas kontakleņķa vērtības iegūšanai, tāpēc mērījumu laikā novēro eksponenciālu kontaktleņķa vērtības samazināšanos, līdz piliens pilnībā iesūcas koksnē.

Koksnes porainās struktūras dēļ uz koksnes virsmas uzliktais piliens porās iesprosto gaisu, līdz ar to piliena robežvirsma ar koksni ir mazāka par piliena noklāto. Iesprostotā gaisa burbuļa robežvirsmas ar šķidruma pilienu virsmas spraigums atšķiras no koksnes un šķidruma robežvirsmas spraiguma, kas izmaina kontaktlenķi. Iesprostotais gaiss var izdalīties difūzijas ceļā caur šķidrumu vai caur koksni, kam nepieciešams laiks, kas atkarīgs no koksnes un šķidruma gāzu caurlaidības (Unsal et al., 2004, 2005). Šķidruma iesūkšanās koksnē samazina piliena tilpumu, un tā sekas ir kontaktleņķa samazināšanās.

Pieņemot, ka straujas kontaktleņķa izmaiņas ir hidrodinamisko procesu sekas, var izvirzīt hipotēzi, ka koksni raksturojošā kontaktleņķa vērtība ir leņķa izmaiņas laikā lineārā posma ekstrapolācija uz piliena veidošanās sākuma momentu.

Materiāli un metode

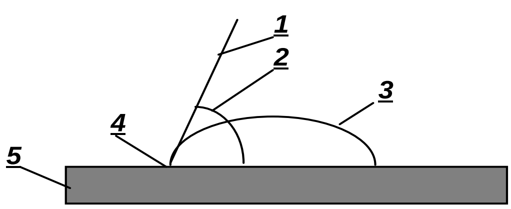
Materiāli

Priedes (*Pinus Sylvestris* L.) kodolkoksnes paraugus (15 × 25 × 50) mm un (20 × 100 × 100) mm (radiālā, tangenciālā un šķiedras virzienā) izzāģēja no dēļiem bez koksnes vainām. Paraugus kondicionēja 20 °C temperatūrā un 50% gaisa relatīvā mitrumā līdz konstantai masai.

Kontaktleņķa mērīšanai par testa šķidrumiem izmantoja dijodmetānu, etilēnglikolu, formamīdu un demineralizētu ūdeni (skat. 1. tabulu).

Aparatūra un metode

Kontaktleņķi noteica ar kontaktleņķu mērīšanas iekārtu OCA20 (Dataphysics), kas aprīkota ar videokameru, elektronisko dozēšanas iekārtu E-MD un četrām 500 µL gāzes ciešām šļircēm DS500/GT (Hamilton). Testa šķidruma padeves



1. att. Šķidruma piliena uz cietas virsmas kontaktleņķis: 1 – pieskare piliena kontūrai tās perimetrā, 2 – kontaktleņķis, 3 – piliena kontūra, 4 – piliena perimetra punkts, kurā konstruēta pieskare, 5 – cieta virsma.
Fig. 1. The contact angle of liquid drop on solid surface: 1 – tangent of drop profile on its perimeter, 2 – contact angle, 3 – drop profile, 4 – point on perimeter of drop where tangent is drawn, 5 – solid surface.

1. tabula / Table 1

Kontaktleņķa mērīšanai izmantotie testa šķidrumi un piliena veidošana
Test liquids and drop development used for contact angle measurement

Testa šķidrums / Test liquid	Tīrība / Purity	Ražotājs / Producer	Piliena tilpums / Volume of drop, μL	Piliena veidošanas ātrums / Speed of drop formation, μL s^{-1}
Dijodmetāns / Diiodomethane	99+%, stabilizēts / 99+%, stabilised	ACROS organics	2.0	1.0
Etilēnglikols / Ethylene glycol	99+%, sevišķi tīrs / 99+%, extra pure	ACROS organics	6.0	1.0
Formamīds / Formamide	99.5+%, sevišķi tīrs / 99.5+%, extra pure	ACROS organics	8.0	2.7
Attīrīts ūdens / Purified water	filtrēts ar apgriezto osmozi, demineralizēts attīrīšanas sistēmā TKA 0.2 μS / reverse osmosis filtered, demineralised in purifying system TKA 0.2 μS	LLU Ķīmijas katedras laboratorija / Laboratory of the Department of Chemistry of LLU	10.0	2.0

ātrums un piliena tilpums dots 1. tabulā. Kontaktleņķi noteica pēc videosignāla apstrādes ar Laplasa-Junga piliena kontūras nogludināšanas un optimizācijas metodi ar maksimālo ātrumu, izmantojot dinamiskās izsekošanas režīmu rezultātu reģistrēšanai. Rezultātu tabulā fiksēja mērījuma numuru, kontaktleņķi (grādi), piliena augstumu (mm), piliena bāzes diametru (mm) un piliena vecumu (ms). Piliena augstuma un bāzes diametra mērogošanas koeficientu noteica pēc dozēšanas adatas attēla ārējā diametra (pikseļi mm^{-1}), izmantojot OCA20 mērogošanas funkciju.

Kontaktleņķa mērījumus veica testa šķidruma piliena profilam gan uz neapstrādātas, gan uz virsmas, kas slīpēta ar smilšpapīru (graudu raupjums 400), koksnes šķiedru virzienā un tām perpendikulāri.

