DATABASE OF SOLONETZ LANDS IN PASTURES USING GIS TECHNOLOGIES

PART I

Research to establish a database of solonetz lands in pastures using GIS technologies across the geographical or climatic zones of Kazakhstan was conducted in 2024 by the Non-Profit Joint-Stock Company “Kazakh National Agrarian Research University” along routes covering seven administrative regions of the republic: Almaty, Zhetysu, Zhambyl, Turkestan, Kyzylorda, Mangystau and Atyrau regions (Figures 2, 3).



Figure 2 – Survey route and study sites in Atyrau and Mangystau regions

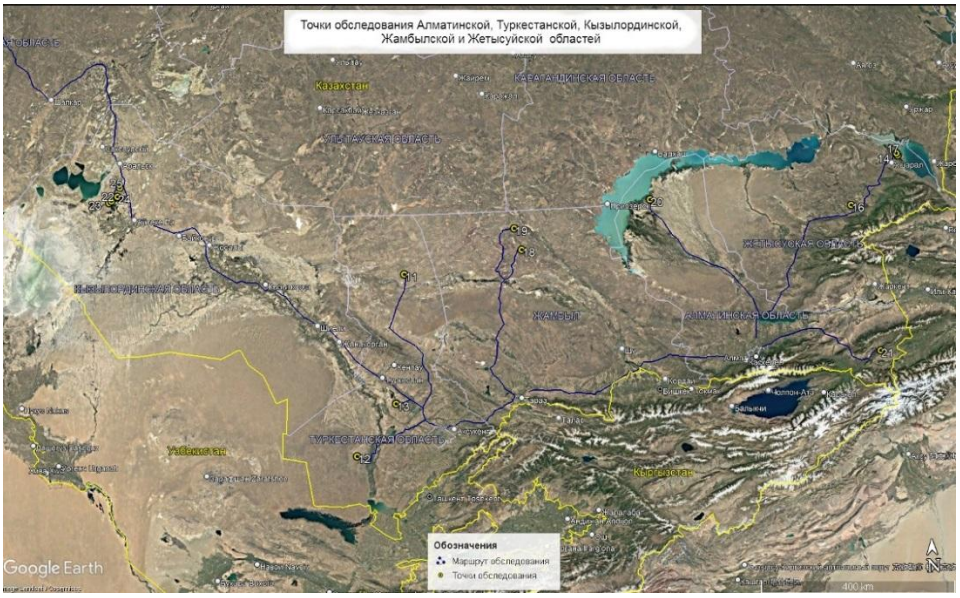


Figure 3 – Survey route and study sites in Almaty, Zhetysu, Zhambyl, Turkestan and Kyzylorda regions

Atyrau region:

Study site №1. A soil pit was excavated (26.08.2024) 26 km north of the settlement of “Dossor”, within Makat district, Atyrau region. The surveyed area has flat terrain and is used as pasture. Its vegetation consists of biyurgun, bluegrass, mortuk, Climacoptera and Tatar rhubarb. The landscape aspect is light brown (Figure 4).

Automorphic shallow solonetz soils occur in microdepressions here; a soil pit was excavated to characterize them. Soil pit coordinates: N47°707'07, E052°879'22.

The morphogenetic description of their genetic horizons is presented below:

0-7 cm Light grey, layered, dry, silty-cloddy, effervesces vigorously with HCl, slightly compacted, medium loam, porous, fine roots, abrupt transition in colour and density;

8-26 cm Dark brown, dry, columnar, heavy loam, small roots, dense, effervesces weakly with HCl, discernible transition in structure;

27-39 cm Brown, dry, cloddy, heavy loam, dense, effervesces with HCl, fine roots, discernible transition in colour;

40-54 cm Lighter than the preceding horizon, fresh, medium loam, cloddy, slightly compacted, effervesces vigorously with HCl, salt and carbonate mottles and veins, clear transition in colour and density;

55-120 Light brown, fresh, slightly compacted, structureless, effervesces vigorously with HCl, light loam.

The morphogenetic features of the shallow solonetz profile at the Dossor study site indicate that the soil has a dark solonetzic B_1 horizon at a depth of 8-26 cm, characterized by a columnar structure, dense fabric and heavy texture. Further down, at a depth of 40-54 cm, salt and carbonate mottles and veins are evident. A distinctive feature of this soil profile is its unfavourable hydrophysical properties, including poor water permeability, swelling and stickiness when wet, shrinkage on drying, etc.



Figure 4 – Profile structure and surface condition of shallow solonetz

Investigation of the biological characteristics of the vegetation at the monitoring plot revealed that the projective vegetation cover on solonetz soils does not exceed 50% of the total area. The pasture type is biyurgun–ephemeral, as the botanical composition showed that biyurgun accounts for 65% and ephemerals for 35%. In addition to biyurgun, small quantities of bluegrass, Climacoptera, Tatar rhubarb and Petrosimonia occur on the solonetz soils. Pasture biomass yield was 6,1 c/ha.

The physicochemical properties of the soils are presented in Tables 1, 2, 3.

Table 1 – Chemical and physicochemical properties of shallow solonetz

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
1	0-7	0,56	0,056	3,17	1,96	2,94	1,84	0,47	7,21	8,80
	10-20	0,65	0,070	0,77	3,92	6,86	25,43	0,05	36,26	8,35
	25-35	0,63	0,098	2,17	2,45	6,86	25,42	0,05	25,47	8,00
	40-50			3,34	3,43	8,82	17,07	0,05	29,37	7,68
	70-80			11,1	24,99	3,43	12,58	0,04	41,04	7,45

Table 2 - Particle-size distribution of shallow solonetz

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
1	0-7	0,52	1,387	45,537	22,517	3,217	10,454	16,888	30,559
	10-20	2,94	0,845	42,283	18,545	5,358	30,084	2,885	38,327
	25-35	2,80	0,535	43,498	10,700	5,761	30,453	9,053	45,267
	40-50	2,02	14,860	41,049	12,247	5,715	22,045	4,082	31,843
	70-80	1,58	0,345	32,595	61,776	2,845	0,406	2,032	5,283

Table 3 – Composition of water-soluble salts in shallow solonetz, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	0-7	0,100	0,056	0,005	0,001	0,015	0,002	0,002	0,021	0,003
			0,92	0,16	0,04	0,31	0,09	0,19	0,92	0,07
	10-20	0,402	0,059	0,002	0,129	0,074	0,002	0,001	0,136	0,001
			0,96	0,08	3,65	1,53	0,09	0,09	5,93	0,02
	25-35	0,728	0,044	0,002	0,326	0,091	0,004	0,005	0,258	0,001
			0,72	0,08	9,20	1,89	0,19	0,37	11,24	0,02
	40-50	0,867	0,017	0,000	0,461	0,065	0,02	0,01	0,293	0,001
			0,28	0,00	12,99	1,35	1,02	0,84	12,75	0,02
	70-80	1,688	0,010	0,000	0,403	0,734	0,213	0,051	0,276	0,001
			0,16	0,00	11,37	15,3	10,65	4,17	11,99	0,02

Characteristics and forage value of the vegetation cover

Monitoring plot № 1 - The study was conducted 26 kilometres north of Dossor settlement, Makat district. Soil type – shallow solonetz; terrain – plain; landscape aspect – light brown; water regime – automorphic.

Investigation of the biological characteristics of the vegetation at the monitoring plot revealed that the projective vegetation cover on solonetz soils does not exceed 50% of the total area. The pasture type is biyurgun–ephemeral, as the botanical composition showed that biyurgun accounts for 65% and ephemerals for 35%. In addition to biyurgun, small quantities of bluegrass, Climacoptera, Tatar rhubarb and Petrosimonia occur on the solonetz soils. The available edible forage is 6,1 c/ha. The content of feed units is 0,54, digestible protein – 15,20%, fat – 1,63%, fibre – 34,80%, and metabolizable energy – 7,80 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №1: N 47º706’25; E 052º878’58.

Study site №2. A soil pit was excavated in Makhambet district, Atyrau region, 3 km west of the Uralsk–Atyrau highway, on the right bank of the Oral River (27.08.2024). Soil pit coordinates: N47°887'83, E051°549'40. The terrain is a plain. The land consists of pastures with annual saltwort–biyurgun–wormwood plant communities, including Climacoptera, biyurgun, Tatar rhubarb, etc. The landscape aspect is yellowish brown. Shallow solonetz soils have developed under these plant species and are characterized by the following morphogenetic features (Figure 5).

0-11 cm Light grey, dry, layered-cloddy, loam, slightly compacted, effervesces vigorously, finely porous, fine roots, abrupt transition in colour and density;

12-25 cm Greyish brown, dry, dense, columnar-cloddy, heavy loam, fine roots, effervesces vigorously with HCl, gradual transition;

26-43 cm Brown, fresh, dense, cloddy, effervesces vigorously, finely porous, heavy loam, small roots, discernible transition in density;

44-65 cm Light brown, fresh, cloddy, loamy, effervesces vigorously with HCl, slightly compacted, clear transition;

66-130 cm Yellowish, with abundant carbonate and salt veins, fresh, structureless, slightly compacted, effervesces vigorously with HCl, loamy.





Figure 5 – Profile structure and surface condition of shallow solonetz

The physicochemical properties of the soils are presented in Tables 4, 5, 6.

Table 4 – Chemical and physicochemical properties of shallow solonetz

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
2	0-10	0,69	0,07	2,04	1,96	1,47	1,13	0,79	5,35	8,77
	15-25	0,83	0,14	2,41	3,43	9,31	10,67	0,05	23,46	8,23
	30-40			4,04	3,92	11,27	12,58	0,05	27,82	7,91
	50-60			3,68	12,74	8,33	15,79	0,03	36,89	7,55
	90-100			2,04	14,7	8,82	7,45	0,02	30,99	7,47

Table 5 - Particle-size distribution of shallow solonetz

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay,
			1,0	0,25-	0,05-	0,01-	0,005-	<0,001	

			-0,25	0,05	0,01	0,005	0,001		<0,01
2	0-10	0,24	2,285	30,353	58,140	1,203	0,802	7,217	9,222
	15-25	2,58	1,519	48,388	26,689	3,695	11,086	8,622	23,404
	30-40	2,48	1,025	47,293	24,200	3,281	20,509	3,692	27,482
	50-60	2,78	0,432	56,778	36,618	0,823	3,292	2,057	6,172
	90-100	2,64	0,534	69,885	25,883	0,822	1,643	1,233	3,698

Table 6 – Composition of water-soluble salts in shallow solonetz, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
2	0-10	0,075	0,044	0,002	0,003	0,006	0,002	0,001	0,013	0,007
			0,72	0,08	0,07	0,13	0,09	0,09	0,57	0,17
	15-25	0,502	0,049	0,002	0,224	0,048	0,004	0,006	0,171	0,001
			0,80	0,08	6,32	1,00	0,19	0,46	7,45	0,02
	30-40	0,766	0,022	0,000	0,454	0,001	0,013	0,016	0,258	0,001
			0,36	0,00	12,81	0,03	0,65	1,30	11,24	0,02
	50-60	1,403	0,012	0,000	0,550	0,370	0,120	0,056	0,293	0,001
			0,20	0,00	15,52	7,70	6,02	4,63	12,75	0,02
	90-100	1,875	0,010	0,000	0,390	0,886	0,250	0,062	0,276	0,001
			0,16	0,00	11,01	18,45	12,50	5,09	11,99	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot № 2 - The second monitoring plot is located 120 kilometres north of Atyrau towards Uralsk and 3 kilometres west of the Atyrau–Uralsk highway, in Makhambet district. Soil type – shallow solonetz; terrain – plain; landscape aspect – yellowish brown; water regime – automorphic.

Total projective vegetation cover on the solonetz soils is only 35% of the total area. The pasture type is annual saltwort–biyurgun–wormwood. The botanical composition comprises Climacoptera – 50%, biyurgun – 20%, wormwood – 20%, and mortuk – 10%. Isolated Tatar rhubarb plants also occur, along with the inedible plant itsigek. The available edible forage is 5,5 c/ha. The content of feed units is 0,57, digestible protein – 11,80%, fat – 2,93%, fibre – 30,70%,

and metabolizable energy – 7,82 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №2: N 47º887’80; E 051º749’61,

Study site №3. A soil pit was excavated in Isatay district, Atyrau region, 10 km northwest of Yergaliyev settlement (28.08.2024). Soil pit coordinates: N47°338'70, E051°114'70. The terrain is a plain. The land is used as pasture with a biyurgun–ephemeral plant community. It includes the following plants: biyurgun itself, mortuk, Petrosimonia, Climacoptera and others. These plants give the landscape a greenish-yellowish aspect. Unlike the previous survey sites, crusted solonetz soils occur here. A description of their morphogenetic features is provided below to characterize their profile structure:

0-4 cm Whitish grey, dry, layered-platy, porous, dense, loam, effervesces vigorously with HCl, fine roots, abrupt transition in colour and structure;

5-16 cm Dark brown with carbonate mottles, dry, dense, heavy loam, small roots, columnar, effervesces vigorously with HCl, discernible transition;

17-43 cm Brown with carbonate and salt veins, fresh, cloddy, slightly compacted, isolated fine roots, effervesces with HCl, carbonate and salt veins, discernible transition;

44-64 cm Darker than the preceding horizon, fresh, slightly compacted, medium loam, abundant carbonate and salt mottles and veins, effervesces vigorously with HCl, cloddy, gradual transition;

65-120 cm Brown with a rusty tinge, fresh, structureless, slightly compacted, loamy, effervesces vigorously, abundant salt and carbonate mottles, isolated dark channels, manganese mottles (Figure 6).

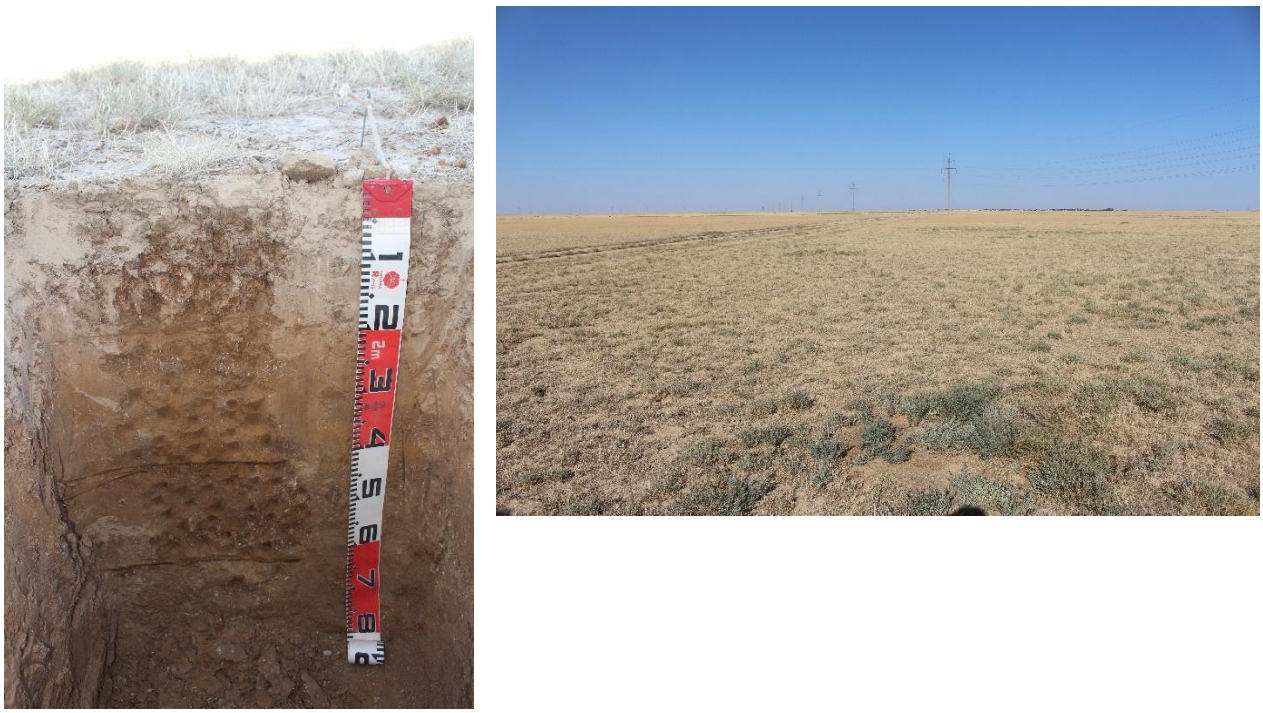


Figure 6 – Profile structure and surface condition of crusted solonetz

The physicochemical properties of the soils are presented in Tables 7, 8, 9.

Table 7 – Chemical and physicochemical properties of crusted solonetz

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
3	0-4	0,86	0,070	3,51	4,90	1,96	0,61	0,35	7,82	8,28
	5-15	0,79	0,098	4,11	5,39	6,86	4,20	0,2	16,65	8,40
	25-35	0,17	0,028	2,34	10,29	11,76	9,38	0,08	31,51	7,54
	50-60			2,21	13,23	11,76	18,99	0,06	44,04	7,54
	100-110			3,15	8,82	11,76	21,56	0,08	42,22	7,63

Table 8 - Particle-size distribution of crusted solonetz

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
3	0-4	0,94	3,230	68,908	20,190	1,211	4,038	2,423	7,672

	5-15	2,74	0,288	38,022	25,910	2,468	26,321	6,992	35,780
	25-35	1,80	0,265	61,039	32,587	2,444	3,259	0,407	6,110
	50-60	3,12	6,069	46,036	36,746	7,019	3,303	0,826	11,148
	100-110	1,02	0,162	52,960	31,522	6,870	5,658	2,829	15,357

Table 9 – Composition of water-soluble salts in crusted solonetz, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
3	0-4	0,080	0,034	0,002	0,009	0,013	0,004	0,002	0,015	0,003
			0,56	0,08	0,25	0,27	0,19	0,19	0,64	0,07
	5-15	0,534	0,081	0,010	0,108	0,167	0,006	0,001	0,171	0,001
			1,32	0,32	3,03	3,49	0,28	0,09	7,45	0,02
	25-35	2,037	0,010	0,000	0,397	0,995	0,250	0,073	0,311	0,002
			0,16	0,00	11,19	20,72	12,50	6,02	13,51	0,04
	50-60	2,439	0,007	0,000	0,717	0,924	0,306	0,084	0,398	0,003
			0,12	0,00	20,21	19,26	15,28	6,95	17,30	0,07
	100-110	1,907	0,010	0,000	0,653	0,616	0,167	0,079	0,380	0,002
			0,16	0,00	18,41	12,84	8,33	6,48	16,54	0,05

Characteristics and forage value of the vegetation cover

Monitoring plot № 3 is located 10 kilometres northwest of Khamit Yergaliyev settlement and 70 kilometres from Atyrau, in Isatay district. Soil type – crusted solonetz; terrain – flat; landscape aspect – greenish-yellowish; water regime – automorphic.

Projective vegetation cover on the solonetz soils is 55%. The pasture type is biyurgun–ephemeral. Investigation of the botanical composition revealed that biyurgun accounts for 80% and ephemerals for 20% of the total area. Mortuk, Petrosimonia and Climacoptera also occur in the vegetation. The available edible forage is 2,5 c/ha. The content of feed units is 0,57, digestible protein – 12,60%, fat – 3,92%, fibre – 34,50%, and metabolizable energy – 8,38 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №3: N 47º338’69; E 051º114’70.

