Ministry of Environment
of the Slovak Republic

STATE OF THE ENVIRONMENT REPORT SLOVAK REPUBLIC 2010

Slovak Environmental Agency

• SOIL

Key questions and key findings

♦ Key questions

- **What is the trend in the situation of the agricultural land types in terms of their contamination by risk elements?**
- **What is the share of the agricultural land types threatened by erosion?**

♦ Key findings

- **Based on the recent observations we can say that over the course of monitoring there was a slight increase in the contents of cadmium, copper, chrome, and lead in the agricultural land's arable soil. However, no statistically significant difference has been detected when assessing the mentioned elements. There was detected an increased content of cadmium and lead in fluvisols caused by the accumulation of these elements within the fluvial sediments and from the surrounding areas, as well as from the areas that are more distant. Content of cadmium in rendzinas was also increased, as its accumulation is facilitated by the organic matter and a neutral soil reaction at which this element is less mobile.**
- **In comparison with the beginning of land types monitoring in Slovakia (the year 1993), the recently detected values of monitored high-risk elements in agricultural land types have been statistically insignificant. This means that the soils that had already been contaminated in the past are still contaminated, so they are to be monitored in the future as well.**
- **There are approximately 40% of all agricultural land types threatened by the water erosion and about 5% of all agricultural land types threatened by the wind erosion.**

Land use

Total size of the Slovak Republic is 4 903 644 ha. In 2010, the share of agricultural land was 49.24% of total land size, while the share of forestland was 41.02%, and the share of non-agricultural and non-forest lands was 9.74%.

Land Use categories (state to the date 1st January 2011)

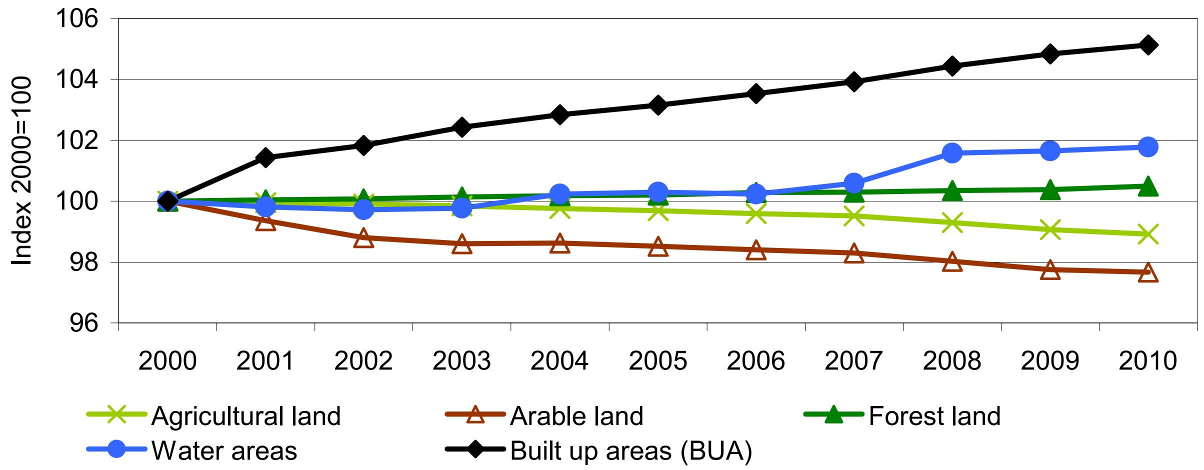
Land category	Area (ha)	% of total area
Agricultural land	2 414 291	49.24
Forest land	2 011 250	41.02
Water areas	94 761	1.93
Build-up land	230 589	4.70
Other land	152 753	3.11
Total area	**4 903 644**	**100.00**

Source: GCCA SR

Anthropogenic pressure to use soil for purposes other than its primary production and environmental functions brings about its gradual decrease.