Rezultāti un diskusija

Ievadā minētās koksnes īpatnības (raupjums, heterogenitāte, caurlaidība un ķīmiskā aktivitāte) nosaka mērījumu rezultātu dinamisku nestabilitāti. Koksnes virsma ātri izmainās apkārtējās vides ietekmē (Gardner, 1996), tāpēc visi mērījumi veikti ar vienu un to pašu paraugu, kam puse no virsmas slīpēta ar smilšpapīru tieši pirms mērījumu veikšanas, lai to salīdzinātu ar novecojušos virsmu. Kontaktleņķa papildu nestabilitāti mērījumu sākuma posmā izraisa pārejas procesi, kas saistīti ar piliena veidošanos un stabilizāciju. Līdz ar to jānoskaidro, kāda rakstura līkne būtu sagaidāma, ja pārejas procesi netraucētu mērījumus. Kontaktleņķa θ izmaiņu gaidāmais raksturs modelēts, balstoties uz pieņēmumu, ka piliena forma ir lodes segments (2. att.), piliena bāzes rādiuss (a) laikā nemainās, un piliena tilpuma (V) samazināšanās ātrums ir konstants. Lodes segmenta tilpumu aprēķina pēc formulas (1) (Бронштейн, Семендяев, 1967):

$$V = h^3\frac{\pi}{6} + h\frac{a^2\pi}{2} = \frac{1}{3}\pi h^2(3r - h), \tag{1}$$

kur

V – lodes segmenta tilpums, μL;
a – piliena saskares virsmas ar koksni rādiuss, mm;
r – lodes rādiuss, mm;
h – piliena augstums, mm.

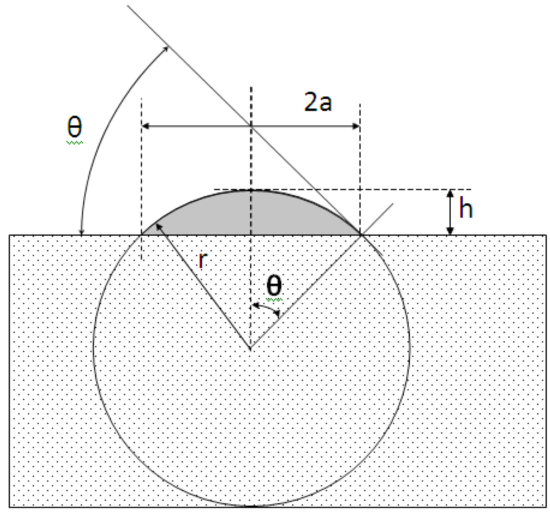
No izteiksmes (1) var iegūt sakarību (2):

$$r = \frac{a^2 + h^2}{2h}. \tag{2}$$

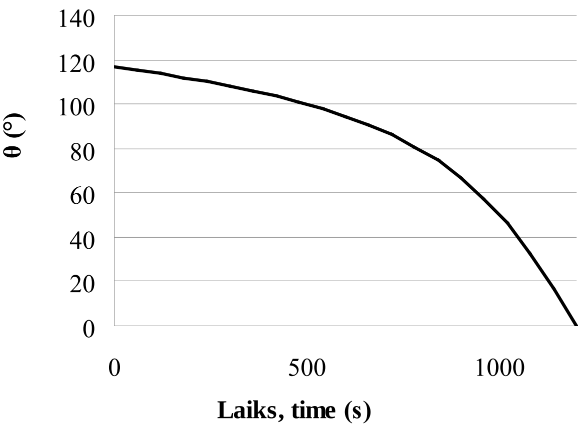
Kontaktleņķis θ ir aprēķināms pēc formulas (3) (Бронштейн, Семендяев, 1967):

$$\theta = \arccos\left(\frac{r-h}{r}\right). \tag{3}$$

3. attēlā redzams kontaktleņķa θ izmaiņas modelis pilienam ar konstantu tilpuma samazināšanās ātrumu. Redzams, ka modelī pie lielākām leņķu vērtībām



2. att. Piliena kontaktleņķa izmaiņas modelēšana ar lodes segmenta šķērsgriezumu:
θ – kontaktleņķis, h – piliena augstums, r – lodes rādiuss, a – piliena un parauga saskares virsmas rādiuss.
Zīmējuma tekstūra: punktētais laukums – paraugs, tonētais laukums – piliens.
Fig. 2. Modelling of the contact angle of a drop by a segment section of a sphere:
θ – contact angle, h – height of the drop, r – radius of the sphere,
a – radius of drop and sample contact surface.
Pattern: dotted area – sample, shaded area – a drop.