Study site №4. A soil pit was excavated in Zhylyoi district, Atyrau region, 3 km southeast of Kosshagyl settlement (28.08.2024). Soil pit coordinates: N46°822'40, E 053°801'95. The terrain is a plain with a saucer-shaped depression. The land consists of pastures with biyurgun–saltwort plant communities, including biyurgun, mortuk, wormwood, Ceratocephala and Climacoptera. They give the landscape a greyish-greenish aspect. The soil cover in microdepressions consists of shallow solonetz soils with the following morphogenetic horizon features.

0-10 cm Light grey, dry, layered-cloddy-silty, loam, slightly compacted, fine roots, finely porous, effervesces vigorously with HCl, abrupt transition in colour and density;

11-21 cm Light brown, dry, dense, penetrated by roots, heavy loam, effervesces moderately with HCl, prismatic-cloddy, clear transition;

22-33 cm Brown, dry, dense, cloddy, isolated fine roots, medium loam, effervesces vigorously with HCl, gradual transition;

34-47 cm Brown with salt and carbonate veins and mottles, fresh, compacted, cloddy, effervesces vigorously with HCl, discernible transition in density;

48-120 cm Yellowish brown, fresh, slightly compacted, loamy, effervesces vigorously with HCl, structureless, salt and carbonate veins and mottles (Figure 7).

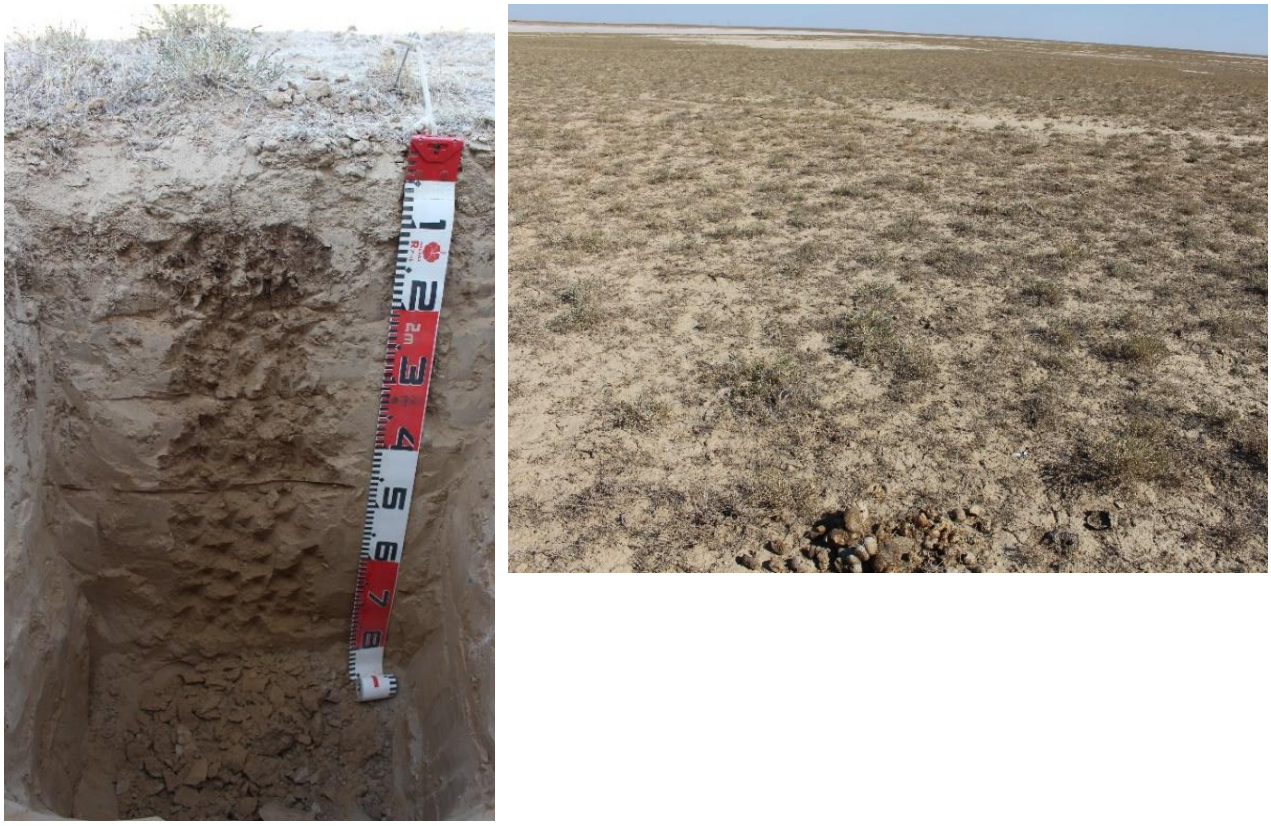


Figure 7 – Profile structure and surface condition of shallow solonetz

The physicochemical properties of the soils are presented in Tables 10, 11, 12.

Table 10 – Chemical and physicochemical properties of shallow solonetz

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
4	0-10	0,40	0,042	1,74	1,96	0,98	0,65	0,15	3,74	8,65
	10-20	0,33	0,042	2,34	3,92	2,45	4,09	0,05	10,51	8,47
	20-30	0,26	0,056	2,51	1,96	2,94	4,00	0,05	8,95	8,40
	35-45			3,04	26,46	1,96	19,65	0,01	48,08	7,81
	90-100			1,67	20,58	5,88	0,98	0,01	27,45	7,71

Table 11 - Particle-size distribution of shallow solonetz

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	

4	0-10	0,88	16,142	58,434	20,178	3,228	1,211	0,807	5,246
	10-20	3,36	8,030	46,854	22,351	2,070	14,073	6,623	22,765
	20-30	1,42	8,399	52,242	19,477	3,652	14,607	1,623	19,882
	35-45	1,88	9,193	65,124	12,638	1,223	10,192	1,631	13,045
	90-100	0,70	11,138	72,749	13,293	0,806	0,403	1,611	2,820

Table 12 – Composition of water-soluble salts in shallow solonetz, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
4	0-10	0,068	0,024	0,002	0,003	0,020	0,004	0,001	0,013	0,002
			0,40	0,08	0,07	0,43	0,19	0,09	0,56	0,06
	10-20	0,444	0,049	0,007	0,111	0,131	0,002	0,001	0,149	0,001
			0,80	0,24	3,14	2,74	0,09	0,09	6,47	0,02
	20-30	0,532	0,046	0,005	0,154	0,147	0,004	0,002	0,178	0,001
			0,76	0,16	4,33	3,05	0,19	0,19	7,76	0,02
	35-45	1,466	0,020	0,000	0,269	0,708	0,172	0,029	0,267	0,001
			0,32	0,00	7,58	14,75	8,60	2,42	11,60	0,03
	90-100	1,549	0,015	0,000	0,256	0,788	0,205	0,032	0,252	0,002
			0,24	0,00	7,22	16,41	10,27	2,60	10,96	0,04

Characteristics and forage value of the vegetation cover

Monitoring plot № 4 is located 3 kilometres southeast of Kosshagyl settlement and 40 kilometres southwest of Kulsary settlement, in Zhylyoi district. Soil type – shallow solonetz; terrain – plain with a saucer-shaped depression; landscape aspect – greyish-greenish; water regime – automorphic.

Investigation of the vegetation cover showed that projective plant cover is 35-40%. The pasture type is biyurgun–saltwort. The botanical composition of this area comprises biyurgun – 55%, Climacoptera – 30%, mortuk – 10%, and wormwood – 5%. Plants such as Ceratocephala, Climacoptera and itsigek also occur. Plants not eaten by livestock, namely itsigek and

Ceratocephala, occupy 2% of the area. The available edible forage is 6,0 c/ha. The content of feed units is 0,53, digestible protein – 12,60%, fat – 2,10%, fibre – 32,40%, and metabolizable energy – 7,51 MJ per 1 kg of pasture forage.

Coordinates of the boundary of study site №4: N 46º49’18,5; E 053º48’06,9

Study site №5. A soil pit was excavated in Zhylyoi district, Atyrau region, 7 km southeast of Kosshagyl settlement (28.08.2024). Soil pit coordinates: N46°815'82, E 053°785'98. The surface morphology is a plain. The land consists of natural pastures characterized by a biyurgun–bluegrass plant community. Its composition includes biyurgun itself, mortuk, isolated pepperweed, fenugreek and Ceratocephala. These plants give the landscape a greyish-pale-greenish aspect. Unlike the previous study sites, medium solonetz soils occur here, with their characteristic morphogenetic profile features. Their description is presented below.

0-13 cm Light grey with a whitish tinge, dry, layered-scaly-silty, sandy loam, slightly compacted, effervesces vigorously, porous, fine roots, abrupt transition in colour and density;

14-24 cm Dark brown, dry, dense, cloddy-prismatic, effervesces vigorously with HCl, isolated fine roots, heavy loam, clear transition;

25-34 cm Brown, fresh, cloddy, compacted, fine roots, loamy, effervesces vigorously with HCl, small salt veins, discernible transition in density;

35-57 cm Brown, fresh, cloddy, loamy, slightly compacted, small roots, effervesces vigorously with HCl, salt mottles, gradual transition;

58-120 cm Greyish brown, fresh, structureless, loamy, abundant veins and mottles, slightly compacted, dark wedge-shaped inclusions, effervesces vigorously with HCl

(Figure 8).





Figure 8 – Profile structure and surface condition of medium solonetz soils

The physicochemical properties of the soils are presented in Tables 13, 14, 15.

Table 13 – Chemical and physicochemical properties of medium solonetz soils

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
5	0-10	0,26	0,042	2,91	0,49	0,98	0,31	0,12	1,90	8,74
	14-24	0,36	0,056	2,04	1,96	2,94	15,16	0,1	20,16	8,15
	25-35			5,01	3,43	7,35	15,79	0,07	26,64	7,94
	40-50			4,04	10,29	6,37	19,63	0,05	36,34	7,64
	80-90			5,08	2,94	6,37	24,12	0,02	33,45	7,76

Table 14 - Particle-size distribution of medium solonetz soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	

5	0-10	0,34	8,449	66,265	16,456	0,401	7,225	1,204	8,830
	14-24	1,28	4,558	30,612	39,708	2,431	19,449	3,241	25,122
	25-35	2,32	2,764	30,487	19,247	7,371	32,760	7,371	47,502
	40-50	2,66	2,281	52,928	27,532	4,109	7,808	5,342	17,259
	80-90	2,34	2,621	43,723	25,394	4,505	20,479	3,277	28,261

Table 15 – Composition of water-soluble salts in medium solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
5	0-10	0,246	0,029	0,005	0,045	0,089	0,002	0,001	0,075	0,005
			0,48	0,16	1,26	1,85	0,09	0,09	3,27	0,14
	14-24	0,746	0,034	0,002	0,346	0,090	0,006	0,003	0,267	0,001
			0,56	0,08	9,75	1,87	0,28	0,28	11,60	0,02
	25-35	1,079	0,027	0,001	0,627	0,012	0,019	0,008	0,385	0,002
			0,44	0,04	17,69	0,24	0,93	0,65	16,73	0,06
	40-50	1,428	0,020	0,000	0,595	0,305	0,083	0,023	0,400	0,003
			0,32	0,00	16,78	6,36	4,16	1,86	17,38	0,07
	80-90	1,121	0,024	0,000	0,659	0,008	0,017	0,011	0,400	0,001
			0,40	0,00	18,59	0,18	0,83	0,93	17,38	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot №5 is located 7 kilometres southeast of Kosshagyl settlement and 47 kilometres south of Kulsary settlement, in Zhylyoi district. Soil type – medium solonetz; terrain – flat; landscape aspect – greyish-pale-greenish; water regime – automorphic.

Field study results show that projective plant cover is 55% of the total area. The pasture type is biyurgun–bluegrass. Investigation of the botanical composition showed that biyurgun occupies 60%, bluegrass – 15%, mortuk – 10%, and fenugreek – 15% of the area. Isolated pepperweed and Ceratocephala plants also occur; the latter is inedible. The available edible forage is 7,3 c/ha. The content of feed units is 0,55, digestible protein – 11,50%, fat – 3,73%, fibre – 30,40%, and metabolizable energy – 7,53 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №5: N 46º48’57,3; E 053º47’10,2

Mangystau region:

Study site №6. A soil pit was excavated in Mangystau district, Mangystau region, 5 km south of the Beineu–Shetpe highway and northeast of Saiotes settlement (29.08.2024). Soil pit coordinates: N44°485'67, E 053°914'75. The terrain is a plain, with pasture land on solonetzic grey-brown soils. The vegetation includes mortuk, wormwood, itsigek and other plants, giving the landscape a greyish-greenish aspect. Solonetzic grey-brown soils have developed in this locality and differ from solonetz soils in the following morphogenetic features.

0-6 cm Light grey, silty, dry, weakly coherent, cloddy-silty, loose, loamy, effervesces vigorously with HCl, penetrated by roots, porous clods, abrupt transition in colour;

7-25 cm Light greyish, dry, cloddy, slightly compacted, loamy, effervesces vigorously with HCl, fine roots, gradual transition;

26-42 cm Light brown, fresh, cloddy, slightly compacted, fine roots, effervesces vigorously with HCl, loamy, gradual transition;

43-64 cm Greyish brown, fresh, cloddy, compacted, loamy, isolated small roots, carbonate mottles, effervesces vigorously with HCl, abrupt transition in density;

65-85 cm Carbonate layer, whitish-yellowish, fresh, structureless, dense, effervesces vigorously with HCl, loamy, clear transition;

86-130 cm Greyish-yellowish, fresh, structureless, effervesces vigorously with HCl, carbonate and salt mottles, loamy, slightly compacted

(Figure 9).





Figure 9 – Profile structure and surface condition of solonetzic grey-brown soils

The physicochemical properties of the soils are presented in Tables 16, 17, 18.

Table 16 – Chemical and physicochemical properties of solonetzic grey-brown soils

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
6	0-6	0,95	0,112	4,04	5,39	1,47	0,28	0,93	8,07	8,16
	10-20	0,56	0,056	5,45	4,9	2,94	0,14	0,5	8,48	8,16
	30-40			7,55	5,39	4,9	0,14	0,05	10,48	8,04
	50-60			7,52	6,86	7,35	1,11	0,05	15,37	8,04
	70-80			3,17	7,35	14,7	0,61	0,05	22,71	7,49
	110-120			2,67	8,82	12,74	1,11	0,05	22,72	7,59

Table 17 - Particle-size distribution of solonetzic grey-brown soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	

6	0-6	0,58	6,276	53,088	34,601	0,402	2,816	2,816	6,035
	10-20	0,20	10,361	45,551	38,878	0,401	2,806	2,004	5,210
	30-40	0,70	5,156	52,548	27,392	5,639	8,056	1,208	14,904
	50-60	1,38	3,630	52,565	23,930	2,434	8,112	9,329	19,874
	70-80	2,64	12,551	54,992	23,418	1,233	4,108	3,698	9,039
	110-120	1,18	15,746	53,491	24,691	0,810	1,619	3,643	6,072

Table 18 – Composition of water-soluble salts in solonetzic grey-brown soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
6	0-6	0,059	0,024	0,000	0,000	0,017	0,006	0,002	0,001	0,010
			0,40	0,00	0,00	0,35	0,28	0,19	0,04	0,25
	10-20	0,039	0,024	0,000	0,001	0,002	0,004	0,001	0,002	0,004
			0,40	0,00	0,04	0,04	0,19	0,09	0,10	0,10
	30-40	0,080	0,024	0,000	0,005	0,028	0,006	0,003	0,013	0,001
			0,40	0,00	0,14	0,59	0,28	0,28	0,56	0,02
	50-60	0,266	0,029	0,000	0,028	0,123	0,007	0,002	0,075	0,001
			0,48	0,00	0,79	2,57	0,37	0,19	3,27	0,02
	70-80	1,488	0,015	0,000	0,027	1,043	0,232	0,096	0,075	0,001
			0,24	0,00	0,76	21,73	11,58	7,87	3,27	0,02
	110-120	1,624	0,012	0,000	0,027	1,143	0,250	0,101	0,090	0,001
			0,20	0,00	0,76	23,80	12,50	8,33	3,91	0,02

Characteristics and forage value of the vegetation cover

Monitoring plot № 6 is located 5 kilometres south of the Beineu–Shetpe highway, in Mangystau district. Soil type – solonetzic grey-brown; terrain – flat; landscape aspect – greyish-greenish; water regime – automorphic.

Data obtained from studying the biological characteristics of the vegetation showed that projective vegetation cover is 60% of the total area. The pasture type is ephemeral–wormwood–saltwort. The botanical composition is dominated by ephemerals – 70%, wormwood – 20%, and saltworts – 10% of the area, and includes plants such as mortuk, wormwood and itsigek. The available edible forage is 7,5 c/ha. The content of feed units is 0,64, digestible protein – 15,80%, fat – 4,53%, fibre – 23,10%, and metabolizable energy – 8,78 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №6: N 44º29’08,4; E 053º54’53,2

Study site №7. A soil pit was excavated (29.08.2024) in Mangystau district, Mangystau region, 6,5 km east of the Beineu–Shetpe highway. Soil pit coordinates: N44°472'88, E053°965'15. The landscape aspect is greyish-greenish (Figure 10). Automorphic medium solonetz soils occur here on flat terrain under a wormwood–biyurgun–ephemeral–saltwort vegetation community (wormwood, biyurgun, mortuk, itsigek, Climacoptera).

The morphological features of the genetic horizons are presented below to characterize these soils:

0-12 cm light grey, dry, loose, cloddy-silty, layered, penetrated by roots, effervesces vigorously, light loam, abrupt transition in colour and density;

13-30 cm grey-brown with a whitish tinge, dry, dense, columnar-prismatic, heavy loam, small roots, effervesces vigorously with HCl, abundant carbonate mottles, gradual transition;

31-52 cm brown, fresh, dense, cloddy, heavy loam, salt and carbonate veins, effervesces vigorously with HCl, decomposed small plant roots, gradual transition;

53-76 cm darker than the preceding horizon, fresh, compacted, cloddy, loamy, decomposed small plant roots, effervesces vigorously with HCl, salt and carbonate veins and mottles, discernible transition;

78-110 cm light brown, fresh, structureless, slightly compacted, carbonate mottles, loamy (Figure 10).