Analysis of the changes to overall values of land types for the year 2010 as compared to 2009 suggests that the loss of agricultural land in 2010 (-3 642 ha) when compared with 2009 (-5 545 ha) is smaller by 1 903 ha. Loss of arable land in 2010 (-1 350 ha) when compared with 2009 (-3 869 ha) is smaller by 2 519 ha. Increment of forestland in 2010 (2 407 ha) when compared with 2009 (586 ha) is greater by 1 821 ha. Trend in the land types of the Slovak Republic in 2010 was marked by a continuing loss of agricultural and arable land types to forest, non-agricultural and non-forest land types, as well as by an increase in forestland at the expense of agricultural land, non-agricultural and non-forest land types.

Development of individual land types in the SR



Source: GCCA SR

Soil properties

Information on state and trend in agricultural soil properties and their degradation may be obtained from the Partial Monitoring System - Soil (PMS-S) carried out by the Soil Science and Conservation Research Institute (SSCRI) and from the Agrochemical soil testing (AST) carried out by Central Controlling and Testing Institute in Agriculture (CCTIA). Information on state and trend in forest soil properties may be obtained from the Partial Monitoring System – Forests (PMS-F) carried out by the National Forest Centre – Forest Research Institute.

♦ Yield potential of land

Primary objective in reviewing the yield potential of agricultural land types and territory is a single-purpose synthesis of ecological and economic review of performance of agricultural production under various soil and ecological conditions. The greatest value of 100 points is assigned to loess-based Chernozem, medium-heavy and deeper than 60 cm, with favourable water regime, in warm, slightly humid climatic region found of plane surfaces. The lowest value of 6 points is assigned to a soil type on steep slopes (over 30%) under very unfavourable weather conditions and covered with grass. The mean value for land types in Slovakia corresponds to 33 points. Lands **with the highest yield potential** in Slovakia are located in the **region of Trnava** (the mean yield potential of 69.6), while **lands with the lowest yield potential** are located in the **region of Žilina** (the mean yield potential of 25.7).

Chemical degradation

Serious soil degradation includes contamination with heavy metals and organic pollutants, acidification, as well as soil salinisation and sodification.

♦ Soil contamination by hazardous substance

Outcomes of the II. PMS - S monitoring cycle with samples extracted in 1997 showed a slight improvement in the sanitary condition of agricultural land types. Apparent vertical migration of high-risk elements in the soil profile was detected. Results from the III. cycle with samples extracted in 2002 showed that the content of the majority of risk substances in selected agricultural land of Slovakia was below the limit, especially in case of arsenic, chromium, copper, nickel, and zinc. In case of cadmium and lead, excessive limit values were recorded only in soils situated in higher altitudes, podsols, andosols, which may relate to remote transfer of emissions.

Soil samples extracted in the 4th extraction cycle were processed and analysed in 2010. (2007 being the year of extraction) Chemical analyses of monitored land types for PG as well as AL categories were completed.

Present situation in the contamination of the analysed land types with extraction carried out in 2007 was first monitored pursuant to annex 2 of Act 220/2004 Coll. on the protection and use of agricultural land and on amendment to Act 245/2003 Coll. on integrated environmental pollution prevention and control and amendments to selected laws as amended, which sets forth the limit values for high-risk elements within the agricultural land. For this reason it is not possible to compare contamination with the previous monitoring cycles there were assessed pursuant to the legislation then valid.

Limit values of risk elements in the agricultural land types defined on the basis of the soil structure and value of soil reaction as well as the critical value of risk elements within the agricultural soil to plant relationship

Risk element	**Limit values for risk elements in agricultural soil** (in mg.kg^{-1} of dry matter, aqua regia decomposition, Hg total content)			**Critical values for risk elements as they relate to the agricultural soil and plant** (in mg.kg^{-1} of dry matter, in leachate of 1 mol/l amonnium nitrate, F in water leachate)
	Sandy, loam-sandy soil	Sand-loamy, loamy soil	Clay-loamy soil, clay	
Arsenic (As)	10	25	30	0.4
Cadmium (Cd)	0.4	0.7 (0.4)*	1 (0.7)*	0.1
Cobalt (Co)	15	15	20	-
Chromium (Cr)	50	70	90	-
Copper (Cu)	30	60	70	1
Mercury (Hg)	0.15	0.5	0.75	-
Nickel (Ni)	40	50 (40)*	60 (50)*	1.5
Lead (Pb)	25 (70)*	70	115 (70)**	0.1
Selenic (Se)	0.25	0.4	0.6	-
Zinc (Zn)	100	150 (100)*	200 (150)*	2
Fluorine (F)	400	550	600	5