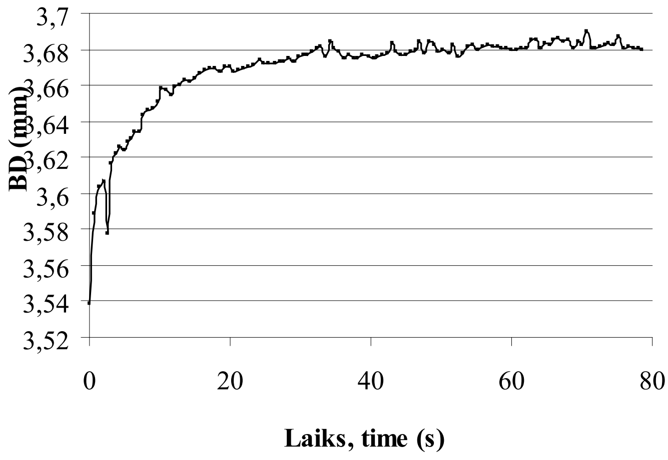


3. att. Kontaktleņķa θ izmaiņas dinamika laikā, pieņemot, ka piliena forma ir lodes segments ar lineāri dilstošu tilpumu un konstantu piliena robežvirsmu ar koksni.
Fig. 3. Dynamics of the contact angle θ assuming that drop has the form of a segment of a sphere, volume of a drop is lineary decreasing, and radius of drop and interface with wood is constant.

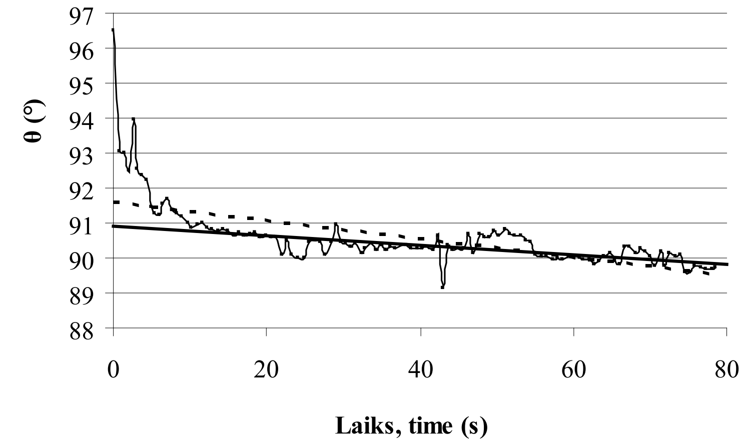
līknes dilšanas raksturs ir ļoti tuvs lineāram. Tātad kontaktleņķa mērījumu sākumposmā vērojamā izteikti nelineārā samazināšanās nav saistāma ar lineāru piliena tilpuma samazināšanos, tam iesūcoties koksnē. To var uzskatīt par pārejas procesu ietekmi (piliena formas ieņemšana, gaisa izspiešana no koksnes porām u.c.), kā arī piliena izplešanos pa virsmu (4. att.), ko neņem vērā modelis.

Pamatojoties uz iepriekš gūto atziņu, kontaktleņķa θ vērtības noteikšana balstāma uz grafika lineārās daļas lineārās aproksimācijas θ_{lin}’ projekciju uz kontaktleņķa ass, kura, pretstatā visa grafika lineārai aproksimācijai θ_{lin}, neņem vērā pārejas procesu raksturojošās nelineāri dilstošās daļas ietekmi (5. att.).

Lai noteiktu, kurā līknes posmā vairs nav novērojama būtiska nelineārās dilstošās daļas ietekme, kopējais mērījuma laiks tiek sadalīts 10 vienādos laika posmos, un pa posmiem tiek veikta lineārā aproksimācija (6. att.), sākot no laika



4. att. Piliena robežvirsmas ar koksni diametra (*BD*) dinamika.
Fig. 4. Dynamics of base diameter (*BD*) of drop interface with wood.



5. att. Kontaktleņķa θ dinamikas eksperimentālo datu lineārā aproksimācija visā laika diapazonā (θ_{lin}) – pārtrauktā taisne; datu lineārā aproksimācija laika posmā, kas neietver nelineāro daļu (θ_{lin}’) – nepārtrauktā taisne.
Fig. 5. Linear approximation in the whole time range (θ_{lin}) of experimental data of contact angle θ dynamics – dashed line; linear approximation of time range excluding non-linear part (θ_{lin}’) – uninterrupted line.

momenta „0”. Tiek meklēts pirmais posms, kura lineārā aproksimācija nešķērso visa grafika lineārās aproksimācijas (θ_{lin}) vienas standartnovirzes koridora augšējo malu. Kad šis posms ir atrasts, tiek veikta jauna to datu daļas lineāra aproksimācija (θ_{lin}’), kura sākas ar atrasto posmu un beidzas līdz ar mērījuma beigām. Šīs lineārās regresijas brīvais loceklis ir meklētā kontaktleņķa θ’ raksturīgā vērtība. Atkarībā no mērījumu skaita un vēlamās precizitātes laiku var sadalīt vairāk vai mazāk posmos. Palielinot posmu skaitu, var nonākt līdz pārāk mazam mērījumu skaitam posmā, kas rada viena mērījuma pārāk lielu ietekmi uz posma lineāro aproksimāciju.