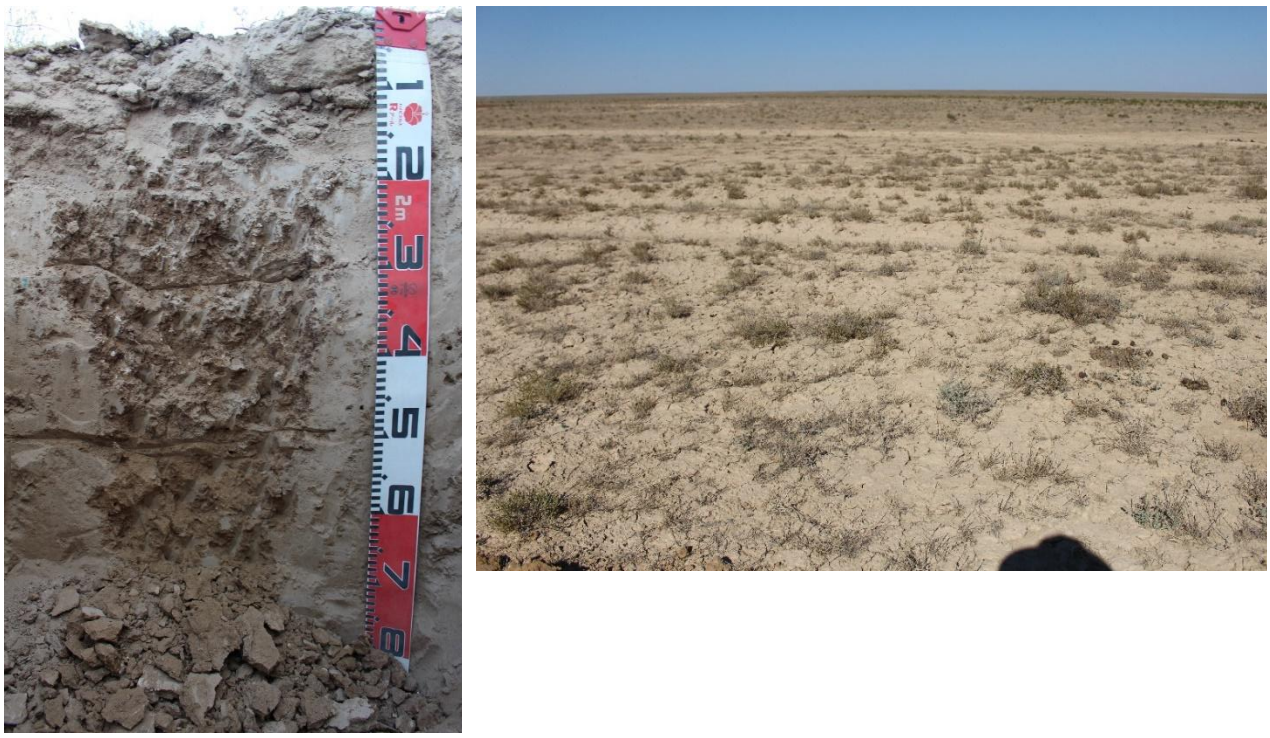


Figure 10 – General surface view and profile structure of medium solonetz soils at the surveyed site

The descriptions of the medium solonetz profile indicate that it consists of several horizons, among which the solonetzic horizon is distinctly different. It has a dense fabric, a columnar-prismatic structure and a heavy texture. The soil effervesces vigorously with hydrochloric acid throughout the profile. This is associated with carbonates, which are clearly visible as veins and mottles from a depth of 13 cm. Readily soluble salts with a whiter colour also occur together with them. The upper organogenic horizon (0-12 cm) has a light grey colour and a loose, layered fabric, characteristic of soils in arid areas.

Analysis of the biological data obtained during the field study indicates that projective vegetation cover is 40% of the total area. The pasture type is wormwood–biyurgun–ephemeral–saltwort, with plants such as wormwood, biyurgun, Climacoptera, mortuk, pepperweed and itsigek. The botanical composition consists mainly of wormwood – 45%, biyurgun – 20%, ephemerals – 25%, and saltworts – 10%. Pasture biomass yield is 5,5 c/ha.

The physicochemical properties of the soils are presented in Tables 19, 20, 21.

Table 19 – Chemical and physicochemical properties of shallow solonetz

Soil pit №	sample, of	Humus, %	Total nitrogen,	CO_2,%	Exchangeable bases, meq/100 g	pH (water)

			%		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
7	0-10	0,65	0,07	7,39	3,43	1,96	0,01	0,42	5,82	8,24
	20-30	0,62	0,07	6,92	4,90	6,85	0,42	0,16	12,33	7,89
	40-50			6,82	7,84	7,84	0,95	0,16	16,79	7,67
	60-70			7,52	1,96	7,35	2,04	0,16	11,51	7,44
	80-90			6,08	15,68	5,88	0,19	0,16	21,91	7,32

Table 20 - Particle-size distribution of medium solonetz soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
7	0-10	0,26	3,429	69,300	17,646	1,604	6,016	2,005	9,625
	20-30	0,90	2,583	45,752	30,676	2,422	16,549	2,018	20,989
	40-50	1,64	2,033	67,060	14,233	8,947	6,507	1,220	16,673
	60-70	1,18	2,752	43,007	33,192	5,262	14,167	1,619	21,048
	80-90	0,54	0,945	68,490	15,685	5,228	7,239	2,413	14,880

Table 21 – Composition of water-soluble salts in medium solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
7	0-10	0,064	0,032	0,002	0,001	0,011	0,004	0,001	0,006	0,010
			0,52	0,08	0,04	0,22	0,19	0,09	0,24	0,26
	20-30	0,529	0,024	0,000	0,151	0,172	0,009	0,008	0,164	0,001
			0,40	0,00	4,26	3,59	0,46	0,65	7,12	0,02
7	40-50	0,890	0,020	0,000	0,256	0,317	0,050	0,024	0,223	0,001
			0,32	0,00	7,22	6,61	2,50	1,95	9,68	0,02

	60-70	0,642	0,022	0,002	0,137	0,268	0,011	0,010	0,193	0,001
			0,36	0,08	3,86	5,58	0,56	0,84	8,40	0,02
	80-90	1,059	0,020	0,000	0,179	0,523	0,085	0,028	0,223	0,001
			0,32	0,00	5,05	10,90	4,26	2,32	9,68	0,02

Characteristics and forage value of the vegetation cover

Monitoring plot № 7 is located 7 kilometres south of the Beineu–Shetpe highway, within Mangystau district. Soil type – medium solonetz; terrain – flat; landscape aspect – greyish-greenish; water regime – automorphic. Analysis of the field study data showed that projective vegetation cover is 40% of the total area. The pasture type is wormwood–biyurgun–ephemeral–saltwort, with plants such as wormwood, biyurgun, Climacoptera, mortuk, pepperweed and itsigek. The botanical composition consists mainly of wormwood – 45%, biyurgun – 20%, ephemerals – 25%, and saltworts – 10%. The available edible forage is 5,5 c/ha. The content of feed units is 0,59, digestible protein – 10,0%, fat – 5,67%, fibre – 27,80%, and metabolizable energy – 7,85 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №7: N 44º28’20,4; E 053º57’53,4.

Study site №8. A soil pit was excavated (30.08.2024) in Mangystau district, 11 km south of Shetpe settlement and 1 km west of the Shetpe–Aktau highway. Soil pit coordinates: N44°061'51, E052°194'03. The terrain is a plain with a saucer-shaped depression. The pasture plant community is wormwood–ephemeral, consisting of wormwood, mortuk, bluegrass, itsigek and isolated southern saltwort plants. They give the landscape a greyish-greenish aspect. Shallow solonetz soils developed under these plants and have the following morphogenetic features.

0-10 cm Light grey, scaly-layered, dry, light loam, slightly compacted, penetrated by roots, effervesces vigorously, abrupt transition in colour and density;

11-31 cm Grey-brown, dry, cloddy-prismatic, dense, carbonate-rich, fine roots, heavy loam, effervesces vigorously with HCl, gradual transition;

32-48 cm Brown, fresh, cloddy, compacted, effervesces vigorously with HCl, isolated fine roots, loamy, gradual transition;

49-67 cm Lighter than the preceding horizon, fresh, cloddy, compacted, effervesces vigorously with HCl, isolated fine roots, loamy, carbonate mottles, clear transition;

68-100 cm Brown with a dark brown tinge, fresh, dense, effervesces vigorously with HCl, salt veins and carbonate mottles, loamy, structureless

(Figure 11).

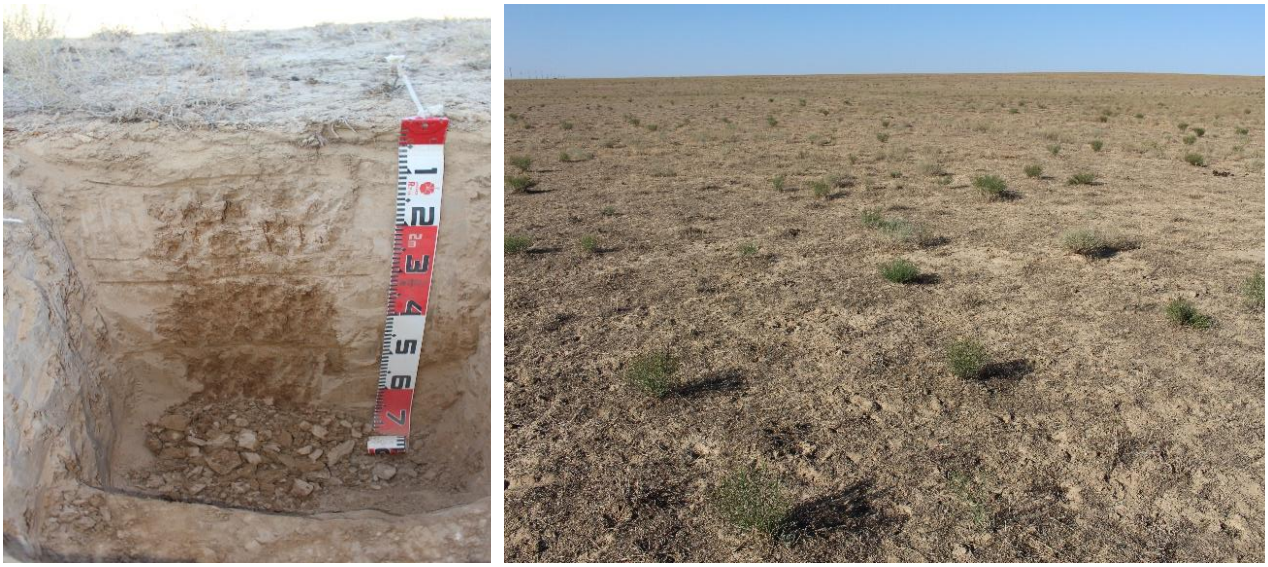


Figure 11 – General surface view and profile structure of shallow solonetz soils at the surveyed site

The physicochemical properties of the soils are presented in Tables 22, 23, 24.

Table 22 – Chemical and physicochemical properties of shallow solonetz soils

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
8	0-10	0,63	0,084	3,74	4,41	3,92	0,12	0,18	8,63	7,88
	20-30	0,36	0,070	7,19	3,43	5,39	1,53	0,16	10,51	8,36
	35-45			4,55	1,96	7,35	2,50	0,16	11,97	8,19
	50-60			4,88	1,47	8,82	1,56	0,16	12,01	8,00
	70-80			6,55	8,33	7,84	14,23	0,16	30,56	7,57

Table 23 - Particle-size distribution of shallow solonetz soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
8	0-10	0,36	1,867	58,792	28,503	4,817	5,620	0,401	10,839
	20-30	1,72	0,366	60,562	20,757	3,256	12,210	2,849	18,315

	35-45	0,64	0,302	44,143	30,193	16,103	6,039	3,221	25,362
	50-60	1,40	0,690	43,327	27,586	5,274	16,633	6,491	28,398
	70-80	1,64	0,407	30,460	41,074	12,607	13,013	2,440	28,060

Characteristics and forage value of the vegetation cover. Monitoring plot № 8 is located 11 kilometres south of Shetpe settlement and 1 kilometre west of the Shetpe–Aktau highway, in Mangystau district. Soil type – shallow solonetz; terrain – plain with a saucer-shaped depression; landscape aspect – greyish-greenish; water regime – automorphic. Projective vegetation cover at this site is 55-60% of the total area. The pasture type is wormwood–ephemeral. The botanical composition comprises wormwood – 50%, bluegrass – 20%, mortuk – 23%, and itsigek – 7% of the area. Southern saltwort, Alyssum and biyurgun also occur. The available edible forage is 3,5 c/ha. The content of feed units is 0,65, digestible protein – 13,50%, fat – 5,52%, fibre – 20,60%, and metabolizable energy – 8,76 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №8: N 44º28’20,4; E 053º57’53,4.

Table 24 – Composition of water-soluble salts in shallow solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
8	0-10	0,043	0,024	0,000	0,000	0,007	0,006	0,001	0,002	0,003
			0,40	0,00	0,00	0,14	0,28	0,09	0,10	0,07
	20-30	0,452	0,063	0,010	0,114	0,121	0,002	0,002	0,149	0,001

			1,04	0,32	3,21	2,52	0,09	0,19	6,47	0,02
	35-45	0,540	0,039	0,005	0,173	0,140	0,004	0,006	0,178	0,001
			0,64	0,16	4,87	2,91	0,19	0,46	7,76	0,02
	50-60	0,533	0,034	0,002	0,224	0,083	0,006	0,007	0,178	0,001
			0,56	0,08	6,32	1,73	0,28	0,56	7,76	0,02
	70-80	0,869	0,020	0,000	0,262	0,295	0,063	0,020	0,208	0,001
			0,32	0,00	7,40	6,15	3,15	1,67	9,04	0,02

Study site №9. A soil pit was excavated in Mangystau district, 5 km southwest of the Shetpe–Zhetybai highway (30.08.2024). Soil pit coordinates: N43°681'74, E052°116'31. The surveyed site has flat terrain with wormwood–keyreuk–biyurgun plant communities. Wormwood, keyreuk, biyurgun, mortuk and other plants form the pasture vegetation and give the landscape a greyish aspect with a brown tinge. Solonetzic grey-brown soils with their characteristic morphogenetic features have developed beneath them. Their description follows.

0-24 cm Light grey, dry, cloddy-silty, slightly compacted, silty and layered at the surface, loamy, effervesces vigorously with HCl, penetrated by fine roots, gradual transition;

25-39 cm Light brown, dry, cloddy, with signs of solonetzicity, loamy, fine roots, effervesces vigorously with HCl, carbonate mottles, compacted, discernible transition;

40-56 cm Light brown with whitish mottles, fresh, cloddy, loamy, compacted, breaks into large clods during excavation, effervesces vigorously, isolated small roots, discernible transition;

57-77 cm Light brown with accumulated gypsum crystal clusters, fresh, slightly compacted, light loam, effervesces vigorously with HCl, structureless, gradual transition, carbonate mottles;

78-120 cm Lighter than the preceding horizon, fresh, small gypsum crystals present, carbonate mottles, effervesces vigorously, light loam, structureless, slightly compacted (Figure 12).



Figure 12 – General surface view and profile structure of solonetzic grey-brown soils

The physicochemical properties of the soils are presented in Tables 25, 26, 27.

Table 25 – Chemical and physicochemical properties of solonetzic grey-brown soils

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
9	10-20	0,53	0,084	10,03	5,39	1,47	0,26	0,83	7,95	8,18
	25-35	0,33	0,070	10,69	4,41	5,39	2,03	0,16	11,99	8,17
	45-55			16,28	7,35	7,84	0,93	0,16	16,28	7,88
	60-70			5,51	8,33	9,31	1,15	0,16	18,95	7,65
	90-100			6,68	9,31	8,33	0,05	0,16	17,85	7,63

Table 26 - Particle-size distribution of solonetzic grey-brown soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
9	10-20	1,00	12,990	61,960	19,798	1,616	3,232	0,404	5,253
	25-35	1,62	7,420	55,580	20,736	7,319	4,066	4,879	16,263
	45-55	1,48	11,064	35,343	35,323	12,586	2,030	3,654	18,270
	60-70	0,40	0,442	68,635	22,088	0,402	3,614	4,819	8,835
	90-100	2,80	24,115	51,193	16,049	6,173	1,235	1,235	8,642

Table 27 – Composition of water-soluble salts in solonetzic grey-brown soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
9	10-20	0,374	0,024	0,000	0,000	0,229	0,006	0,001	0,105	0,010
			0,40	0,00	0,00	4,77	0,28	0,09	4,55	0,25
	25-35	0,253	0,032	0,000	0,032	0,107	0,004	0,002	0,075	0,001
			0,52	0,00	0,90	2,23	0,19	0,19	3,27	0,02
	45-55	0,641	0,020	0,000	0,127	0,288	0,031	0,014	0,164	0,001
			0,32	0,00	3,50	6,00	1,57	1,12	7,12	0,02
	60-70	1,491	0,012	0,000	0,078	0,971	0,269	0,056	0,105	0,001
			0,20	0,00	2,20	20,22	13,43	4,63	4,55	0,02
	90-100	1,805	0,010	0,000	0,115	1,175	0,278	0,107	0,119	0,001
			0,16	0,00	3,25	24,49	13,89	8,80	5,19	0,02

Characteristics and forage value of the vegetation cover

Monitoring plot № 9 is located 5 kilometres southwest of the Shetpe–Zhetybai highway, in Mangystau district. Soil type – solonetzic grey-brown; terrain – flat; landscape aspect – greyish with a brown tinge; water regime – automorphic.

Projective vegetation cover at this site is 60% of the total area. The pasture type is wormwood–keyreuk–biyurgun. The botanical composition comprises wormwood – 60%, keyreuk – 25%, biyurgun – 10%, and mortuk – 5% of the area. Isolated Ceratocephala plants

also occur, occupying 0,2% of the area and belonging to the inedible plants. The available edible forage is 8,6 c/ha. The content of feed units is 0,58, digestible protein – 14,50%, fat – 3,41%, fibre – 29,50%, and metabolizable energy – 8,17 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №9: N 48º40’54,8; E 052º06’58,9.

Study site №10. A soil pit was excavated in Karakiya district, 1,5 km south of the Zhetybai–Zhanaozen highway (30.08.2024). Soil pit coordinates: N43°344'62, E052°615'25. The locality has flat terrain. The plant community is wormwood–biyurgun, consisting of wormwood, biyurgun, keyreuk, gergentsiyan and adraspan. The landscape aspect is grey. The land is pasture, where solonetzic grey-brown soils occur. Their morphogenetic features are presented below.

0-14 cm Light grey, dry, silty-cloddy, loamy, effervesces vigorously with HCl, penetrated by roots, slightly compacted, clear transition in density;

15-31 cm Darker than the preceding horizon, dry, cloddy, loamy, isolated small roots, effervesces vigorously with HCl, slightly compacted, gradual transition;

32-54 cm Light brown, fresh, cloddy, loamy, small roots, effervesces vigorously with HCl, isolated carbonate mottles, slightly compacted, clear transition;

55-74 cm Brown, fresh, cloddy, loamy, compacted, dead fine roots, effervesces vigorously with HCl, carbonate mottles, clear transition;

75-112 cm Lighter than the preceding horizon, fresh, loamy, compacted, effervesces vigorously with HCl, abundant carbonates, structureless.

(Figure 13).



Figure 13 – General surface view and profile structure of solonetzic grey-brown soils

The physicochemical properties of the soils are presented in Tables 28, 29, 30.

Table 28 – Chemical and physicochemical properties of solonetzic grey-brown soils

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
10	0-10	0,70	0,098	10,56	4,9	2,45	0,14	0,45	7,94	8,19
	20-30	0,36	0,070	10,86	3,43	4,9	0,12	0,31	8,76	8,31
	40-50			11,36	2,94	5,88	1,16	0,16	10,14	8,22
	60-70			14,37	2,45	8,82	0,58	0,16	12,01	8,16
	80-90			16,71	2,94	4,41	0,28	0,18	7,81	7,95

Table 29 - Particle-size distribution of solonetzic grey-brown soils

Soil pit №	Depth, cm	A.S.N. % H_2O	Fraction content as % of oven-dry soil						
			Particle size in mm						
			Sand		Silt			Clay	Physical clay, <0,01
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
10	0-10	0,54	3,921	40,177	39,815	9,652	5,228	1,207	16,087
	20-30	0,60	0,262	62,314	29,376	3,219	3,219	1,610	8,048
	40-50	0,44	7,834	55,605	24,106	7,634	3,214	1,607	12,455
	60-70	0,18	15,508	52,835	20,838	2,004	6,412	2,404	10,819
	80-90	0,12	8,831	59,131	20,425	4,005	6,007	1,602	11,614

Table 30 – Composition of water-soluble salts in solonetzic grey-brown soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal carbonates as CO_3^{-2}						
10	0-10	0,069	0,027	0,000	0,000	0,021	0,006	0,003	0,001	0,011
			0,44	0,00	0,00	0,44	0,28	0,28	0,04	0,29
	20-30	0,077	0,032	0,002	0,000	0,024	0,004	0,005	0,006	0,007
			0,52	0,08	0,00	0,50	0,19	0,37	0,28	0,18
	40-50	0,140	0,027	0,001	0,022	0,050	0,006	0,007	0,028	0,001

			0,44	0,04	0,61	1,04	0,28	0,56	1,23	0,03
	60-70	0,322	0,024	0,001	0,042	0,152	0,007	0,006	0,090	0,001
			0,40	0,04	1,19	3,17	0,37	0,46	3,91	0,02
	80-90	0,338	0,020	0,000	0,052	0,160	0,019	0,011	0,075	0,001
			0,32	0,00	1,48	3,34	0,93	0,93	3,27	0,02

Characteristics and forage value of the vegetation cover

Monitoring plot № 10 is located 1,5 kilometres south of the Zhetybai–Zhanaozen highway and 12 kilometres west of Zhanaozen settlement, in Karakiya district. Soil type – solonetzic grey-brown; terrain – flat; landscape aspect – greyish; water regime – automorphic.