Note: Supplied data apply to samples obtained in arable land types from the upper layer of 0.2 m and air-dried to reach constant weigh, * if pH (KCl) is less than 6, ** if pH (KCl) is less than 5,

During the process of monitoring the Slovak land types were monitored contents of high-risk elements through applying the aqua regia solution (for As, Cd, Co, Cr, Cu, Ni, Pb, Zn) while assessing determined basic statistical parameters (Xmin - minimum value, Xmax - maximum value, Xp - mean value) for the 4th extraction cycle applied to the following types of monitored soils:

1. Podsols, rankers and lithomorphic soils on acidic substrates - high-altitude mountain sites (PG) – **S1**
2. Pseudogley and pseudogley luvisols on polygenetic loess loams (AL) - **S13**

3. Pseudogley soils on polygenetic loess loams (PG) - **S14**
4. Brunisolic soils and loess-based pseudogley brunisolic soils (mostly AL)
5. Regosols on calcareous blown sands (AL) - **S21**
6. Regosols on non-calcareous blown sands (AL) - **S22**

Proportion of As, Cd, Co (in $mg.kg^{-1}$ in aqua regia) in selected soils within the 4th extraction cycle (year of extraction - 2007)

Group of soils	Culture	Soil depth	As			Cd			Co		
			Xmin	Xmax	Xp	Xmin	Xmax	Xp	Xmin	Xmax	Xp
S1	PG	0-10	2.3	47.1	13.5	0.24	2.14	0.88	1.0	2.5	1.3
		35-45	3.1	23.9	10.9	0.05	0.51	0.23	1.0	8.1	3.2
S14	PG	0-10	6.4	18.4	10.3	0.14	1.69	0.40	1.0	16.8	7.8
		35-45	3.8	14.1	9.07	0.03	0.24	0.123	3.1	61.7	13.8
S13	AL	0-10	2.1	53.8	9.8	0.1	1.3	0.3	4.9	28.3	10.2
		35-45	1.8	49.4	9.8	0.06	3.54	0.31	5.0	27.6	11.0
S15	AL	0-10	3.1	15.5	9.2	0.14	0.5	0.24	3.6	20.8	10.0
		35-45	3.0	15.6	9.1	0.05	0.48	0.18	4.6	21.5	10.1
S21	AL	0-10	3.0	4.3	3.7	0.07	0.3	0.1	1.0	4.5	2.0
		35-45	1.8	7.7	3.9	0.009	0.123	0.072	1.8	14.2	6.5
S22	AL	0-10	1.5	4.8	2.8	0.07	0.16	0.11	1.0	2.0	3.9
		35-45	0.8	4.9	2.3	0.07	0.126	0.090	1.0	3.8	1.9

Source: SSCRI

Note: x_{min} – the minimum set value of a selected group, x_{mas} - the maximum set value of a selected group, x_2 average value of a selected group, AL - arable land, PG - permanent grassland

Proportion of Cr, Cu, Ni (in $mg.kg^{-1}$ in aqua regia) in selected soils within the 4th extraction cycle (year of extraction - 2007)