Visa grafika lineārās aproksimācijas standartnovirzes koridors tiek noteikts, izdarot lineāru aproksimāciju x_{lin} pēc laika visā kontaktleņķu līknes garumā. Standartnovirzi $s_{\Theta lin}$ nosaka pēc pielāgotās standartnovirzes (Ennos, 2000) formulas (4):

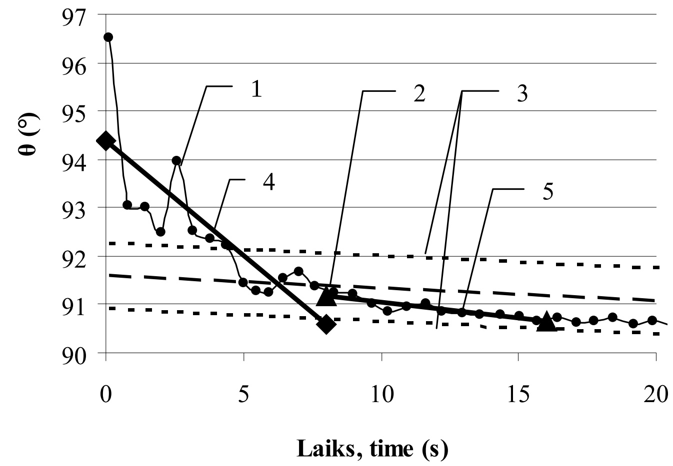
$$s_{\theta lin} = \sqrt{\frac{\sum(\theta_i - \theta_{lin i})^2}{N-1}}, \tag{4}$$

kur

θ_i – kontaktleņķa mērījums laika momentā i, °;

$\theta_{lin\,i}$ – lineārās aproksimācijas vērtība laika momentā i, °;

N – mērījumu skaits kontaktleņķa dinamikas grafikā.



6. att. Kontaktleņķa θ dinamikas (1) nelineārās daļas noteikšana ar lineāro aproksimāciju visā laika diapazonā (θ_{lin}) (2), vienas standartnovirzes koridors ap lineāro aproksimāciju (θ_{lin} + s un θ_{lin}–s) (3), laika posma 0-8 sekundes lineārā aproksimācija (θ_{lin} (0-8)) (4) un laika posma 8-16 sekundes lineārā aproksimācija (θ_{lin} (8-16)) (5).
Fig. 6. Determinaton of nonlinear part of contact angle θ dynamics (1) by linear approximation in the whole time range (θ_{lin}) (2), one standard deviation wide corridor around the linear approximation (θ_{lin} + s and θ_{lin}– s) (3), linear approximation of time range 0-8 seconds (θ_{lin} (0-8)) (4), and linear approximation of time range 8-16 seconds (θ_{lin} (8-16)) (5).

Standartovirzes koridora augšējo malu veido taisne θ_{lin} + s, bet apakšējo malu – taisne θ_{lin}– s.

Atdalot kontaktleņķu izmaiņas dinamikas līknēs nelineāri dilstošo komponenti no lineārās pēc iepriekš aprakstītās metodikas, rodas divas raksturīgu gadījumu kopas. Visbiežāk novērojamais līknes raksturs ir nelineāri dilstoša līkne sākuma daļā, kas turpinājumā pāriet uz lineāri dilstošu. Tomēr pastāv arī līknes, kuras atbilst piedāvātajiem linearitātes kritērijiem visā to garumā.

Nelineārās daļas beigas t_n (pēdējā nelineārā posma beigu moments) norāda laika momentu, pēc kura mērījumos vairs nav būtiskas nelineārās daļas ietekmes. Tātad to var izmantot mērījumu procedūras vienkāršošanai, nosakot nelineārās komponentes ietekmes beigu momentu konkrētiem testa šķidrumiem.

Apkopojot datus par dažādiem testa šķidrumiem, iegūti dati par nelineārās daļas beigu momentu t_n un to standartnovirzi s_n (2. tabula). Nelineārā daļa visātrāk beidzas formamīdam gadījumā ar neslīpētu paraugu garenvirzienā (4.4 s), bet visvēlāk – dijodmetānam gadījumā ar slīpētu koksni šķiedru virzienā (40.0 s). Lai vienkāršotu mērījumu procedūru, neveicot mērījumus nelineārās daļas posmā, iesakām sākt mērījumus laika momentā t_m, kas tiek aprēķināts pēc formulas (5):

$$t_m = t_n + 3s_n. \quad (5)$$

Tādējādi mērījumi tiktu sākti 3 standartnoviržu attālumā no eksperimentāli noteiktās t_n vērtības, nodrošinot 99.7% varbūtību, ka nelineārā daļa ir beigusies. Laika momentā t_m pēc piliena novietošanas uz koksnes parauga uzsāktie kontaktleņķa mērījumi atbilst pirmās kārtas regresijas vienādojumam (6), un tā brīvais loceklis b būs meklētā raksturīgā kontaktleņķa vērtība:

$$y = -ax + b. \quad (6)$$

2. tabulā apkopotas kontaktleņķu θ vidējās vērtības, kas iegūtas visa grafika lineārās aproksimācijas krustojumā ar vertikālo asi (projekcija uz θ ass), salīdzinājumā ar raksturīgo kontaktleņķa vērtību θ’ – kontaktleņķa vērtību grafika lineārās daļas aproksimācijas brīvo locekli. Nelineārās daļas ietekme θ-θ’ dažādiem testa šķidrumiem (nosaukti dilstošā secībā): formamīdam – 16-21%, etilēnglikolam – 7-16%, ūdenim 1-4% un dijodmetānam 1-4%. Tā kā pēdējiem diviem nosauktajiem testa šķidrumiem nelineārās daļas ietekme ir neliela (līdz 4%), tad to varētu arī ignorēt un uzskatīt, ka kontaktleņķa izmaiņa ir lineāra visā mērījumu diapazonā.