Projective vegetation cover at this site is 45% of the total area. The pasture type is wormwood–biyurgun. The botanical composition comprises wormwood – 75%, keyreuk – 7%, biyurgun – 15%, gergentsion – 2%, and Ceratocephala – 1%. Isolated adraspan plants also occur, indicating the intensity of livestock grazing at this site. The available edible forage is 7,5 c/ha. The content of feed units is 0,62, digestible protein – 9,10%, fat – 5,13%, fibre – 23,40%, and metabolizable energy – 8,08 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №10: N 43º20’39,7; E 052º36’54,1

Turkestan region:

Study site №11. A soil pit was excavated in Turkestan region; soil: desert solonetz. Soil pit coordinates: N 45°01’ 40,9”; E 68 O 51’ 35,5”; H = 196 m. It was excavated on a flat surface under keyreuk–wormwood vegetation (keyreuk, wormwood, teresken, mortuk, tulip). Projective cover – 30-35%. Height – from 10-15 to 30-40 cm. Soil pit depth – 75 cm. A+B=28 cm. Effervescence – from the surface. Carbonates – in the solonetzic horizon. Horizons: A^{k} 0-8 cm; B_1 8-18 cm; B_2 18-28 cm; C_1^{ksn} 28-60 cm; C_2 60-75 cm. Samples collected: 0-8 cm; 8-18 cm; 18-28 cm; 39-49 cm; 65-75 cm (Figure 14).



Figure 14 – Desert solonetz under keyreuk–wormwood vegetation

The profile is characterized by a dense vesicular crust underlain by a subcrustal horizon. The solonetzic horizon is denser and heavier in texture. The parent material is saline.

A^{k} 0-8 cm Grey, strong, vesicular crust, almost without fine roots, light loam

B_1 8-18 cm Greyish-brownish, dry, slightly compacted, with isolated small roots, weakly cloddy-silty, light loam

B_2^{sn} 18-28 cm Greyish brown, dry, dense, with isolated fine roots, silty-cloddy, medium loam

C_1^{ksn} 28-60 cm Brown, dry, very dense, with numerous carbonate mottles and isolated fine roots, coarse-blocky-nutty, clayey

C_2 60-75 cm Bright brown, dry, very dense, coarse-blocky-fine-nutty, clayey

The physicochemical properties of the soils are presented in Tables 31, 32, 33.

Table 31 – Chemical and physicochemical properties of solonetz soils

Soil pit	depth	Humus	Total	CO_2,	Exchangeable bases, meq/100 g	pH

№		, %	nitrogen, %	%	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	(water)
11	0-8	0,5	0,056	3,7	3,5	2,25	1,48	0,3	7,5	9,7
	8-18	0,37	0,028	2,2	4,0	2,0	1,56	0,18	7,7	9,5
	18-28	0,33	0,042	0,5	3,5	1,75	0,7	0,02	6,0	9,6
	39-49			2,8						9,2
	65-75			8,8						8,6

Table 32 - Particle-size distribution of solonetz soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		Particle size in mm						
		Sand		Silt			Clay	Physical clay, <0,01
		1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
11	0-8	17,87	42,68	23,35	4,83	7,65	3,62	16,10
	8-18	21,95	40,15	20,16	4,84	8,06	4,84	17,74
	18-28	17,53	44,45	18,20	3,64	8,49	7,68	19,82
	39-49	12,58	47,47	8,97	1,63	10,19	19,16	30,98
	65-75	5,79	26,62	8,71	6,22	15,76	36,91	58,88

Table 33 – Composition of water-soluble salts in solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal						

				carbonates as CO_3^{-2}						
11	39-49	4,34	0,039	0,002	0,084	0,165	0,005	0,002	0,139	none
			0,64	0,07	2,37	3,44	0,25	0,16	6,04	none
	65-75	1,587	0,022	none	6,15	0,840	0,134	0,029	0,343	0,001
			0,36			17,51	6,70	2,38	14,91	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot № 11. Analysis of the data obtained during assessment of the biological characteristics of the vegetation showed that the soil type is medium solonetz; terrain – flat; landscape aspect – greyish; water regime – automorphic.

Projective vegetation cover at this site is 30-35% of the total area. The pasture type is wormwood–keyreuk. The botanical composition comprises wormwood – 70%, keyreuk – 17%, and mortuk – 13%. Isolated teresken plants and dry ephemeral remains also occur. The available edible forage is 8,3 c/ha. The content of feed units is 0,57, digestible protein – 14,60%, fat – 3,40%, fibre – 29,47%, and metabolizable energy – 7,81 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №11: N 45°01’ 41,3” E 68 O 51’ 34,2”

Study site № 12, soil: solonetzic grey-brown heavy loam on heavy loam. Soil pit coordinates: N 41059I 47,1II E 67042I 20,9II H = 211 m. The area bordering the Kyzylkum sands. Broad flat surfaces with hard soils alternate with narrow sandy ridges. The soil pit is on a flat surface under biyurgun vegetation. Biyurgun predominates. Projective cover – 50%. Height – 7-8 cm. Horizons: A_1^k 0-5 cm; AB^{sn} 5-19 cm; B_1^{sn} 19-32 cm; C_1^{zs} 32-49 cm; C_2^{zs} 49-59 cm; C_3^{zs} 59-85 cm.

Samples collected: 0-5 cm; 7-17 cm; 20-30 cm; 35-45 cm; 49-59 cm; 75-85 cm.

A_1^k 0-5 cm Light grey, dry, compacted, crusted, porous with horizontal layering, medium loam

AB^{sn} 5-19 cm Brown, dense, cloddy-coarse-blocky, heavy loam

B_1^{sn} 19-32 cm Dark brown, fresh, dense, coarse-blocky, heavy loam

C_1^{zs} 32-49 cm Dull brown, with numerous salt veins and mottles, indistinctly coarse-blocky, heavy loam

C_2^{zs} 49-59 cm Almost like the preceding horizon, but with fewer salts

C_3^{zs} 59-85 cm Yellow-brown, fresh, compacted, indistinctly coarse-blocky, heavy loam (Figure 15).



Figure 15 – Solonetzic grey-brown heavy loam soil on heavy loam

A distinctive feature of the solonetzic grey-brown soil is the B^{sn} horizon, which is denser and darker than the surface horizons and has an increased exchangeable sodium content. Salinization of the parent material is characteristic.

The physicochemical properties of the soils are presented in Tables 34, 35, 36.

Table 34 – Chemical and physicochemical properties of solonetzic grey-brown soil

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
Solonetzic grey-brown heavy loam soil on heavy loam.										
12	0-5	0,42	0,056	6,8	5,25	1,0	0,79	0,29	7,3	8,8
	7-17	0,58	0,056	5,4	6,75	1,25	0,17	0,42	8,6	8,8
	20-30	0,55	0,056	7,3	6,25	13,0	0,91	0,78	20,9	8,5
	35-45			6,9						8,5
	49-59			8,1						8,7
	75-85			9,8						8,7

Table 35 - Particle-size distribution of solonetzic grey-brown soil

Soil pit nos.	Depth, cm	Fraction content as % of oven-dry soil			
		particle size in mm			
		sand	silt	clay	physical

								clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
12	0-5	1,0	36,8	34,7	9,7	12,5	5,3	27,5
	7-17	0,5	30,3	19,6	8,6	14,7	26,2	49,5
	20-30	1,4	30,2	11,9	7,4	17,7	31,3	56,4
	35-45	2,5	11,5	15,3	13,2	31,9	25,6	70,7
	49-59	0,9	9,9	18,5	15,2	28,8	26,7	70,7
	75-85	1,5	23,4	9,9	11,9	28,3	25,0	65,3

Characteristics and forage value of the vegetation cover

Monitoring plot № 12. Examination of the data obtained during assessment of vegetation characteristics showed that the soil type is solonetzic grey-brown; terrain – flat; landscape aspect – greyish; water regime – automorphic.

Projective vegetation cover at this site is 50% of the total area. The pasture type is biyurgun–ephemeral–wormwood. The botanical composition comprises biyurgun – 56%, ephemerals – 30%, and wormwood – 14% of the area. Isolated dry remains of Ferula and Tatar rhubarb also occur. The available edible forage is 12,7 c/ha. The content of feed units is 0,57, digestible protein – 9,17%, fat – 5,23%, fibre – 23,70%, and metabolizable energy – 8,13 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №12: N 41059I 46,4II E 67042I 19,2II

Table 36 – Composition of water-soluble salts in solonetzic grey-brown soil, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
12	7-17	0,672	0,022	0,002	0,233	0,175	0,009	0,002	0,227	0,004
			0,36	0,07	6,57	3,65	0,45	0,16	9,87	0,1
	20-30	2,088	0,017	none	0,672	0,66	0,07	0,012	0,65	0,005
			0,28	0,4	18,95	13,75	3,60	0,99	28,26	0,13
	35-45	3,297	0,007	none	0,865	1,307	0,317	0,029	0,768	0,004
			0,11	0,33	24,39	27,22	15,85	2,38	33,4	0,10
	49-59	3,306	0,01	none	0,871	1,327	0,192	0,088	0,815	0,003
			0,16	0,13	24,56	27,64	9,60	7,24	35,44	0,08

	75-85	3,041	0,007	none	1,004	0,962	0,14	0,029	0,893	0,002
			0,11	0	28,31	20,04	7,20	2,38	38,83	0,05

Study site № 13. Soil: solonchakous-solonetzic meadow-serozem medium loam. Soil pit coordinates: N 42 52/31.9// E 68 36/40.8//. Vegetation is saltwort–ephemeroid. Projective cover 80%. Height 15-20 to 40 cm. Soil pit depth – 100 cm. A+B=47 cm. Effervescence – from the surface. Carbonates – no visible accumulations. Salts – moderately numerous veins and speckles at 70 cm to the bottom. Horizons: 0-7; 7-17; 17-27; 17-28; 28-48; 48-70; 70-bottom. Samples collected: 0-7; 7-17; 17-27; 33-43; 55-65; 90-100 (Figure 16).



Figure 16 - Solonchakous-solonetzic meadow-serozem medium loam soil.

0-7 (A1)	Light grey, dry, dense, layered, with numerous thin roots, platy, medium loam
7-17 (A2)	Greyish brown, fresh, compacted, with numerous roots, powder-like fine-granular, medium loam
17-28 (B1sn)	Darkish brown with a slightly chestnut tinge, fresh, dense, with moderately numerous fine roots, fine-nutty, heavy loam
28-48 (B2)	Darkish brown, slightly moist, compacted, with few fine roots, coarse-blocky-indistinctly-nutty, heavy loam
48-70 (BC)	Dark brown, moist, slightly compacted, coarse-blocky, clayey
70-bottom (C)	Bright brown, moist, slightly compacted, weakly coarse-blocky, clayey

The solonetzicity of the soil profile is indicated by compaction of the 17-27 cm horizon, accompanied by a dense fabric, nutty structure, heavier texture and increased exchangeable sodium content.

The physicochemical properties of the soils are presented in Tables 37, 38, 39.

Table 37 – Chemical and physicochemical properties of solonchakous-solonetzic meadow-serozem soil

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
Solonetzic grey-brown heavy loam soil on heavy loam.										
13	0-7	0,99	0,07	7,17	6,0	1,5	0,39	0,45	8,34	8,71
	7-17	0,40	0,056	6,57	5,5	2,25	0,79	0,72	9,26	9,07
	17-27	0,38	0,042	6,79	5,0	2,75	2,0	0,73	10,48	9,20
	33-43	0,36	0,028	6,79	4,0	3,25	2,97	0,46	10,68	9,14
	55-65			6,86						8,98
	90-100			6,79						8,82

Table 38 - Particle-size distribution of solonchakous-solonetzic meadow-serozem soil

Soil pit nos.	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3	4	5	6	7	8	9
13	0-7	5,45	33,33	21,08	14,19	17,03	8,92	40,14
	7-17	4,23	25,35	22,46	10,57	16,25	21,14	47,96
	17-27	2,85	32,41	17,5	10,99	12,21	24,04	47,24
	33-43	5,92	59,5	3,66	0,81	10,58	19,53	30,92
	55-65	3,44	28,14	26,88	7,33	16,29	17,92	41,54
	90-100	3,9	55,23	8,17	3,27	11,85	17,58	32,7

Table 39 – Composition of water-soluble salts in solonchakous-solonetzic meadow-serozem soil, %/meq

Soil pit	Depth,	Total	Alkalinity	Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}

№	cm	salts, %	Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
13	33-43	0,384	0,051	0,01	0,077	0,127	0,005	0,002	0,119	0,003
			0,84	0,33	2,17	2,65	0,25	0,16	5,17	0,08
	55-65	0,898	0,017	none	0,206	0,375	0,03	0,018	0,25	0,002
			0,28		5,81	7,81	1,5	1,48	10,87	0,05
	90-100	1,545	0,012	none	0,226	0,822	0,158	0,042	0,283	0,002
			0,20		6,37	17,13	7,90	3,45	12,3	0,05

Characteristics and forage value of the vegetation cover

Monitoring plot № 13. Vegetation surveys showed that the soil type is solonchakous-solonetzic meadow-serozem; terrain – plain with a saucer-shaped depression; landscape aspect – greenish-greyish; water regime – automorphic.

Projective vegetation cover at this site is 60-75% of the total area. The pasture type is saltwort–ephemeral. The botanical composition comprises biyurgun – 35%, bluegrass – 15%, mortuk – 20%, and kokpek – 30% of the area. Annual and southern saltwort, Alyssum, izen and azhrek also occur. The available edible forage is 14,5 c/ha. The content of feed units is 0,53, digestible protein – 13,40%, fat – 2,47%, fibre – 28,10, and metabolizable energy – 7,56 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №13: N 42 52/30.7// E 68 36/41.5//

Zhetysu region:

Study site № 14. Soil: solonchakic meadow-desert solonetz. Soil pit coordinates: 46° 19’ 05,0” 81° 12’ 33,7” H=364 m. Flat lacustrine plain with pronounced microrelief. Kokpek vegetation with wormwood and bulbous bluegrass: kokpek sp-sol; white-earth wormwood sol; bulbous bluegrass sol; saltmarsh sea lavender sol. Canopy cover 60%. Height 25-30 cm. Depth 115 cm. A+B=35 cm. Effervescence from the surface. Salts in the subsolonetzic horizon occur as small crystals and, deeper down, as diffuse coatings. Horizons: Horizons: 0-3 A^k, 3-10 A^{pk}, 10-22 B_1^{sn}, 22-35 B_2^{sn}, 35-70 C_1^{zs}, 70-115 C_2^{zs}

A^k	0-3 cm	Light grey, dry, dense, porous crust, heavy loam
A^{pk}	3-10 cm	Brownish-light-grey, dry, somewhat loose, with signs of layering, leafy-cloddy, heavy loam
B_1^{sn}	10-22 cm	Brown, dry, dense, blocky, with sparse small roots, clayey
B_2^{sn}	22-35 cm	Dark brown (chestnut), fresh, very dense, with thin roots, blocky,

clayey

C_1^{zs}	35-70 cm	Darkish-yellowish-brown, fresh, irregularly coarse-blocky, with salt mottles, heavy loam
C_2^{zs}	70-115 cm	Slightly lighter, with more salts, clayey (Figure 17).

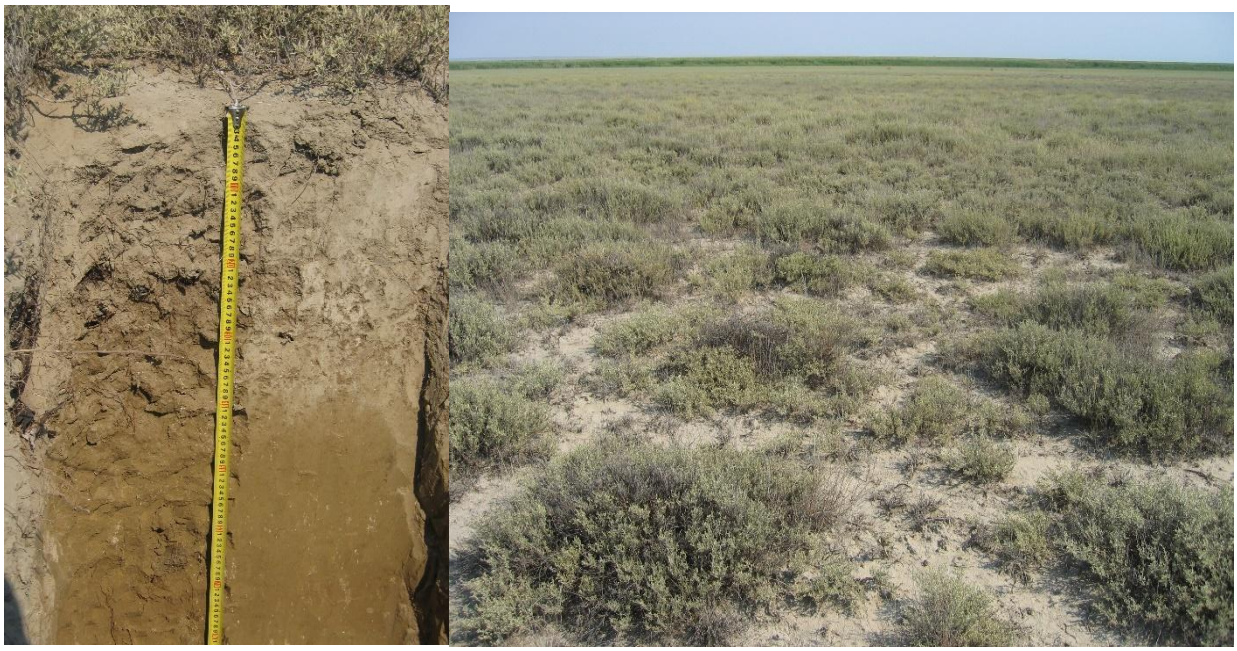


Figure 17 - Solonchakic meadow-desert solonetz under kokpek vegetation

Meadow-desert solonetz soils form on low plains where groundwater occurs at a depth of 4-6 m. They are distinguished by a very dense, dark brown or chestnut, blocky horizon underlain by parent material containing abundant salts.

The physicochemical properties of the soils are presented in Tables 40, 41, 42.