Group of soils	Culture	Soil depth	Cr			Cu			Ni		
			Xmin	Xmax	Xp	Xmin	Xmax	Xp	Xmin	Xmax	Xp
S1	PG	0-10	2.0	35.6	14.5	3.0	39.7	10.6	1.1	9.6	5.6
		35-45	2.0	24.2	11.4	2.4	23.4	7.7	5.0	27.1	10.0
S14	PG	0-10	22.2	74.8	45.3	7.8	17.7	13.8	7.8	24.5	16.8
		35-45	23.3	61.4	41.8	4.7	19.7	14.2	1.0	33.6	19.0
S13	AL	0-10	5.5	101.1	42.1	9.5	44.7	18.0	0.2	100.0	25.3
		35-45	6.9	81.3	47.3	9.8	41.2	18.8	8.1	141.0	30.9
S15	AL	0-10	10.8	74.1	41.5	13.8	80.7	22.9	14.3	45.5	32.6
		35-45	5.0	94.9	45.9	11.0	31.4	20.1	16.9	51.2	36.3
S21	AL	0-10	18.5	50.1	29.2	9.2	58.5	22.6	10.0	20.5	15.0
		35-45	2.0	90.1	29.2	5.5	53.1	22.8	7.2	55.9	19.9
S22	AL	0-10	1.0	7.8	3.3	4.4	11.9	7.6	0.8	16.0	7.1
		35-45	2.0	11.1	5.0	2.5	10.9	5.9	1.0	7.7	16.2

Source: SSCRI

Note: x_{min} – the minimum set value of a selected group, x_{mas} - the maximum set value of a selected group, x_2 average value of a selected group, AL - arable land, PG - permanent grassland

Proportion of Pb, Zn, Hg (in $mg.kg^{-1}$ in aqua regia) in selected soils within the 4th extraction cycle (year of extraction - 2007)

Group of soils	Culture	Soil depth	Pb			Zn			Hg		
			Xmin	Xmax	Xp	Xmin	Xmax	Xp	Xmin	Xmax	Xp
S1	PG	0-10	18.3	207.0	81.0	22.2	68.9	38.1	0.07	0.64	0.27
		35-45	5.0	30.6	14.3	20.5	54.4	40.6	0.03	0.13	0.08
S14	PG	0-10	12.0	41.9	23.8	50.9	77.6	64.7	0.036	0.176	0.075
		35-45	8.0	20.0	13.6	44.5	71.8	54.7	0.03	0.14	0.05
S13	AL	0-10	7.8	199.5	24.4	198.7	42.0	67.3	0.22	0.328	0.073

		35-45	7.1	74.8	17.8	42.2	111.0	64.4	0.02	0.13	0.049
S15	**AL**	0-10	5.5	47.4	20.2	48.6	89.6	68.8	0.0281	0.084	0.05
		35-45	5.0	30.6	16.6	42.0	98.5	68.0	0.012	0.079	0.041
S21	**AL**	0-10	5.0	17.9	9.3	35.7	62.4	45.8	0.02	0.03	0.03
		35-45	5.0	17.2	8.5	21.8	106.0	59.0	0.05	0.073	0.026
S22	**AL**	0-10	5.0	5.0	5.0	19.8	53.9	33.0	0.021	0.027	0.024
		35-45	5.0	5.0	5.0	9.3	49.4	26.2	0.011	0.024	0.017

Source: SSCRI

Note: x_{min} – the minimum set value of a selected group, x_{mas} - the maximum set value of a selected group, x_2 average value of a selected group, AL - arable land, PG - permanent grassland

Comparison of the contents of heavy metals inside the soil profile for the assessed soil categories within the IV. extraction cycle:

Arsenic	Contents of arsenic for individual categories of analysed soils of a new extraction cycle (extraction year of 2007) shows lower values in the depth of 35-45 cm than in the upper horizon.
Cadmium	Contents of cadmium for individual categories of analysed soils shows lower values in the depth of 35-45 cm than in the upper horizon.
Cobalt	Contents of cobalt for individual categories of analysed soils shows slightly higher values in the depth of 35-45 cm for all soil categories with the exception of regosol arable land on non-calcareous blown sands, which points to the vertical migration of Co in the direction of the deeper strata of the soil profile.
Chromium	Contents of chromium for individual categories of analysed soils shows that both horizons have almost identical or only slightly raised contents in the depth of 35-45 cm.
Copper	Contents of copper for individual categories of analysed soils shows that in the depth of 35-45 cm for brunisolic soil and loess-based pseudogley brunisolic soil, podsols, rankers, and lithomorphic soils on acidic substrates, and regosols on non-calcareous blown sands, the contents of copper is lower than inside the A-horizon. Within the second half of the analysed categories there has been a slight increase in the contents of copper.
Nickel	Contents of nickel for individual categories of analysed soils in the depth of 35-45 cm is slightly higher for all categories, which points to vertical migration of Ni in the direction of the deeper strata of the soil profile.
Lead	Contents of lead for individual categories of analysed soils shows significantly lower values in the depth of 35-45 cm than in the depth of 0-10 cm.
Zinc	Contents of zinc for individual categories of analysed soils shows higher values in the depth of 0-10 cm than in 35-45 cm, with the exception of the categories of podsols, rankers, and lithomorphic soils on acidic substrates, and regosols on calcareous blown sands.
Mercury	Contents of mercury for individual categories of the new extraction cycle (extraction year of 2007) shows significantly lower contents in the depth of 0-10 cm than in the depth of 35-45 cm.

Source: SSCRI

In terms of soil contamination by **organic pollutants,** notwithstanding the fact that the production of polychlorinated biphenyls (PCBs) had been stopped in the past, soil contamination remains high. However, this type of contamination is only point contamination that is often very difficult to also illustrate in space. With the exceeding limit for polycyclic aromatic hydrocarbons (PAH) we detected in the soil mainly fluoranthene (Fl), benzo(a)pyrene (BaP), benzo(b)fluoranthene (BbF), and other compounds that show carcinogenic properties together with direct or late toxicity. Also exceeded values for these substances have been detected only locally and as individual points. They are typical especially for the sites of Strážske, and Žiar nad Hronom.

♦ Acidification of soils

Acidification as a process of raising the soil's acidity represents one of the important processes of chemical degradation. Ability of the agro-ecosystem to cope with natural and anthropogenic acidification is defined by the capacity and potential of the buffering function of the soil. This reflects a degree of soil resistance to acidification.

Outcomes from the third monitoring cycle with the extraction year of 2002 showed significantly greater acidification tendencies, especially in cases of mollic fluvisols, cambisols, rendzinas, podsols, rankers, and lithomorphic soils.

The table shows the results obtained from the soil samples treated and analysed since 2010 for the IV. monitoring cycle with extraction of samples in 2007.

Shown pH values dependent on active aluminium in selected SR soils for the A horizon within the basic partial monitoring system in fourth monitoring cycle (active Al determined in soils with pH in KCl of < 6.0)

Soil representative	pH in H_2O	Al in $mg.kg^{-1}$	Al^{3+}/Ca^{2+}
		x	
Chernozems AL	7.14	-	-
Brunisolic soils AP	6.66	7.28	0.63
Pseudogley soils AL	6.45	3.43	0.33
Pseudogley soils PG	5.88	12.52	0.92
Rendzinas AL	7.97	-	-
Rendzinas PG	7.27	3.92	0.25
Regosols AL	6.90	-	-
Cambisols AL	6.24	11.81	1.99
Cambisols PG	5.48	60.65	18.33
Solonchaks and Solonetz PG	-	-	-
Podsols PG	3.77	455.57	38.73

AL – arable land, PG – permanent grassland, x – arithmetic average Source: SSCRI

In total, there has been a reduction in the mean value of the active soil reaction (compared to 1993) in four out of six assessed soil categories. These results point to an alarming trend in the development of slightly acidic and acidic soils.

The ratio of equivalent values of the exchange cations of Al^{3+}/Ca^{2+} indicates a degree of soil degradation in relation to acidification for the assessed soil categories that are used as arable lands. This value was exceeded in 35% of sites for the category of pseudogley soils and pseudogley luvisols found on polygenetic loess loams, and in 28% it was exceeded in the categories of brunisolic soil and pseudogley loess brunisolic soil, which represents an active aluminium stress for the cultivated crop.