Lai raksturotu kontaktleņķu θ un θ’ vērtību noteikšanas metodes ietekmi uz koksnes virsmas brīvās enerģijas vērtībām, tās aprēķinātas ar divām metodēm: skābes–bāzes metodi (Della Volpe et al., 2004; Shalel-Levanon, Marmur, 2003; Gardner, 1996) un Owens, Wendt, Rabel un Kaelble (OWRK) metodi (Gindl et al., 2001).

2. tabula / Table 2

Kontaktleņķa θ eksperimentālie rezultāti, ieteicamais mērījumu uzsākšanas laiks un nelineārās daļas ietekme (θ–θ')
Experimental results of contact angle θ measurement, suggested starting time of measurements, and impact of the nonlinear part (θ–θ')

Testa šķidrums / Test liquid	Skaits / Number	Nelineārās daļas beigas t_n (t_n vidējā vērtība; t_n standartnovirze s_n) / The end of nonlinear part t_n (t_n mean; t_n standard deviation s_n), s	Ieteicamais mērījumu uzsākšanas laiks t_m / Suggested starting time of measurements t_m, s	θ (<0.05)	θ'(<0.05)	θ–θ'
Neslīpēts, garenvirzienā / Non-sanded, longitudinally						
Ūdens / Water	10	8.2; 4.1	20.5	80.1±8.0	77.9±9.3	2.2 (3%)
Etilēnglikols / Ethylene glycol	7	3.4; 1.5	7.9	33.5±4.9	28.2±4.1	5.3 (16%)
Dijodmetāns / Diiodomethane	6	7.8; 1.6	12.6	27.1±4.8	26.1±4.9	1.0 (4%)
Formamīds / Formamide	–	–	–	–	–	–
Neslīpēts, šķērsvirzienā / Non-sanded, transversally						
Ūdens / Water	9	3.8; 3.7	14.9	109.4±6.6	108.5±7.7	0.9 (1%)
Etilēnglikols / Ethylene glycol	6	7.9; 4.7	22.0	47.2±5.9	40.9±6.3	6.3 (7%)
Dijodmetāns / Diiodomethane	5	4.6; 5.0	19.6	46.1±4.3	45.0±5.2	1.1 (3%)
Formamīds / Formamide	4	1.7; 0.9	4.4	43.5±11.1	34.6±8.5	9.0 (21%)
Slīpēts (raupjums 400), garenvirzienā / Sanded (grid 400), longitudinally						
Ūdens / Water	9	11.2; 1.8	16.6	96.2±6.7	92.5±7.0	3.7 (4%)
Etilēnglikols / Ethylene glycol	6	11.3; 3.7	22.4	54.1±11.9	47.6±11.7	6.5 (12%)
Dijodmetāns / Diiodomethane	6	6.8; 7.7	29.9	59.3±11.2	58.9±11.6	0.4 (1%)
Formamīds / Formamide	9	4.2; 4.3	17.1	50.7±9.2	41.6±9.7	9.1 (18%)
Slīpēts (raupjums 400), šķērsvirzienā / Sanded (grid 400), transversally						
Ūdens / Water	9	8.4; 6.9	29.1	122.5±12.4	121.2±12.7	1.3 (1%)
Etilēnglikols / Ethylene glycol	8	11.8; 4.8	26.2	70.6±16.8	63.9±18.4	5.9 (8%)
Dijodmetāns / Diiodomethane	9	12.1; 9.3	40.0	66.3±5.8	65.8±5.9	0.6 (1%)
Formamīds / Formamide	9	6.9; 6.0	24.9	66.7±14.0	55.8±16.7	11.0 (16%)

3. tabula / Table 3

Testa šķidrumus raksturojošo parametru σ_L, σ_L^{LW}, σ_L^A un σ_L^B izmantotās vērtības aprēķiniem pēc skābes–bāzes metodes
Values of parameters σ_L, σ_L^{LW}, σ_L^A and σ_L^B used in calculations with acid–base method

Testa šķidrums / Test liquid	σ_L, mJ m^{-2}	σ_L^{LW}, mJ m^{-2}	σ_L^A, mJ m^{-2}	σ_L^B, mJ m^{-2}
Ūdens / Water	72.8	21.8	25.5	25.5
Etilēnglikols / Ethylene glycol	48.0	29.0	1.92	47.0
Dijodmetāns / Diiodomethane	50.0	50.0	0	0
Formamīds / Formamide	58.0	33.0	3.25	48.1

Skābes–bāzes metodes gadījumā izmanto Junga–Good–Grifalko–Fovkes vienādojumu (7) (Gardner, 1996):

$$(1+\cos\Theta)\cdot\sigma_{Li} = 2\sqrt{\sigma_S^{LW}\cdot\sigma_{Li}^{LW}} + 2\sqrt{\sigma_S^{A}\cdot\sigma_{Li}^{B}} + 2\sqrt{\sigma_S^{B}\cdot\sigma_{Li}^{A}}\,, \tag{7}$$

kur

σ_L – testa šķidruma virsmas brīvā enerģija, mJ m^{-2};
σ_L^{LW} – testa šķidruma brīvās enerģijas Lifšica van der Valsa jeb dispersā komponente, mJ m^{-2};
σ_L^A – testa šķidruma brīvās enerģijas skābā komponente, mJ m^{-2};
σ_L^B – testa šķidruma brīvās enerģijas bāziskā komponente, mJ m^{-2};
i – testa šķidruma indekss;
σ_S^{LW} – koksnes brīvās enerģijas Lifšica van der Valsa jeb dispersā komponente, mJ m^{-2};
σ_S^A – koksnes brīvās enerģijas Luisa skābes (elektronakceptorā) komponente, mJ m^{-2};
σ_S^B– koksnes brīvās enerģijas Luisa bāzes (elektrondonorā) komponente, mJ m^{-2}.