Table 40 – Chemical and physicochemical properties of solonetz soils

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
14	0-3	1,10	0,11	4,07	17,5	0,0	0,47	1,24	19,2	8,16
	3-10	1,07	0,08	4,31	11,0	14,5	0,51	1,43	27,4	8,45
	10-20	0,86	0,07	4,28	6,5	3,0	0,38	0,63	10,5	8,84
	25-33	0,62		5,03						8,79
	50-60			6,08	2,5	15,5	0,26	0,26	9,5	8,84
	105-115			6,63						9,31

Table 41 - Particle-size distribution of solonetz and solonchak soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3	4	5	6	7	8	9
14	0-3		41,1	28,3	10,2	11,3	9,1	30,6
	3-10		37,4	28,2	8,9	12,2	13,3	34,4
	10-20		44,4	24,1	5,3	16,6	9,6	31,5
	23-33		23,9	20,8	6,1	20,8	28,4	55,3
	50-60		10,1	19,6	15,5	18,0	36,8	70,3
	105-115		6,8	22,2	11,9	24,6	34,5	71,0

Table 42 – Composition of water-soluble salts in solonetz and solonchak soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
14	0-3	0,079	0,039	none	0,001	0,015	0,004	0,002	0,01	0,008
			0,64	0,24	0,03	0,32	0,20	0,16	0,43	0,20
	3-10	0,09	0,041	0,002	0,003	0,018	0,004	0,001	0,014	0,009
			0,67	0,07	0,08	0,37	0,20	0,08	0,61	0,23
	10-20	0,118	0,054	0,002	0,006	0,022	0,004	0,002	0,022	0,008
			0,89	0,07	0,17	0,46	0,20	0,16	0,96	0,2
	23-33	0,68	0,076	0,005	0,01	0,375	0,004	0,001	0,20	0,014
			1,25	0,17	0,28	7,81	0,20	0,08	8,70	0,36
	50-60	1,219	0,041	0,005	0,153	0,619	0,10	0,005	0,389	0,002
			0,67	0,17	4,31	12,89	0,50	0,41	16,91	0,05
	105-115	1,716	0,02	0,001	0,061	1,085	0,05	0,018	0,466	0,016
			0,33	0,03	1,72	22,60	2,50	1,48	20,26	0,41

Characteristics and forage value of the vegetation cover

Monitoring plot № 14. Field vegetation surveys show that the soil type is meadow-desert solonetz; terrain – lakeside plain with pronounced microrelief; landscape aspect – greyish-greenish; water regime – automorphic.

Analysis of field study data showed that projective vegetation cover is 60% of the total area. The pasture type is kokpek–saltwort–wormwood, with plants such as kokpek, white-earth and Schober's wormwood, sarsazan, sea lavender, mortuk and Climacoptera. The botanical composition consists mainly of kokpek – 30%, wormwood – 15%, ephemerals – 10%, and saltworts – 45%. The available edible forage is 15,5 c/ha. The content of feed units is 0,41, digestible protein – 11,90%, fat – 5,13%, fibre – 30,43, and metabolizable energy – 7,10 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №14: N 44º35’19,7; E 053º51’52,2

Study site № 15. Soil: meadow solonetz, heavy loam on clay. Soil pit coordinates: N 49°35′10,2″ E 79°46′42,1″ H=577 m. Low lacustrine-alluvial plain with a well-developed river network. Wormwood–Camphorosma vegetation occurs on elevations, and meadows in depressions. The soil pit is under wormwood–Camphorosma vegetation with bulbous bluegrass. Effervescence from the surface. No visible salts or carbonates. Depth 70 cm, A+B=40 cm. Horizons: A_1 0-7 cm; B_1 7-25 cm; B_2 25-40 cm; C_1 40-70 cm.

A_1	0-7 cm	Light brownish, dense, root-rich, horizontally layered (plastic), medium loam.
B_1^{sn}	7-25 cm	Brown, blocky, very dense, clayey, dry.
B_2	25-40 cm	Brown, fresh, dense, coarse-blocky, heavy loam.
C_1	40-60 cm	Yellowish-dark-brown, fresh, dense, with small roots, clayey (Figure 18).



Figure 18 – Meadow solonetz under wormwood–Camphorosma vegetation

Meadow solonetz soils form on low lacustrine and lacustrine-alluvial plains with shallow groundwater at 2-3 m. They may contain a sufficient amount of humus in the surface horizon. They are generally less saline than meadow-desert solonetz soils.

The physicochemical properties of the soils are presented in Tables 43, 44, 45.

Table 43 – Chemical and physicochemical properties of meadow solonetz soils

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
15	0-7	1.71	0.126	1.46	7.5	2.0	0.24	0.57	10.31	8.34
	10-20	0.68	0.098	2.72	4	2.0	2.94	0.46	9.40	9.2
	27-37	0.61	0.098	8.93	2	1.5	4.77	0.53	8.80	9.47
	60-70			3.59	1	1.5	4.99	0.21	7.70	9.58

Table 44 - Particle-size distribution of meadow solonetz soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
15	0-7	0,261	77,277	4,813	4,813	4,814	8,022	17,649

	10-20	0,381	74,815	6,022	4,729	4,818	9,235	18,782
	27-37	0,482	78,229	6,427	1,205	6,427	7,23	14,862
	60-70	0,642	76,905	6,415	3,208	5,212	7,618	16,038

Table 45 – Composition of water-soluble salts in meadow solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
15	0-7	0.069	0.032	none	0.007	0.009	0.006	0.002	0.006	0.007
			0.52	0,07	0.2	0.18	0.3	0.16	0.26	0.18
	10-20	0.184	0.112	0.029	0.008	0.012	0.004	0.004	0.038	0.006
			1.84	0.97	0,23	0.26	0.2	0.33	1.65	0.15
	27-37	0.359	0.198	0.074	0.007	0.053	0.006	0.006	0.083	0.006
			3.25	2.47	0.2	1.1	0.3	0.49	3.61	0.15
	60-70	0.49	0.166	0.022	0.013	0.165	0.015	0.003	0.125	0.003
			2.72	0.073	0.37	3.43	0.75	0.25	5.44	0.08

Characteristics and forage value of the vegetation cover

Monitoring plot № 15. Analysis of vegetation study data showed that the soil type is heavy loam meadow solonetz; terrain – lacustrine-alluvial plain; landscape aspect – greenish-greyish; water regime – automorphic.

Data obtained from studying the biological characteristics of the vegetation showed that projective vegetation cover is 45% of the total area. The pasture type is wormwood–saltwort–ephemeral. The botanical composition is dominated by wormwood – 45%, saltworts – 35%, and ephemerals – 20% of the area, and includes wormwood, kokpek, Camphorosma, Suaeda and bluegrass. The available edible forage is 12,5 c/ha. The content of feed units is 0,59, digestible protein – 10,50%, fat – 5,54%, fibre – 30,10, and metabolizable energy – 8,03 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №15: N 44º29’09,7; E 053º54’52,2

Study site № 16. Soil: solonetzic-solonchakic meadow medium loam on loam. Soil pit coordinates: N 45°33′45,3″ E 79°47′33,7″ H=590 m. Horizons: A_1^d 0-6 cm; B_1 6-12 cm; B_2 12-

21 cm; BC 21-35 cm; C_1 35-55 cm; C_2 55-80 cm. Depth 70 cm, A+B=21 cm. Low plain. Vegetation is azhrek–chi with Schrenk's wormwood.

Canopy cover 60-70%, chi height 120-130 cm. Infested with Sophora; the surface is trampled by livestock trails.

A_1^d	0-6 cm	10 YR 5/3	Grey, brownish, dry, compacted, strongly root-rich, cloddy-silty, medium loam.
B_1	6-12 cm	10 YR 5/3	Light brownish, greyish, compacted, with fine roots, silty-cloddy, medium loam.
B_2	12-21 cm	10 YR 5/4	Grey with moderately numerous salt grains, dry, heavy loam.
BC	21-35 cm	10 YR 3/3	Dull dark grey, with numerous salt veins, fresh, slightly compacted, weakly coarse-blocky, medium loam.
C_1	35-55 cm	10 YR 3/3	Same, but with moderately numerous salt veins, slightly moist.
C_2	55-80 cm	10 YR 4/3	Dull brown, slightly moist, fresh, weakly coarse-blocky, medium loam.

(Figure 19).



Figure 19 - Solonetzic-solonchakic meadow medium loam soil on loam

Solonetzic meadow soils form in complexes with meadow solonetz and meadow solonchak soils. They are distinguished by high humus content and solonetzization of the surface horizon

The physicochemical properties of the soils are presented in Tables 46, 47, 48.

Table 46 – Chemical and physicochemical properties of solonetzic-solonchakic meadow soils

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
16	0-6	3.19	0.252	-	8.3	7.2	0.76	1.53	17.7	7.52
	12-22	1.02	0.126	1.23	7.0	2.0	0.27	0.69	9.96	8.13
	30-40	0.96	0.112	2.27	6.5	3.5	0.24	0.63	10.87	8.02
	40-50	0.72	0.084	3.41	7.0	3.5	0.91	0.80	12.2	8.57
	60-70			5.74						8.80
	85-95			7.62						8.84

Table 47 - Particle-size distribution of solonetzic-solonchakic meadow soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
16	0-6	0,301	41,419	28,135	5,627	12,058	12,46	30,145
	6-12	0,782	69,942	10,427	2,407	5,614	10,828	18,849
	12-21	0,603	74,885	10,448	2,411	4,822	6,831	14,064
	22-32	0,703	74,397	8,427	4,018	4,017	8,438	16,473
	37-47	0,466	13,923	32,294	11,755	23,510	19,052	53,317
	70-80	1,516	23,923	30,919	14,053	16,463	13,251	43,767

Characteristics and forage value of the vegetation cover

Monitoring plot № 16. Vegetation study results showed that the soil type is solonetzic-solonchakic meadow medium loam; terrain – plain with a depression; landscape aspect – greyish-pale-greenish; water regime – automorphic.

Field study results show that projective plant cover is 60% of the total area. The pasture type is chi–azhrek with Schrenk's wormwood. Investigation of the botanical composition showed

that chi occupies 60%, azhrek – 30%, and wormwood – 10% of the area. Isolated reed and reedgrass plants also occur. The available edible forage is 14,3 c/ha. The content of feed units is 0,48, digestible protein – 8,70%, fat – 4,50%, fibre – 33,40, and metabolizable energy – 7,15 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №16: N 45°33′44,3″ E 79°47′33,5″

Table 48 – Composition of water-soluble salts in solonetzic-solonchakic meadow soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
16	0-7	0.079	0.015	none	0.004	0.019	0.01	0.001	0.001	0.005
			0.25	none	0.11	0.39	0.5	0.08	0.04	0.13
	10-20	0.083	0.015	none	0.001	0.014	0.006	0.001	0.001	0.006
			0.25	none	0.03	0.29	0.30	0.08	0.0	0.15
	27-37	1.431	0.012	none	0.001	0.13	0.006	0.001	0.001	0.003
			0.2	none	0.03	0.27	0.3	0.08	0.04	0.08
	60-70	2.332	0.029	0.002	0.003	0.004	0.01	0.001	0.001	0.001
			0.48	0.07	0.08	0.09	0.5	0.08	0.04	0.03
	27-37	1.638	0.017	none	0.004	0.061	0.01	0.006	0.015	0.001
			0.28	none	0.11	1.28	0.5	0.49	0.65	0.03
	60-70	0.079	0.037	0.001	0.004	0.026	0.01	0.004	0.008	0.003
			0.61	0.03	0.11	0.54	0.5	0.33	0.35	0.08

Study site № 17. Soil: solonchakic meadow-desert solonetz. Soil pit coordinates: 46° 19’ 05,0”; 81° 12’ 33,7”. H=364 m. Flat lacustrine plain with pronounced microrelief. Kokpek vegetation with wormwood and bulbous bluegrass: kokpek sp-sol; white-earth wormwood sol; bulbous bluegrass sol; saltmarsh sea lavender sol. Canopy cover 60%. Height 25-30 cm. Depth 115 cm. A+B=35 cm. Effervescence from the surface. Salts in the subsolonetzic horizon occur as small crystals and, deeper down, as diffuse coatings. Horizons: Horizons: 0-3 A^k, 3-10 A^{pk}, 10-22 B_1^{sn}, 22-35 B_2^{sn}, 35-70 C_1^{zs}, 70-115 C_2^{zs}

A^k	0-3 cm	Light grey, dry, dense, porous crust, heavy loam
A^{pk}	3-10 cm	Brownish-light-grey, dry, somewhat loose, with signs of layering, leafy-cloddy, heavy loam

B_1^{sn}	10-22 cm	Brown, dry, dense, blocky, with sparse small roots, clayey
B_2^{sn}	22-35 cm	Dark brown (chestnut), fresh, very dense, with thin roots, blocky, clayey
C_1^{zs}	35-70 cm	Darkish-yellowish-brown, fresh, irregularly coarse-blocky, with salt mottles, heavy loam
C_2^{zs}	70-115 cm	Slightly lighter, with more salts, clayey

(Figure 20).



Figure 20 - Solonchakic meadow-desert solonetz under kokpek vegetation

Meadow-desert solonetz soils form on low plains where groundwater occurs at a depth of 4-6 m. They are distinguished by a very dense, dark brown or chestnut, blocky horizon underlain by parent material containing abundant salts.

The physicochemical properties of the soils are presented in Tables 49, 50, 51.

Table 49 – Chemical and physicochemical properties of meadow-desert solonetz

Soil pit №	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}				
1	2	3	4	5	6	7	1	2	3	4
17	0-3	1,10	0,11	4,07	17,5	0,0	0,47	1,24	19,2	8,16
	3-10	1,07	0,08	4,31	11,0	14,5	0,51	1,43	27,4	8,45
	10-20	0,86	0,07	4,28	6,5	3,0	0,38	0,63	10,5	8,84

	25-33	0,62		5,03						8,79
	50-60			6,08	2,5	15,5	0,26	0,26	9,5	8,84
	105-115			6,63						9,31

Table 50 - Particle-size distribution of meadow-desert solonetz

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
17	0-3		41,1	28,3	10,2	11,3	9,1	30,6
	3-10		37,4	28,2	8,9	12,2	13,3	34,4
	10-20		44,4	24,1	5,3	16,6	9,6	31,5
	23-33		23,9	20,8	6,1	20,8	28,4	55,3
	50-60		10,1	19,6	15,5	18,0	36,8	70,3
	105-115		6,8	22,2	11,9	24,6	34,5	71,0

Table 51 – Composition of water-soluble salts in meadow-desert solonetz, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
17	0-3	0,079	0,039	none	0,001	0,015	0,004	0,002	0,01	0,008
			0,64	0,24	0,03	0,32	0,20	0,16	0,43	0,20
	3-10	0,09	0,041	0,002	0,003	0,018	0,004	0,001	0,014	0,009
			0,67	0,07	0,08	0,37	0,20	0,08	0,61	0,23
	10-20	0,118	0,054	0,002	0,006	0,022	0,004	0,002	0,022	0,008

			0,89	0,07	0,17	0,46	0,20	0,16	0,96	0,2
17	23-33	0,68	0,076	0,005	0,01	0,375	0,004	0,001	0,20	0,014
			1,25	0,17	0,28	7,81	0,20	0,08	8,70	0,36
	50-60	1,219	0,041	0,005	0,153	0,619	0,10	0,005	0,389	0,002
			0,67	0,17	4,31	12,89	0,50	0,41	16,91	0,05
	105-115	1,716	0,02	0,001	0,061	1,085	0,05	0,018	0,466	0,016
			0,33	0,03	1,72	22,60	2,50	1,48	20,26	0,41

Characteristics and forage value of the vegetation cover

Monitoring plot № 17. Vegetation study results show that the soil type is meadow-desert solonetz; terrain – lakeside plain with a saucer-shaped depression; landscape aspect – greyish-greenish; water regime – automorphic.

Investigation of the vegetation showed that projective plant cover is 60%. The pasture type is saltwort–kokpek–wormwood, with Tamarix. The botanical composition of this area comprises sarsazan – 45%, kokpek – 35%, wormwood – 10%, and bluegrass – 10%. Climacoptera, Tamarix, Suaeda, mortuk and azhrek also occur. The available edible forage is 13,0 c/ha. The content of feed units is 0,43, digestible protein – 10,70%, fat – 5,20%, fibre – 30,54, and metabolizable energy – 6,70 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №4: N 44º37’09,7; E 053º45’52,2

Zhambyl region

Study site № 18. Soil: solonchakic desert solonetz, clayey, on sandy-gravelly deposits. Soil pit coordinates: N 45°21′54,8" E 71°39′03,2" H=371 m

Footslope of a hill composed of Paleogene deposits. Vegetation is tasbiyurgun–biyurgun. Depth 60 cm, A+B=24 cm. Effervescence from the surface. Carbonates at 15-24 cm – sharply delineated mottles. Salts at 24 cm to the bottom – white glistening particles. Horizons: A^{k} 0-6 cm; B_1^{sn} 6-15 cm; B_2^{ksn} 15-24 cm; C_1^{zs} 24-40 cm; CD 40-60

A^{k}	0-6 cm	Greyish-brown, dry, very dense, porous crust, clayey.
B_1^{sn}	6-15 cm	Dark brown (chestnut), dry, very dense, blocky, with thin roots, clayey.
B_2^{ksn}	15-24 cm	Dark brown with whitish carbonate mottles, fresh, dense, nutty-coarse-blocky, heavy loam.
C_1^{zs}	24-40 cm	Yellowish-dark-brown, fresh, slightly compacted, with glistening salt particles, medium loam.

CD 40 -60 cm Yellowish-dark-brown, fresh, somewhat loose, sandy-gravelly deposits

(Figure 21).



Figure 21 - Solonchakic desert solonetz under tasbiyurgun–biyurgun vegetation

This profile is characterized by a very dense, porous crust that passes abruptly into a brown, very dense, blocky horizon with high exchangeable sodium content. This solonetz is classified as shallow. The physicochemical properties of the soils are presented in Tables 52, 53, 54.

Table 52 – Chemical and physicochemical properties of desert solonetz soils

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
18	0-6	0,3	0,014	5,8	5,9	5,0	0,78	0,45	12,1	9,21
	6-15	0,2	0,014	4,58	5,4	2,0	1,50	0,35	9,3	9,60
	15-24	0,1	0,014	5,11	5,9	3,5	2,58	0,16	12,1	9,37
	25-35			1,4						8,70
	50-60			0,78						8,59

Table 53 - Particle-size distribution of desert solonetz soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil			
		particle size in mm			
		sand	silt	clay	physical clay

		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
18	0-6	17,62	25,8	22,39	8,55	9,76	15,88	34,19
	6-15	17,76	29,06	17,05	11,77	11,37	12,99	36,13
	15-24	18,37	12,71	12,23	24,48	14,67	17,54	56,69
	25-35	38,39	35,94	2,48	9,11	5,39	8,69	23,19
	50-60	41,11	34,79	2,96	6,76	5,92	8,46	21,14

Table 54 – Composition of water-soluble salts in desert solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
18	0-6	0,285	0,032	0,002	0,056	0,101	0,012	0,002	0,076	0,006
			0,52	0,07	1,58	2,11	0,60	0,16	3,30	0,15
	6-15	0,223	0,054	0,010	0,03	0,067	0,008	0,002	0,056	0,006
			0,89	0,33	0,85	1,40	0,40	0,16	2,43	0,15
	15-24	0,487	0,037	0,005	0,071	0,218	0,008	0,003	0,149	0,001
			0,61	0,17	2,0	4,55	0,40	0,25	6,48	0,03
	25-35	1,516	0,010	0,002	0,137	0,706	0,322	0,06	0,279	0,002
			0,16	0,07	3,86	14,70	1,61	4,93	12,13	0,05
	50-60	2,414	0,005	none	0,137	1,549	0,396	0,060	0,260	0,007
			0,08		3,86	32,27	19,80	4,93	11,3	0,18

Characteristics and forage value of the vegetation cover

Monitoring plot № 18. Vegetation surveys show that the soil type is solonchakic desert solonetz; terrain – flat; landscape aspect – greyish-pale-greenish; water regime – automorphic.