♦ Salinisation and sodification

The process of soil monitoring assesses the contents of sodium salts and sodium ions in the soil. Their exceeded values deteriorate soil properties and thus prevent good growth of plants. **Processes of salinisation and sodification** have been monitored through a built network of stationary monitoring sites. The network includes both weak and medium solonchaks and solonetz, as well as the typical solonetz soil types. Of the total number of 8 monitored sites, 6 are situated in the Podunajská rovina (Podunajská plane). Anthropogenic soil sodification is measured in Central Slovakia by the exhausts from the aluminium production plant in Žiar nad Hronom. In the Eastern Slovakian Lowland, the monitoring network includes a typical solonetz in the cadastre area of Malé Raškovce.

The monitored area shows concurrent processes of salinisation and sodification, with sodification being more dominant.

Weak - initial to medium **salinisation,** with salt content of 0.10 - 0.35% was recorded within individual horizons of these sites: Iža, Gabčíkovo, Zemné, Komárno-Hadovce, Zlatná na Ostrove, and Malé Raškovce. High (0.36 - 0.70%) to extremely high (over 0.71%) salt content was detected at Kamenín and at Žiar nad Hronom where these salts are of anthropogenic origin.

Over the last eleven years no significant trends have been recorded in the process of salinisation.

Soil sodification as a process of binding exchangeable sodium onto the sorption complex of monitored soil in 2010 is comparable with the previous years. Its trend over the recent years (2000-2010) can be assessed by the content of exchangeable sodium percentage (ESP) and soil reaction (pH).

Content of exchangeable sodium within the sorption complex of 5-10% indicating a weak sodification was detected within the lower horizons of these sites: Zemné, Gabčíkovo, Zlatná na Ostrove, as well as throughout the whole Komárno-Hadovce site. High (10-20%) to very high (over 20%) content of exchangeable sodium was recorded in these sites: Malé Raškovce, Kamenín, and Žiar nad Hronom.

The soil reaction values (pH) as the soil sodification indicator suggest strongly alkaline reaction (pH>7.7) within the lower horizons of these sites: Iža, Zemné, as well as throughout the whole soil type of Zlatná na Ostrove, Žiar nad Hronom, Malé Raškovce, and Kamenín.

The provided data on salinisation and sodification shows that total trend in saline soils is not linear in space and time. The measured main characteristics of saline soil trend (salt content, ECe, pH, ESP) are significantly different per different soil types and horizons in time and space and there is little mutual correlation among them. This is determined both by their significant spatial variability, as well as by the type of trend itself.

Physical degradation

Erosion and soil compaction belong among the major phenomena of physical degradation in Slovakia.

♦ Soil erosion

Potential erosion means possible threat to agricultural land types by processes of water erosion if we do not take into account the soil-protective effect of the vegetation cover. Water erosion (of different intensity) impacts 957 173 ha of agricultural land types in Slovakia.

Sizes of land categories potentially impacted by water erosion

Erosion categories	Water erosion	
	Land area in ha	% from Agricultural Land
No erosion or slightly	1 457 118	60.35
Medium	245 734	10.18
Strong	356 897	14.78
Extremely strong	354 542	14.69
Total	**2 414 291**	**100.00**

Source: SSCRI

Size of agricultural land types potentially impacted by wind erosion is 130 301 ha. These are mainly light granulated soil types with lower content of organic matter that are highly vulnerable to drying (and thus to wind erosion) especially when they are without vegetation cover.

Sizes of land categories potentially impacted by wind erosion

Erosion categories	Wind erosion	
	Land area in ha	% from Agricultural Land
No erosion or slightly	2 283 990	94.62
Medium	54 717	2.26
Strong	45 046	1.86
Extremely strong	30 538	1.26
Total	**2 414 291**	**100.00**

Source: SSCRI

♦ Soil compaction

For soil types, granulated heavy soil types show higher rate of compaction over the whole soil profile. In soil assessed for compaction the most resistant were regosols followed by sand and loamy pseudogley soil and brunisolic soil, while the least resistant were clay-loamy pseudogley soil and brunisolic soil. Of all the soil types, brunisolic soil shows the greatest rate of compaction, most likely due to its intensive exploitation.