Savukārt koksnei σ_S^{LW}, σ_S^A un σ_S^B vērtības tiek iegūtas, risinot minimizācijas uzdevumu summai (8), izmantojot Excel Solver programmatūru

$$\sum_i\left(\sigma_{Li}\cdot(1+\cos\theta) - 2\cdot\sqrt{\sigma_S^{LW}\cdot\sigma_{Li}^{LW}} - 2\cdot\sqrt{\sigma_S^{A}\cdot\sigma_{Li}^{B}} - 2\cdot\sqrt{\sigma_S^{B}\cdot\sigma_{Li}^{A}}\right) \tag{8}$$

un testa šķidrumus raksturojošo parametru σ_L, σ_L^{LW}, σ_L^A un σ_L^B izmantotās vērtības, kas norādītas 3. tabulā. Trīs meklējamo mainīgo (σ_S^{LW}, σ_S^A un σ_S^B) vērtības var aprēķināt, ja tiek minimizēta vismaz trīs vienādojumu (viens vienādojums katram testa šķidrumam) sistēma. Šo prasību var apmierināt dažādās kombinācijās, jo ir pieejami eksperimentālie dati par četriem testa šķidrumiem.

OWRK metodes gadījumā koksnes virsmas brīvās enerģijas σ_{OWRK} vērtību nosaka atkarībā no divām komponentēm:

$$\sigma_{OWRK} = \sigma_S^D + \sigma_S^P\,, \tag{9}$$

kur

σ_S^D – koksnes brīvās enerģijas dispersā komponente, mJ m^{-2};
σ_S^P – koksnes brīvās enerģijas polārā komponente, mJ m^{-2}.

Summējot disperso un polāro komponenti, tiek noteikta arī testa šķidrumu brīvā virsmas enerģija σ_L:

$$\sigma_L = \sigma_L^{\,D} + \sigma_L^{\,P}, \qquad (10)$$

kur

$\sigma_L^{\,D}$ – testa šķidruma brīvās enerģijas dispersā komponente, mJ m^{-2};

$\sigma_L^{\,P}$ – testa šķidruma brīvās enerģijas polārā komponente, mJ m^{-2}.

4. tabula / Table 4

Testa šķidrumus raksturojošo parametru σ_L, $\sigma_L^{\,D}$ un $\sigma_L^{\,P}$ izmantotās vērtības aprēķiniem pēc OWRK metodes
Values of parameters σ_L, $\sigma_L^{\,D}$ and $\sigma_L^{\,P}$ used in calculations with OWRK method

Testa šķidrums / Test liquid	σ_L, mJ m^{-2}	$\sigma_L^{\,D}$, mJ m^{-2}	$\sigma_L^{\,P}$, mJ m^{-2}
Ūdens / Water	72.1	19.9	52.2
Etilēnglikols / Ethylene glycol	48.0	29.0	19.0
Dijodmetāns / Diiodomethane	50.0	47.4	2.6
Formamīds / Formamide	56.9	23.5	33.4

5. tabula / Table 5

Virsmas spraigums σ_{sb}
Surface tension σ_{sb}

Paraugs / Sample	Izejas dati / Calculation data	Testa šķidruma leņķis ar / Contact angle with: ūdeni / water	etilēnglikolu / ethylene glycol	dijodmetānu / diiodomethane	formamīdu / formamide	σ_S^{LW}, mJ m^{-2}	σ_S^{A}, mJ m^{-2}	σ_S^{B}, mJ m^{-2}	σ_{sb}, mJ m^{-2}	$\overline{\sigma}_{sb}(\theta') - \overline{\sigma}_{sb}(\theta)$ *
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Neslīpēts garenvirzienā / Non-sanded, longitudinally	θ	80.1	33.5	27.1	–	45.4	0.73	1.87	47.71	0.94 (1%)
	θ'	77.9	28.2	26.1	–	45.8	0.94	2.23	48.65	
Neslīpēts šķērsvirzienā / Non-sanded, transversally	θ	109.4	47.2	46.1	43.5	36.42	1.30	0.00	36.42	
		109.4	47.2	46.1		36.4	1.30	0.00	36.42	0.68 (2%)
		109.4	47.2		43.5	0.00	34.57	0.00	0.00	
		109.4		46.1	43.5	36.42	4.91	0.00	36.42	
	θ'	108.5	40.9	45.0	34.6	37.01	1.87	0.00	37.01	
		108.5	40.9	45.0		37.01	1.87	0.01	37.28	
		108.5	40.9		34.6	0.00	37.78	0.00	0.00	
		108.5		45.0	34.6	37.01	6.68	0.00	37.01	