Projective vegetation cover on the solonetz soils is 45%. The pasture type is biyurgun–ephemeral. Investigation of the botanical composition revealed that biyurgun accounts for 80% and ephemerals for 20% of the total area. Mortuk, bluegrass, Petrosimonia and Climacoptera also occur. The available edible forage is 7,5 c/ha. The content of feed units is 0,50, digestible protein – 11,60%, fat – 3,75%, fibre – 31,20, and metabolizable energy – 7,16 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site № 18: N 45°21′53,8″ E 71°39′13,2″.

Study site № 19. Soil: solonetzic grey-brown desert heavy loam on Paleogene clay. Soil pit coordinates: N 45°43′33,5″. E 71°29′59,3″. H = 425 m. Rolling surfaces composed of Neogene–Paleogene white and red clays. The soil pit is on the gentle northern slope of a ridge. Vegetation is tasbiyurgun with biyurgun: tasbiyurgun cop1; biyurgun sol; Turanian wormwood sol; desert rhubarb un-sol. Depth 40 cm, A+B=30 cm. Effervescence from the surface. Carbonates at 30-40 cm – sharply delineated mottles and cocoon-shaped accumulations. Horizons: A^{k} 0-6 cm; A^{pk} 6-12 cm; B_1^{sn} 12-20 cm; B_2 20-30 cm; C_1^{k} 30-40; CD >40 cm (Figure 22).



Figure 22 - Solonetzic grey-brown desert heavy loam soil on Paleogene clay

A^{k}	0-6 cm	Brownish-light-grey, dry, somewhat loose, layered crust, medium loam
A^{pk}	6-12	Light brownish, dry, slightly compacted, with plates and scales, heavy loam
B_1^{sn}	12-20 cm	Darkish brown, dry, dense, nutty-cloddy, with carbonate mottles, heavy loam
B_2	20-30 cm	Brown with whitish carbonate mottles, dry, somewhat loose, with fine roots and small stones, medium loam
C_1^{k}	24-40 cm	Red-dark-brown, dry, dense, with carbonate concretions, clayey
CD	> 40 cm	Red-brown clay

The profile of this soil is characterized by a solonetzic horizon immediately beneath the crustal and subcrustal horizons. It has a dense nutty structure, a darker colour and increased

exchangeable sodium content. As the soil forms among sands, salinization within the profile is slight. The physicochemical properties of the soils are presented in Tables 55, 56, 57.

Table 55 – Chemical and physicochemical properties of solonetzic grey-brown desert soil

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
19	0-6	0,76	0,056	4,3	4,0	4,0	0,30	0,49	8,8	9,48
	6-12	0,66	0,042	4,4	3,5	2,5	0,71	0,56	7,3	10,14
	12-20	0,43	0,042	3,5	5,9	6,0	0,69	0,46	13,1	9,68
	20-30	0,33	0,028	2,5	11,4	2,0	0,48	0,11	14,0	8,56
	30-40			3,6						8,66

Table 56 - Particle-size distribution of solonetzic grey-brown desert soil

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
19	0-6	21,96	25,67	26,19	9,26	12,49	4,43	26,18
	6-12	16,1	24,91	27,07	8,49	15,35	8,08	31,92
	12-20	19,1	22,96	31,01	3,26	11,84	11,83	26,93
	20-30	12,84	21,21	23,76	13,93	15,56	12,7	42,19
	30-40	13,4	21,65	16,85	13,98	14,8	19,32	48,1

Table 57 – Composition of water-soluble salts in solonetzic grey-brown soil, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal carbonates as CO_3^{-2}						
19	0-6	0,082	0,029	0,001	none	0,028	0,009	0,002	0,006	0,008

			0,48	0,03	none	0,59	0,45	0,16	0,26	0,2
	6-12	0,138	0,061	0,006	none	0,036	0,008	0,002	0,023	0,008
			1,0	0,2	none	0,76	0,40	0,16	1,0	0,2
	12-20	0,118	0,046	0,004	0,001	0,036	0,008	0,001	0,021	0,005
			0,75	0,13	0,03	0,74	0,40	0,08	0,91	0,13
	20-30	0,161	0,020	none	0,015	0,078	0,021	0,004	0,023	none
			0,33	0,07	0,42	1,63	1,05	0,33	1,00	none
	30-40	0,168	0,024	none	0,041	0,048	0,014	0,002	0,039	none
			0,39		1,16	1,01	0,70	0,16	1,70	none

Characteristics and forage value of the vegetation cover

Monitoring plot № 19. Vegetation study results show that the soil type is solonetzic grey-brown heavy loam; terrain – gently rolling plain; landscape aspect – greyish brown; water regime – automorphic.

Total projective vegetation cover on the solonetz soils is only 35-40% of the total area. The pasture type is biyurgun–izen–wormwood. The botanical composition comprises biyurgun – 60%, izen – 15%, wormwood – 20%, and mortuk – 5%. Isolated Tatar rhubarb, Ferula, Climacoptera, tulip and bluegrass plants also occur. The available edible forage is 11,5 c/ha. The content of feed units is 0,60, digestible protein – 15,61%, fat – 3,45%, fibre – 28,70, and metabolizable energy – 8,24 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №19: N 45°43′30,5″ E 71°29′56,3″

Almaty region

Study site № 20. Soil: buried takyr-like solonetzic-solonchakic medium loam on sand. Soil pit coordinates: 46,264139; 74,324545. H=343 m. Flat surface of the ancient Ili delta. Cracks at the surface. Vegetation: ephemeral–saxaul: saxaul sol-sp; pepperweed; groundsel sol-sp. Canopy cover 20-30%. Saxaul height up to 2 m. No visible salts. Depth =110 cm. A+B=20 cm. Horizons: A 0-7 cm, B_1 7-20 cm, C_1 20-35 cm, C_2 35-60 cm, C_3 60-75 cm, C_4^d 75-bottom.

A	0-7 cm	Light grey, dry, dense, coarse-pored crust, layered below, medium loam
B_1	7-20 cm	Brownish-light-grey, fresh, slightly compacted, silty-weakly-cloddy, with rusty mottles, sandy loam
C_1	20-35 cm	Yellow-brown, slightly moist, loose sand with rusty mottles, alternating with a sandy loam interlayer
C_2	35-60 cm	Yellow-brown, wet sand with rusty mottles
C_3	60-75 cm	Layered darkish-grey and brown horizon with rusty mottles, stratified,

		light loam
C_4^d	75-bottom	Yellow-brown, moist sand with rusty mottles

Takyr-like soils form on ancient alluvial plains of major rivers and often retain features of a former hydromorphic regime. In this profile, this is indicated by the buried humus horizon at 60-75 cm, meaning that the soil has undergone desertification from a floodplain meadow soil (Figure 23).



Figure 23 - Buried takyr-like solonetzic-solonchakic medium loam soil on sand

The physicochemical properties of the soils are presented in Tables 58, 59, 60.

Table 58 – Chemical and physicochemical properties of takyr-like solonetzic-solonchakic soil

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
20	0-7	0,42	0,07	3,9	10,89	5,94	0,99	1,36	19,18	8,61
	8-18 cm	0,19	0,028	6,47	2,48	5,94	1,23	0,74	10,39	9,22
	22-32	0,11	0,014	4,39	1,49	4,46	0,88	0,86	7,68	9,1
	42-52			3,22						9,09

	62-72			5,3						8,95
	100-110			3,96						9,01

Table 59 - Particle-size distribution of takyr-like solonetzic-solonchakic soil

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
20	0-7	0,98	0,69	37,91	33,53	16,97	1,21	9,70
	8-18 cm	0,82	0,30	26,70	34,28	9,68	21,78	7,26
	22-32	0,54	0,64	72,41	1,61	0,40	23,73	1,21
	42-52	0,30	1,30	73,02	1,61	2,01	21,26	0,80
	62-72	0,44	0,38	74,71	14,87	5,22	2,41	2,41
	100-110	0,46	0,72	92,45	1,61	0,40	1,61	3,22

Table 60 – Composition of water-soluble salts in takyr-like solonetzic-solonchakic soil, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
20	0-7	1,657	0,017	0,002	0,574	0,473	0,092	0,024	0,422	0,054
			0,28	0,08	16,19	9,85	4,61	1,96	18,37	1,39
	8-18 cm	0,598	0,034	0,005	0,101	0,259	0,004	0,002	0,187	0,011
			0,56	0,16	2,84	5,39	0,2	0,2	8,11	0,29
	22-32	0,598	0,02	0,002	0,093	0,198	0,008	0,006	0,139	0,005
			0,32	0,08	2,62	4,13	0,39	0,49	6,06	0,12
	42-52	0,598	0,012	0	0,045	0,167	0,01	0,005	0,092	0,003
			0,2	0	1,27	3,49	0,49	0,39	4,01	0,07
	62-72	0,598	0,015	0	0,181	0,397	0,047	0,012	0,234	0,004
			0,24	0	5,09	8,26	2,35	0,98	10,16	0,1

100-110	0,598	0,015	0	0,117	0,304	0,016	0,011	0,187	0,004
		0,24	0	3,31	6,34	0,78	0,88	8,11	0,11

Characteristics and forage value of the vegetation cover

Monitoring plot №20. Vegetation study results showed that the soil type is takyr-like solonetzic-solonchakic medium loam; terrain – plain; landscape aspect – pale greenish; water regime – automorphic.

Field study results show that projective plant cover is 60% of the total area. The pasture type is saxaul–ephemeral–wormwood. Investigation of the botanical composition showed that saxaul occupies 60%, ephemerals – 25%, and wormwood – 15% of the area. Isolated bluegrass, pepperweed, groundsel, Climacoptera and Girgensohnia plants also occur. The available edible forage is 6,3 c/ha. The content of feed units is 0,51, digestible protein – 13,40%, fat – 3,78%, fibre – 34,50, and metabolizable energy – 7,44 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №20: N 46,264109 E 74,324535

Study site № 21. Soil: solonetzic-solonchakic meadow medium loam on loam. Lacustrine terrace of Lake Tuzkol in the intermontane valley of the Kegen River. Soil pit coordinates: 43º 1' 35.58". 79º 59' 17.35". H = 1963 m. Vegetation is chi–Schrenk's wormwood: Schrenk's wormwood sp; chi sol-sp; Camphorosma sol; saltmarsh plantain sol; sheep fescue sol. Canopy cover 100%. Height 10-15 cm, chi up to 60-70 cm. Depth 90, A+B=23. Effervescence from the surface. Salts: none visible. Carbonates from 50 cm. Horizons: 0-6 A_1, 6-23 B_1, 23-40 BC, 40-60 C_1, 600-90 C2.

A_1	0-6	Darkish grey, dry, strongly compacted, root-rich, weakly cloddy, silty, sandy loam
B_1	6-23	Dark brown, fresh, compacted, with fine roots, weakly cloddy, sandy loam
BC	23-40	Brown, fresh, compacted, indistinctly cloddy, medium loam
C_1	40-60	Brown, fresh, compacted, silty-cloddy, light loam
C_2	60- 90	Similar to the preceding horizon, but wet

The soil formed in the intermontane valley of the Kegen River at an elevation of more than 1800 m above sea level. Solonetzicity is associated with saline parent materials represented by Neogene saline clays (Figure 24).





Figure 24 - Solonetzic-solonchakic meadow medium loam soil on loam

The physicochemical properties of the soils are presented in Tables 61, 62.

Table 61 – Chemical and physicochemical properties of solonetzic-solonchakic meadow soil

Soil pit №	Depth of sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
21	0_6	4,0	0,4	3,7	10,4	2,0	0,2	0,4	12,91	9,3
	10_20	2,0	0,2	8,3	1,5	2,5	11,7	0,9	16,57	10,2
	27_37	0,1	0,2	7,8	1,5	3,5	2,3	0,4	7,69	10,2
	45_55									10,1
	80_90									10,3

Table 62 - Particle-size distribution of solonetzic-solonchakic meadow soil

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3	4	5	6	7	8	9

21	0-6	14,755	12,084	54,665	3,699	4,932	9,864	18,496
	10-20	21,221	6,268	54,486	6,145	4,097	7,784	18,025
21	27-37	31,703	5,784	23,950	4,465	18,267	15,831	38,563
	45-55	40,700	13,607	17,388	2,022	12,940	13,344	28,306
	80-90	39,523	26,126	12,932	4,041	8,082	9,295	21,418

Characteristics and forage value of the vegetation cover

Monitoring plot №21. Analysis of vegetation study data showed that the soil type is solonchakous medium loam solonetz; terrain – interhill plain; landscape aspect – greyish-pale-yellowish; water regime – automorphic.

The chemical properties of the soils are presented in Table 63.

Table 63 – Composition of water-soluble salts in solonetzic-solonchakic meadow soil, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
1	2	3	4	5	6	7	8	9	10	11
21	0_6	0,377	0,078	0,007	0,047	0,13	0,002	0,004	0,108	0,008
			1,28	0,24	1,33	2,7	0,1	0,3	4,7	0,21
	10_20	1,063	0,229	0,067	0,156	0,33	0,002	0,006	0,321	0,018
			3,76	2,24	4,4	6,87	0,1	0,49	13,97	0,47
	27_37	0,87	0,166	0,017	0,119	0,299	0,004	0,001	0,27	0,011
21			2,72	0,56	3,36	6,23	0,2	0,1	11,73	0,28
	45_55	0,704	0,134	0,01	0,079	0,263	0,002	0,001	0,22	0,006
			2,2	0,32	2,22	5,48	0,1	0,1	9,55	0,15
	80_90	0,486	0,124	0,01	0,037	0,172	0,004	0,001	0,144	0,003
			2,04	0,32	1,03	3,59	0,2	0,1	6,28	0,08

Data obtained from studying the biological characteristics of the vegetation showed that projective vegetation cover is 45% of the total area. The pasture type is chi–wormwood–ephemeral. The botanical composition is dominated by chi – 45%, wormwood – 35%, and ephemerals – 20% of the area, and includes wormwood, bluegrass, sheep fescue, small sedge and

couch grass. The available edible forage is 9,5 c/ha. The content of feed units is 0,45, digestible protein – 10,11%, fat – 4,50%, fibre – 33,40, and metabolizable energy – 7,01 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site № 21: N 43° 1' 35.56" E 79° 59' 17.45"

Kyzylorda region:

Study site № 22. Soil: solonchakic desert solonetz, heavy loam on sandy loam. Soil pit coordinates: N 46° 09' 08,9". E 61° 37' 15,0". H = 79 m. High western shore of Lake Kamysh-Lobash. The surface is composed of white clays. The soil pit was excavated on a flat surface under biyurgun vegetation. In addition to biyurgun, there are an unidentified saltwort, Alyssum, wormwood and a small yellow flower. Projective cover – 30-40%. Height – 5-7 cm. Soil pit depth – 80 cm. A+B=18 cm. Effervescence with HCl – from the surface.

Carbonates – sharply delineated mottles from 50 cm. Salts – mottles at 18-35 cm. Horizons: A_1^k 0-5 cm; B_1^{sn} 5-18 cm; C_1^{zs} 18-35 cm; C_2^{zs} 35-50 cm; C_3^k 50-65 cm; CD 65-80 cm. Samples collected: 0-5 cm; 7-17 cm; 22-32 cm; 37-47 cm; 52-62 cm; 70-80 cm.

A_1^k	0-5 cm	Dull brown crust, wet after rain, horizontally layered with pores, heavy loam
B_1^{sn}	5-18 cm	Brown, wet, compacted, curd-like with clods, with fine roots, clayey
C_1^{zs}	18-35 cm	Dull brown with salt mottles, fresh, compacted, sharp-edged cloddy, with sparse fine roots, medium loam
C_2^{zs}	35-50 cm	Light brownish, fresh, slightly compacted, cloddy-silty, sandy loam
C_3^k	50-65 cm	Dull brown with white carbonate mottles, fresh, dense, coarse-blocky, heavy loam
CD	65-80 cm	Yellowish brown, dry, dense, coarse-blocky-silty, sandy loam cemented by carbonates



Figure 25 - Solonchakic desert solonetz, heavy loam on sandy loam

Typical desert solonetz with sharp profile differentiation in colour and texture, high sodium content in the solonetzic horizon and abundant salts in the parent material. The physicochemical properties of the soils are presented in Tables 64, 65, 66.

Table 64 – Chemical and physicochemical properties of solonetz soils

Soil pit №	Depth sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
22	0-5	0,21	0,042	2,4	6,0	2,5	1,23	0,28	10,0	9,1
	7-17	0,14	0,028	3,3	6,5	3,0	2,61	0,19	12,3	9,6
	22-32	0,21	0,014	1,0	3,5	2,25	4,34	0,09	10,2	9,3
	37-47	none	0,014	1,0	4,5	2,25	3,1	0,08	9,9	9,0
	52-62			1,6						8,4
	70-80			1,4						8,8

Table 65 - Particle-size distribution of solonetz soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01

22	0-5	21,21	10,53	20,85	9,81	17,99	19,62	47,41
	7-17	21,43	9,60	13,63	7,85	9,50	37,99	55,34
	22-32	17,64	19,01	29,43	9,40	10,22	14,31	33,93
	37-47	46,47	10,36	26,51	4,06	6,10	6,50	16,66
	52-62	40,93	1,48	11,93	12,75	15,22	17,69	45,66
	70-80	32,39	31,60	19,42	3,64	1,62	11,33	16,59

Table 66 – Composition of water-soluble salts in solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
22	0-5	0,071	0,032	0,002	none	0,019	0,006	0,001	0,011	0,002
			0,52	0,07	none	0,39	0,3	0,08	0,48	0,05
	7-17	0,114	0,068	0,017	none	0,014	0,002	0,001	0,027	0,002
			1,11	0,57	none	0,29	0,1	0,08	1,17	0,05
	22-32	0,265	0,056	0,01	0,075	0,044	0,002	0,001	0,086	0,001
			0,92	0,33	2,12	0,91	0,10	0,08	3,74	0,03
	37-47	0,423	0,027	0,002	0,186	0,055	0,006	0,002	0,146	0,001
			0,44	0,07	5,25	1,15	0,3	0,16	6,35	0,03
	52-62	1,518	0,015	none	0,17	0,855	0,267	0,009	0,201	0,001
			0,25	0	4,79	17,82	13,35	0,74	8,74	0,03
	70-80	0,406	0,015	none	0,097	0,159	0,033	0,006	0,095	0,001
			0,25	0	2,74	3,31	1,65	0,49	4,13	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot №22. Analysis of vegetation study data showed that the soil type is solonchakic desert solonetz, heavy loam; terrain – lacustrine-alluvial plain; landscape aspect – greenish with a whitish tinge; water regime – automorphic.

Data obtained from studying the biological characteristics of the vegetation showed that projective vegetation cover is 30-40% of the total area. The pasture type is biyurgun–wormwood–saltwort. The botanical composition is dominated by biyurgun – 50%, wormwood – 30%, and saltworts – 20% of the area, and includes wormwood, Alyssum, bluegrass, Climacoptera and Suaeda. The available edible forage is 9,7 c/ha. The content of feed units is

0,51, digestible protein – 12,40%, fat – 3,89%, fibre – 36,40, and metabolizable energy – 7,40 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №22: N 46º 09' 07,7" E 61º 37' 14,3"

Study site № 23. Soil: solonchakic desert solonetz, heavy loam on sand. Soil pit coordinates: N 46º 07' 46,7". E 61º 33' 10,3". H = 71 m

Undulating plain north of Amanotkel settlement. The soil pit was excavated on a trampled surface under wormwood–itsigek vegetation (ephemerals, small sedge). Soil pit depth – 90 cm. A+B=30 cm. Effervescence with HCl – from the surface. Carbonates – none visible. Salts – from 28 cm to the bottom. Horizons: 0-3 cm; 3-14 cm; 15-28 cm; 28-42 cm; 42-65 cm; 65-90 cm. Samples collected: 0-3 cm; 4-14 cm; 17-27 cm; 30-40 cm; 50-60 cm; 80-90 cm (Figure 26).



Figure 26 - Solonchakic desert solonetz, heavy loam on sand

0-3 cm	Light grey, dry, loose crust, medium loam
3-14 cm	Brown-chestnut, fresh, dense, coarse-blocky with vertical cracks, heavy loam
15-28 cm	Yellow-brown, slightly moist, indistinctly cloddy, medium loam
28-42 cm	Chestnut-brown, fresh, compacted, with salt veins, heavy loam
42-65 cm	Dull brown, with abundant salts, coarse-blocky, medium loam
62-90 cm	Yellow-brown, fresh, sandy loam

The profile of this soil is characterized by a solonetzic horizon occurring at a depth of 17 cm rather than immediately beneath the crustal and subcrustal horizons. It has a dense nutty structure, a darker colour and increased exchangeable sodium content. It is classified as medium solonetz.

The physicochemical properties of the soils are presented in Tables 67, 68, 69.

Table 67 – Chemical and physicochemical properties of solonetz soils

Soil pit №	Depth sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
23	0-3	0,13	0,028	0,8	4,0	2,0	1,29	0,27	7,56	8,3
	4-14	0,27	0,014	0,9	4,25	2,25	2,60	0,11	9,21	9,2
	17-27	0,43	0,028	1,0	4,25	3,25	4,95	0,07	12,52	9,0
	30-40	0,9	0,014	0,6	10,0	5,0	2,48	0,03	17,51	8,1
	50-60			1,0						7,9
	80-90			none						7,7

Table 68 - Particle-size distribution of solonetz soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3	4	5	6	7	8	9
23	0-3	13,79	15,27	37,49	9,27	10,08	14,11	33,46
	4-14	19,47	6,79	29,58	13,78	12,56	17,83	44,17
	17-27	4,20	68,87	5,30	1,63	2,04	17,96	21,63
23	30-40	18,23	46,06	5,75	2,87	6,98	20,12	29,97
	50-60	6,32	26,85	29,79	8,45	11,68	16,91	37,04
	80-90	21,97	19,13	46,00	1,61	2,82	8,47	12,91

Table 69 – Composition of water-soluble salts in solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal carbonates as CO_3^{-2}						
23	0-3	0,087	0,029	none	0,015	0,015	0,004	0,001	0,019	0,004
			0,48	0,08	0,42	0,31	0,20	0,08	0,83	0,1
	4-14	0,167	0,059	0,007	0,017	0,04	0,008	0,001	0,041	0,001
			0,97	0,23	0,48	0,84	0,40	0,08	1,78	0,03
	17-27	0,368	0,076	0,012	0,108	0,06	0,004	0,003	0,117	none

			1,25	0,4	3,05	1,24	0,20	0,25	5,09	none
	30-40	0,917	0,029	none	0,086	0,511	0,086	0,009	0,196	none
			0,48	0	2,43	10,65	4,3	0,74	8,52	none
	50-60	1,678	0,022	none	0,166	0,965	0,257	0,017	0,25	0,001
			0,36	0	4,68	20,11	12,85	1,4	10,87	0,03
	80-90	0,72	0,017	none	0,028	0,46	0,167	0,006	0,041	0,001
			0,28	0	0,79	9,58	8,35	0,49	1,78	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot № 23. Vegetation study results showed that the soil type is solonchakic desert solonetz; terrain – gently undulating plain; landscape aspect – greyish; water regime – automorphic.

Field study results show that projective plant cover is 30-35% of the total area. The pasture type is wormwood–itsigek. Investigation of the botanical composition showed that wormwood occupies 70%, itsigek – 25%, and ephemerals – 5% of the area. Bluegrass, pepperweed, groundsel, Climacoptera and Girgensohnia occur in the vegetation. The available edible forage is 7,3 c/ha. The content of feed units is 0,55, digestible protein – 13,80%, fat – 4,23%, fibre – 35,40, and metabolizable energy – 7,82 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №23: N 46º 07' 40,7" E 61º 33' 15,3"

Study site № 24. Soil: solonchakic desert solonetz, heavy loam over sand from 80 cm. Soil pit coordinates: N 46º 14' 35,8". E 61º 45' 23,9". H = 101 m. The soil pit was excavated in a microdepression, within a patch of biyurgun. Projective cover – 30%. Height – 3-5 cm. Soil pit depth – 85 cm. A+B=35 cm. Effervescence with HCl – from the surface. Carbonates – continuous white veins at 35-80 cm, very abundant from 60 cm. Salts – veins and mottles at 18-35 cm, veins from 80 cm. Horizons: A_1^k 0-6 cm; B_1^{sn} 6-18 cm; BC^{zs} 18-35 cm; C_1^k 35-58 cm; C_2^k 58-80 cm; C_3 80-85 cm. Samples collected: 0-6 cm; 6-16 cm; 20-30 cm; 40-50 cm; 65-75 cm; 80-75 cm (Figure 27)



Figure 27 - Solonchakic desert solonetz, heavy loam on sand

A_1^k	0-6 cm	Brownish-light-grey crust, wet, slightly compacted, separates into horizontal units with pores, medium loam
B_1^{sn}	6-18 cm	Brown, wet after rain, currently weakly coherent but later becoming a platy solonetzic horizon, clayey
BC^{zs}	18-35 cm	Yellow-brown, fresh, slightly compacted, with salt veins, with an unclear structure, heavy loam
C_1^k	35-58 cm	Yellowish-light-brown, dry, dense, with carbonates, cemented sand or sandy loam
C_2^k	58-80 cm	Dull grey with whitish carbonate and salt mottles and rusty mottles, structureless, clayey
C_3	80-85 cm	Yellow-brown, dry, dense sand cemented by carbonates, with salt veins.

Desert solonetz soils form in flat microdepressions on plains and shallow interhill depressions in low-hill landscapes, with no groundwater influence on soil formation, in association with zonal automorphic soils. They form mainly on saline parent materials under biyurgun and tasbiyurgun–biyurgun communities. Most desert solonetz soils belong to the solonchakic category.

The physicochemical properties of the soils are presented in Tables 70, 71, 72.

Table 70 – Chemical and physicochemical properties of solonetz soils

Soil pit №	Depth sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Total	
24	0-6	0,38	0,042	2,9	4,5	2,25	1,38	0,25	8,4	9,3
	6-16	0,36	0,042	2,0	4,8	3,0	5,87	0,08	13,7	8,6
	20-30	0,34	0,042	1,6	9,5	3,0	2,3	0,05	14,9	8,3
	40-50	0,14	0,014	1,2	6,0	2,75	2,14	0,05	10,9	8,7
	65-75	26,97	4,02	2,9						8,3
	80-85	19,12	63,77	0,8						8,6

Table 71 - Particle-size distribution of solonetz and solonchak soils

Soil pit №	Depth, cm	Fraction content as % of oven-dry soil						
		particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3	4	5	6	7	8	9
24	0-6	22,41	55,65	2,10	16,00	1,41	2,43	19,84
	6-16	20,91	9,88	16,60	6,88	10,93	34,81	52,62
	20-30	26,71	19,66	19,23	4,86	6,48	23,07	34,40
24	40-50	32,51	29,45	21,85	2,83	2,02	11,33	16,19
	65-75	26,97	4,02	15,43	6,09	16,64	30,85	53,58
	80-85	19,12	63,77	10,60	2,85	0,82	2,85	6,52

Table 72 – Composition of water-soluble salts in solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^{-}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total as HCO_3^{-}	From normal carbonates as CO_3^{-2}						
24	0-6	0,086	0,037	0,004	none	0,024	0,004	0,001	0,018	0,002
			0,61	0,13	none	0,5	0,2	0,08	0,78	0,05
	6-16	0,28	0,088	0,022	0,054	0,048	0,002	0,001	0,086	0,001
			1,44	0,73	1,52	0,99	0,1	0,08	3,74	0,03
	20-30	1,020	0,017	none	0,164	0,507	0,124	0,006	0,201	0,001

			0,28	0,4	4,62	10,56	6,2	0,49	8,74	0,03
	40-50	0,547	0,017	none	0,104	0,244	0,043	0,003	0,135	0,001
			0,28	0	2,93	5,09	2,15	0,25	5,87	0,03
	65-75	1,615	0,017	none	0,146	0,95	0,228	0,023	0,25	0,001
			0,28	0	4,12	19,79	11,40	1,89	10,87	0,03
	80-85	0,458	0,015	none	0,079	0,214	0,029	0,006	0,114	0,001
			0,25	0	2,23	4,45	1,45	0,49	4,96	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot № 24. Analysis of vegetation study data showed that the soil type is solonchakic desert solonetz; terrain – gently undulating plain; landscape aspect – greyish; water regime – automorphic.

Data obtained from studying the biological characteristics of the vegetation showed that projective vegetation cover is 35-40% of the total area. The pasture type is biyurgun–wormwood–ephemeral. The botanical composition comprises biyurgun – 60%, wormwood – 25%, and ephemerals – 15% of the area, and includes wormwood, bluegrasses and annual saltworts. The available edible forage is 6,1 c/ha. The content of feed units is 0,52, digestible protein – 12,10%, fat – 4,50%, fibre – 33,70, and metabolizable energy – 7,45 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site № 24: N 46º 14' 44,8" E 61º 45' 30,9"

Study site № 25. Soil: solonchakic desert solonetz, heavy loam on loam. Soil pit coordinates: N 46º 22' 53,4". E 61º 46' 51,1". H = 75 m. Rolling surfaces composed of white clays. Biyurgun stands predominate, with only a small proportion, less than 10%, of wormwood stands. Clay outcrops occur on slopes, and takyrs in depressions. The soil pit was excavated under biyurgun–wormwood vegetation on a broad watershed surface. Projective cover – 30-40% (including ephemerals). Height 10-15 cm. Soil pit depth – 75 cm. A+B=42 cm. Carbonates – visible from 42 cm. Salts – 14-42 cm. Horizons: A_1^k 0-5 cm; 5-14 cm; B_1^{sn} 14-30 cm; B_2^{sn} 30-42 cm; C^k 42-80 cm. Samples collected: 0-5 cm; 5-14 cm; 17-27 cm; 31-41 cm; 70-80 cm.

A_1^k	0-5 cm	Light grey, brownish crust with horizontal layering; the surface is divided into polygons
A_1^k	5-14 cm	Dark brown, fresh, slightly compacted, granular-cloddy, medium loam
B_1^{sn} cm	14-30	Dark chestnut-brown with salt mottles, fresh, dense, columnar-blocky, clayey
B_2^{sn}	30-42 cm	Dark brown, fresh, dense, without visible salts, cloddy-nutty, medium

loam

C^k 42-75 cm Light yellow, with carbonates, dry, dense, light loam (Figure 28).





Figure 28 - Solonchakic desert solonetz, heavy loam on loam

Desert solonetz soils form in flat microdepressions on plains and shallow interhill depressions in low-hill landscapes, with no groundwater influence on soil formation, in association with zonal automorphic soils. They form mainly on saline parent materials under biyurgun and tasbiyurgun–biyurgun communities. Most desert solonetz soils belong to the solonchakic category.

The physicochemical properties of the soils are presented in Tables 73, 74, 75.

Table 73 – Chemical and physicochemical properties of solonetz soils

Soil pit №	Depth sample, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, meq/100 g					pH (water)
					Ca^{+2}	Mg^{+2}	Na^+	K^+	Total	
25	0-5	0,38	0,042	1,3	3,5	2,0	1,0	0,22	6,7	9,2
	5-14	0,21	0,028	1,7	4,25	2,5	1,81	0,18	8,7	9,6
	17-27	0,38	0,028	1,5	8,5	3,0	3,68	0,05	15,2	9,1
	31-41	0,27	0,014	0,8	6,0	2,25	8,42	0,03	16,7	8,9
	70-80			0,7	6,09	16,64				8,2

Table 74 - Particle-size distribution of solonetz and solonchak soils

Soil pit	Depth,	Fraction content as % of oven-dry soil

№	cm	particle size in mm						
		sand		silt			clay	physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
25	0-5	11,91	67,17	6,84	7,24	1,61	5,23	14,08
	5-14	14,72	46,50	16,56	2,83	2,83	16,56	22,22
	17-27	11,52	15,71	21,43	8,49	15,77	27,09	51,35
	31-41	10,71	44,84	26,10	4,89	8,56	4,89	18,35
	70-80	8,68	68,76	5,24	4,43	2,82	10,07	17,32

Table 75 – Composition of water-soluble salts in solonetz soils, %/meq

Soil pit №	Depth, cm	Total salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total as HCO_3^-	From normal carbonates as CO_3^{-2}						
25	0-5	0,06	0,024	0,001	0,001	0,018	0,006	0,002	0,006	0,003
			0,39	0,03	0,03	0,38	0,3	0,16	0,26	0,08
	5-14	0,086	0,049	0,012	none	0,013	0,002	0,001	0,02	0,001
			0,8	0,4	none	0,28	0,1	0,08	0,87	0,03
	17-27	0,248	0,061	0,01	0,057	0,048	0,003	0,001	0,078	none
			1,0	0,33	1,61	1,01	0,15	0,08	3,39	none
	31-41	0,419	0,037	0,004	0,164	0,067	0,004	0,001	0,146	none
			0,61	0,13	4,62	1,4	0,2	0,08	6,35	none
	70-80	1,234	0,012	none	0,109	0,728	0,209	0,009	0,166	0,001
			0,2	0	3,07	15,17	10,45	0,74	7,22	0,03

Characteristics and forage value of the vegetation cover

Monitoring plot № 25. Field vegetation surveys show that the soil type is solonchakic desert solonetz; terrain – rolling-undulating plain; landscape aspect – greenish grey; water regime – automorphic.

Analysis of field study data showed that projective vegetation cover is 40% of the total area. The pasture type is biyurgun–wormwood, with plants such as biyurgun, wormwood, bluegrass, Climacoptera, izen and Alyssum. The botanical composition consists mainly of biyurgun – 75%, wormwood – 15%, and ephemerals – 5%. The available edible forage is 5,8

c/ha. The content of feed units is 0,50, digestible protein – 12,60%, fat – 4,80%, fibre – 34,10, and metabolizable energy – 7,35 MJ per 1 kg of pasture forage. Coordinates of the boundary of study site №25: N 46º 22' 50,4" E 61º 46' 56,1"

Establishment of a database of solonetz lands in pastures using GIS technologies across the geographical and climatic zones of Kazakhstan

Establishing a database of solonetz lands in pastures using GIS technologies is an important task that will support land resource management in Kazakhstan. The developed database stores geospatial and tabular data that can be queried and accessed through various web services located on different servers. The database ensures data integrity and simultaneous availability to multiple web services, for example for visualization and downloading.

At the database (DB) level, multiple thematic spatial databases can be connected and managed to ensure their availability at the logical level for visualization and service processing. This enables support for spatial functions and indexes that improve the performance of spatial data retrieval and processing. Different datasets do not necessarily reside in a single central database, because the system is modular and the layer logic can work with different data sources. The data layer is managed using PostgreSQL with the PostGIS spatial extension, as this is the most mature solution. This database management system supports importing and exporting data in all major spatial formats, such as Shapefile, GeoTiff, GeoJSON, Well-Known Text (WKT), etc. PostGIS includes support for GiST-based R-Tree spatial indexes and functions for GIS feature analysis and processing.

Data and preparation requirements

Database management systems (DBMSs) are required to manage large volumes of data. A spatial database provides spatial types (geometry types such as points, lines and polygons), spatial functions and the ability to create spatial indexes to improve the performance of spatial queries and functions. A DBMS offers many advantages for managing and working with large amounts of data, including multi-user support (concurrency), data consistency and integrity, persistent storage and querying capabilities through a programming interface.

The following stages were implemented to meet the basic requirements for loading and preparing spatial data:

- Definition of the spatial data inventory: Development of the geodatabase structure, including a review of reference directories, classifiers and rules for spatial data identification codes.

- Optimization and indexing: Spatial and attribute indexing to improve query performance.

- Unified map projection: Application of a single map projection to all data.

- Consistent map legends: Establishment of common legends, scales and gradations for maps.

- Uniform level of generalization: Maintenance of a common level of generalization for all cartographic products.

All requirements for representing the geodatabase structure have been met, except those that would compromise geodatabase integrity. Feature classes repeated with identical attribute information but referring to different dates are physically included in a feature class dataset and may be omitted from the description.

Database composition

The main database includes the datasets listed in Table 76 and is updated using satellite imagery.

Table 76 – Composition of the published project layers

Feature class dataset	Name in the geodatabase	Type
Monitoring of solonetz lands	salinity_monitoring(date_span)	Polygon
	biomass_monitoring(date_span)	Polygon
Hydraulic structures	hydro_structures_lines	Line
	hydro_structures_points	Point
Agricultural facilities	agricultural_areas	Polygon

The “Monitoring of solonetz lands” feature class dataset contains several layers and is updated regularly. Satellite monitoring data are presented in Table 77.

Table 77 - List of published remote sensing data

Types of parametric interpretation of remote sensing data	Names of output raster products	Alias
NDVI (Normalized Difference Vegetation Index)	salinity_ndvi	LC150030_salinity_ndvi
LST (Land Surface Temperature)	salinity_lst	LC150030_salinity_lst
NDWI (Normalized Difference Water Index)	salinity_ndwi	LC150030_salinity_ndwi

The geodatabase is supplemented with data as satellite imagery and ground survey data become available.

The choice of spatial resolution for map production is determined by the specific monitoring tasks. These may be regional-scale maps covering Kazakhstan as a whole, or maps at the administrative region or district scale.

The choice of time intervals is also determined by the specific task. The frequency of database updates was assessed using data on the timeliness of imagery acquisition from Sentinel-1, Sentinel-2 and Landsat-8 satellites and the time required to process this information in GIS.

Solonetz and solonchak land polygons were delineated within the project; Figures 29-34 show the solonetz and solonchak polygons.