5. tabulas turpinājums / Table 5 continued

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Slīpēts garenvirzienā / Sanded, longitudinally		96.2	54.1	59.3	50.7	28.98	1.67	0.03	29.39	0.60 (2%)
	θ	96.2	54.1	59.3		28.98	1.67	0.03	29.39	
		96.2	54.1		50.7	39.68	0.37	0.00	39.68	
		96.2		59.3	50.7	28.98	5.62	0.00	28.98	
		92.5	47.6	58.9	41.6	29.21	2.39	0.12	30.30	
	θ’	92.5	47.6	58.9		29.21	2.39	0.12	30.30	
		92.5	47.6		41.6	55.08	0.001	0.00	55.08	
		92.5		58.9	41.6	29.21	3.60	0.00	29.21	
Slīpēts šķērsvirzienā / Polished, transversally		122.5	70.6	66.3	66.7	24.96	0.55	0.00	24.96	0.29 (1%)
	θ	122.5	70.6	66.3		24.96	0.55	0.00	24.96	
		122.5	70.6		66.7	0.00	21.74	0.00	0.00	
		122.5		66.3	66.7	24.96	2.88	0.00	24.96	
		121.2	63.9	65.8	55.8	25.25	1.28	0.00	25.25	
	θ’	121.2	63.9	65.8		25.25	1.19	0.00	25.25	
		121.2	63.9		55.8	0.00	25.80	0.00	0.00	
		121.2		65.8	55.8	25.25	5.62	0.00	25.25	

* vidējās vērtības rēķinātas bez rindām ar dijodmetānu
* mean values are calculated without diiodomethane

Testa šķidrumu raksturojošo parametru σ_L, σ_L^D un σ_L^P izmantotās vērtības norādītas 4. tabulā. Koksnes virsmas brīvās enerģijas komponenšu atrašanai izmanto taisnes vienādojumu (11) (Ferreira et al., 2007):

$$y = a \cdot x + b, \quad (11)$$

kur

$$y = \frac{1+\cos\theta}{2} \cdot \frac{\sigma_L}{\sqrt{\sigma_L^D}}, \quad (12)$$

$$x = \sqrt{\frac{\sigma_L^P}{\sigma_L^D}}, \quad (13)$$

$$a = \sqrt{\sigma_S^P}, \quad (14)$$

$$b = \sqrt{\sigma_S^D}. \quad (15)$$

Ievietojot vienādojumā (12) eksperimentāli iegūtās, ar katru testa šķidrumu izmērītās kontaktleņķa vērtības, tiek iegūti taisnei piederošie punkti, kas ļauj noteikt koeficientus *a* un *b* taisnes vienādojumā (11), un līdz ar to meklējamās σ_S^D un σ_S^P vērtības aprēķina saskaņā ar vienādojumiem (14) un (15).

Izmantojot 2. tabulā norādītās θ un θ’ vērtības, aprēķinātas virsmas spraiguma vērtības pēc skābes–bāzes (5. tabula) un OWRK (6. tabula) metodes. Veicot aprēķinus pēc skābes–bāzes metodes ar 3 izmantotajiem testa šķidrumiem gadījumos, kad netiek izmantots dijodmetāns, aprēķinātās vērtības būtiski atšķiras no pārējām, kas ir izskaidrojams ar to, ka ar vidējā ģeometriskā vienādojumu aprēķinātās virsmas brīvās enerģijas vērtības ir atkarīgas no mērījumos izvēlētajiem šķidrumiem, un ticamas vērtības var iegūt tikai tad, ja izmanto polāra un nepolāra šķidruma pāri (Gindl et al., 2001). No izmantotajiem četriem testa šķidrumiem tikai dijodmetāns ir nepolārs (nav skābes un bāzes komponentes), tāpēc arī aprēķinātās vērtības koksnes virsmas enerģijai bez nepolārā dijodmetāna kontaktleņķiem ir nereālas, kas apstiprina empīrisko likumību.

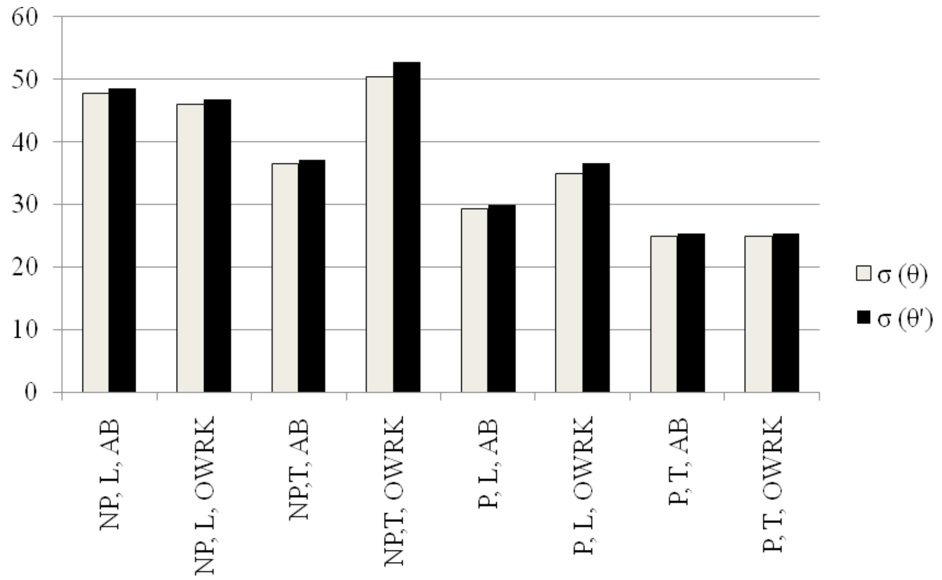
6. tabula / Table 6

Virsmas spraigums σ_{OWRK}
Surface tension σ_{OWRK}

Paraugs / Sample	Izejas dati / Calculation data	Testa šķidruma leņķis ar / Contact angle with: ūdeni / water	etilēnglikolu / ethylene glycol	dijodmetānu / diiodomethane	formamīdu / formamide	σ_S^D, mJ m^{-2}	σ_S^P, mJ m^{-2}	σ_{OWRK}, mJ m^{-2}	$\sigma_{OWRK}(\theta)$- $\sigma_{OWRK}(\theta')$, mJ m^{-2}
Neslīpēts garenvirzienā / Non-sanded, longitudinally	θ	80.1	33.5	27.1	–	42.45	3.47	45.92	0.87 (2%)
	θ'	77.9	28.2	26.1	–	42.56	4.23	46.79	
Neslīpēts šķērsvirzienā / Non-sanded, transversally	θ	109.4	47.2	46.1	43.5	43.94	6.37	50.31	2.41 (5%)
	θ'	108.5	40.9	45.0	34.6	52.62	0.10	52.72	
Slīpēts garenvirzienā / Sanded, longitudinally	θ	96.2	54.1	59.3	50.7	31.88	3.08	34.95	1.73 (5%)
	θ'	92.5	47.6	58.9	41.6	32.02	4.65	36.68	
Slīpēts šķērsvirzienā / Polished, transversally	θ	122.5	70.6	66.3	66.7	36.31	0.09	36.40	2.33 (6%)
	θ'	121.2	63.9	65.8	55.8	38.73	0.01	38.73	

Lineāri aproksimētās θ vērtības aizvietojot ar koriģētajām θ' vērtībām, pēc skābes–bāzes metodes aprēķinātās virsmas spraiguma σ_{sb} vērtības palielinās par 1-2%, bet OWRK metodes gadījumā – par 2-6%.

Pēc abām metodēm ar identiskiem izejas datiem iegūtās vērtības salīdzinātas 7. attēlā. Nebūtiskas atšķirības vērojamas neslīpētiem paraugiem garenvirzienā un slīpētiem paraugiem šķērsvirzienā,



7. att. Koksnes virsmas enerģijas aprēķinu pēc skābes–bāzes (AB) metodes un Owens, Wendt, Rabel, Kaelble (OWRK) metodes rezultātu salīdzinājums.
Lietotie apzīmējumi: NP – neslīpēts, P – slīpēts, L – garenvirzienā, T – šķērsvirzienā.
Fig. 7. Comparison of the results of surface tension calculations using acid-base (AB) and Owens, Wendt, Rabel, Kaelble (OWRK) methods.
Applied abbreviations: NP – non polished, P – polished, L – longitudinally, T – transversally.

turpretī pēc OWRK metodes aprēķinātais virsmas spraigums neslīpētiem paraugiem šķērsvirzienā ir par 28% un 30% augstāks (attiecīgi rēķinot ar θ un θ' vērtībām), bet slīpētiem garenvirzienā – par 16% un 18% augstāks, kas izskaidrojams ar atšķirīgiem cietas vielas virsmas un šķidruma mijiedarbības modeļiem, uz ko balstās katra no metodēm.

Secinājumi

1. Modelējot piliena, kam ir konstanta robežvirsma ar koksni un konstants tilpuma izmaiņas ātrums, kontaktleņķa dinamiku, secināts, ka mērījumu sākumposmā izmaiņai jābūt tuvu lineāri dilstošai.
2. Līdz ar to ir pieņemts, ka kontaktleņķa raksturīgā vērtība ir kontaktleņķa dinamikas lineārās daļas aproksimācijas brīvais loceklis, izslēdzot nelineārās kontaktleņķa izmaiņas.
3. Izstrādāta metodika raksturīgā kontaktleņķa iegūšanai, izslēdzot nelineārās, pārejas procesiem raksturīgās, daļas ietekmi. Par nelineāro daļu pieņem visas mērījumu kopas lineārās aproksimācijas vienas standartnovirzes platā koridorā neietilpstošo daļu.
4. Nelineārās daļas ietekme uz kontaktleņķi, izmantojot dažādus testa šķidrumus, samazinās secībā: formamīds>etilēnglikols>ūdens≅dijodmetāns.
5. Mērījumu procedūras vienkāršošanai tiek piedāvāts uzsākt mērījumus, kad nelineārie procesi ir beigušies. Visātrāk mērījumi uzsākami formamīdam gadījumā uz neslīpētas koksnes perpendikulāri šķiedrām (pēc 4.4 s), bet visvēlāk – dijodmetānam gadījumā uz slīpētas koksnes perpendikulāri šķiedrām (pēc 40.0 s).
6. Lineāri aproksimētās θ vērtības aizvietojot ar raksturīgām θ' vērtībām, pēc skābes–bāzes metodes aprēķinātās virsmas spraiguma σ_{sb} vērtības palielinās par 1-2%, bet OWRK metodes gadījumā – par 2-6%. Līdz ar to skābes–bāzes metodes gadījumā korekcija ir mazāka.

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