Figure 29 - Map of solonetz and solonchak soils in Almaty and Zhetysu regions produced using remote sensing methods



Figure 30 - Map of solonetz and solonchak soils in Zhambyl region produced using remote sensing methods

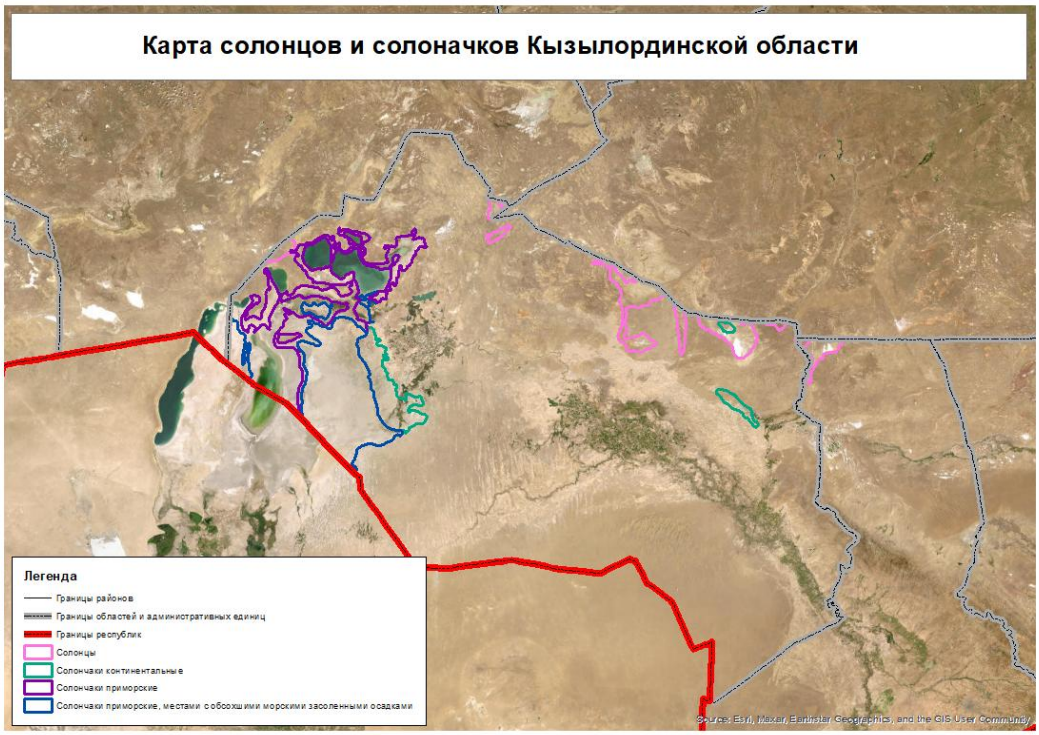


Figure 31 - Map of solonetz and solonchak soils in Kyzylorda region produced using remote sensing methods



Figure 32 - Map of solonetz and solonchak soils in Turkestan region produced using remote sensing methods



Figure 33 - Map of solonetz and solonchak soils in Atyrau region produced using remote sensing methods

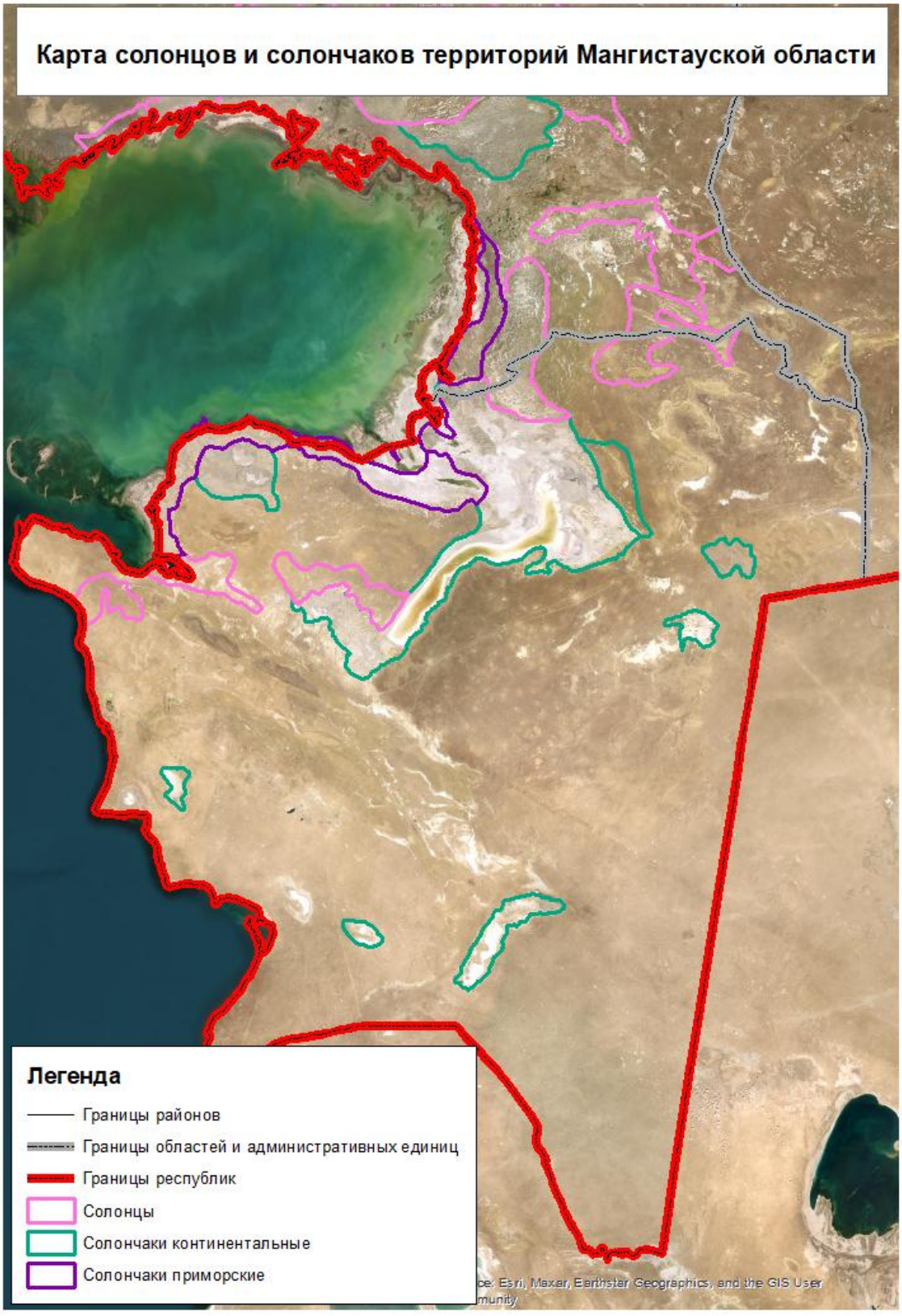


Figure 34 - Map of solonetz and solonchak soils in Mangystau region produced using remote sensing methods

Table 78 - Total areas of solonetz and solonchak soils in seven administrative regions of the republic: Almaty, Zhetysu, Zhambyl, Turkestan, Kyzylorda, Mangystau and Atyrau regions

Region name	Name	Area, ha
Mangystau region	Continental solonchaks	1 713 740
	Coastal solonchaks	863 921
	Solonetz soils	471 700
	Total:	2 749 361
Atyrau region	Continental solonchaks	3 374 782
	Coastal solonchaks	443 861
	Solonetz soils	183 822
	Total:	4 002 465
Kyzylorda region	Continental solonchaks	397 974
	Coastal solonchaks	668 760
	Solonetz soils	508 443
	Coastal solonchaks, locally with dried saline marine sediments	1 240 372
	Total:	1 575 177
Turkestan region	Solonetz soils	90 765
	Total:	90 765
Zhambyl region	Solonetz soils	289 285
	Continental solonchaks	62 175
	Total:	351 460
Almaty and Zhetysu regions	Solonetz soils	502 451
	Continental solonchaks	503 060
	Total:	1 005 511

Table 78 provides information on the total areas of solonetz and solonchak soils in seven administrative regions of the republic: Almaty, Zhetysu, Zhambyl, Turkestan, Kyzylorda, Mangystau and Atyrau regions

Databases of solonetz lands in pastures have been established using GIS technologies in Kazakhstan, enabling effective land resource management and monitoring. This will support the development of strategies for pasture restoration and improvement, which are important for sustainable agriculture and environmental protection.

In accordance with the 2024 work schedule, a preliminary interactive map of solonetz lands in pastures at a scale of 1:1 000 000 was developed using GIS technology for seven

administrative regions of the republic: Almaty, Zhetysu, Zhambyl, Turkestan, Kyzylorda, Mangystau and Atyrau regions (Figure 35).

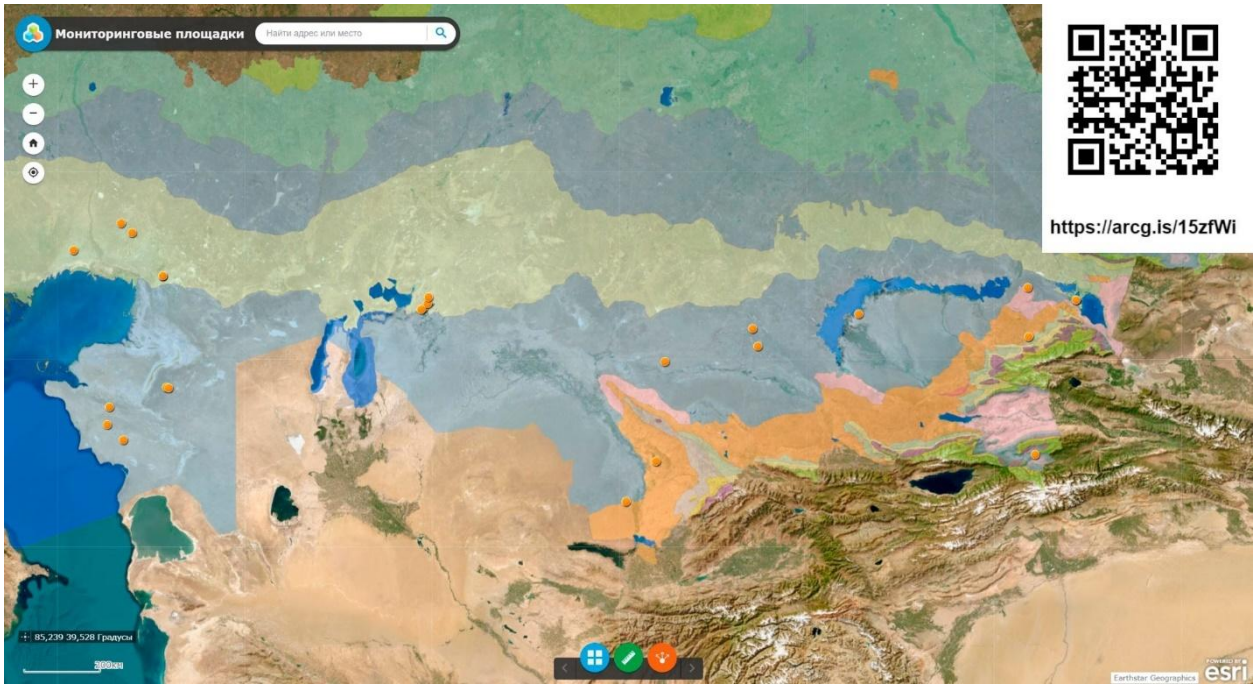


Figure 35 - Preliminary interactive geoinformation map of solonetz lands in pastures using GIS technologies for seven administrative regions of the republic: Almaty, Zhetysu, Zhambyl, Turkestan, Kyzylorda, Mangystau and Atyrau regions

PART II

Research to establish a database of solonetz lands in pastures using GIS technologies across the geographical or climatic zones of Kazakhstan was conducted in 2025 by the Non-Profit Joint-Stock Company “Kazakh National Agrarian Research University” along routes covering five administrative regions of the republic: Karaganda, Ulytau, Akmola, Aktobe and West Kazakhstan regions. Field studies were conducted at monitoring plots selected using soil maps, geographical maps and satellite imagery (Figures 1 and 2).

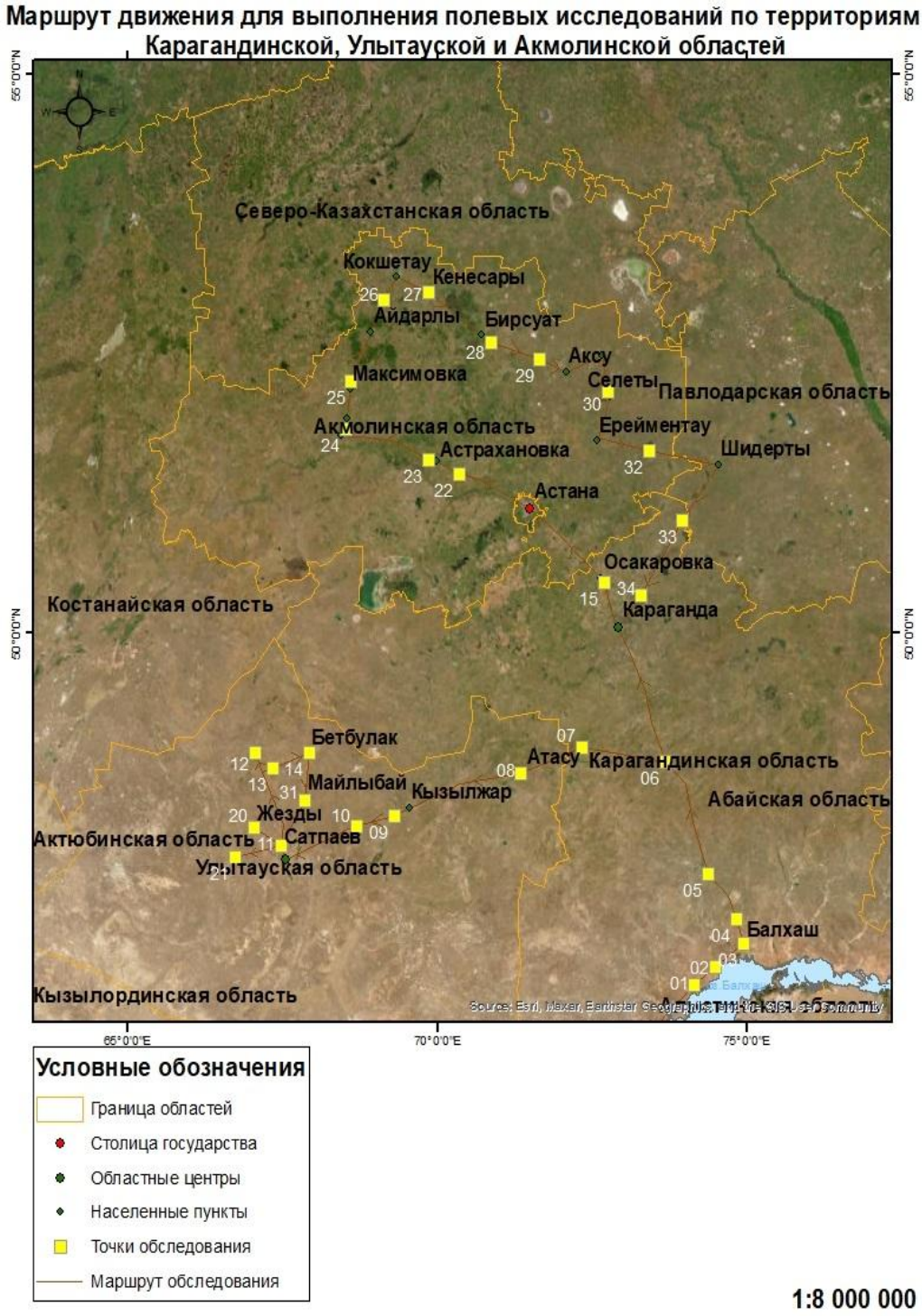


Figure 1 – Location and travel route for field studies in Karaganda, Ulytau and Akmola regions

In Aktobe and West Kazakhstan regions, 20 study polygons (10 in Aktobe and 10 in West Kazakhstan region) were selected to investigate solonetz lands in pastures (Figure 2).

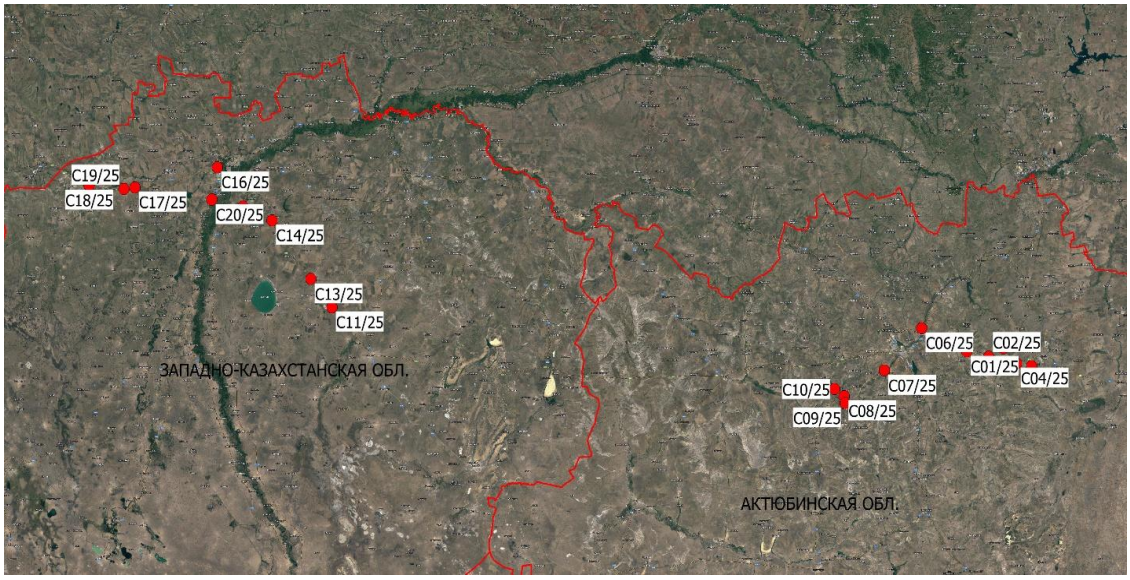


Figure 2 – Location of monitoring plots in Aktobe and West Kazakhstan regions

At these study polygons, the landscapes, vegetation and morphological properties of the soils were described, and soil samples were collected to study their physicochemical properties. Landscapes and soil profiles were photographed at the same time. After the work was completed, each soil pit was backfilled to prevent damage to machinery and livestock from falling into it.

A forage and botanical survey was also conducted at these study polygons. It involved determining projective vegetation cover and species composition, collecting plant samples from a 1 m by 1 m plot, and weighing the aboveground biomass to determine yield.

Karaganda region

Monitoring site №1 – The study was carried out in the Karaganda region, Aktogay district and is located from the Almaty – Karaganda highway 500 meters in the southeast (Figure 3). Soil type – medium saltbush, relief – plain, landscape aspect – greyish-greenish, water regime – atmospheric. Coordinates N 46° 530' 784", E 074° 146' 130".



A



B

Figure 3 – Structure of the profile (A) of the middle salt licks and surface condition (B)

0-14 cm, light grey, fresh, finely clumped, weakly compacted, pierced by roots, boils violently from HCI, granular loamy, transition sharp in density;

15-33cm, Dark brown with a whitish tint, dry, dense prismatic-columnar, heavy loam, roots, boils violently from HCI transition noticeable;

34-57 cm, Brown with a whitish tint, dry, dense, lumpy, loamy, few roots, boils violently from HCl, the transition is noticeable;

58-85 cm, whitish brown, dry, dense, structureless, loamy, boils violently from HCl, many spots of carbonates, gradual transition;

86-130 cm, light fawn, fresh, dense, structureless, boils violently from HCl, crushed stone.

The middle solonetzes of the Aktogay district of the Karaganda region are characterized by a superficially (0-10 cm) sandy loam and deeper than it (20-50 cm) medium loamy granulometric composition. The physical clay content in the indicated soil strata was 11.23 and 25.13%, respectively (Table 1).

Table 1 – Granulometric composition of mean solonetz

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
1	0-10	0,30	36,409	36,309	16,048	3,210	4,814	3,210	11,234
	20-30	1,36	32,036	32,279	10,543	3,650	8,921	12,571	25,142
	40-50	1,30	20,709	38,359	15,805	4,458	15,805	4,863	25,127
	70-80	2,48	16,756	24,590	46,349	5,332	0,410	6,563	12,305
	120-130	2,22	27,879	28,758	30,272	3,273	0,409	9,409	13,091

A study of the chemical composition of the middle solonetzes of the Aktogay district of the Karaganda region showed that they have a low level of fertility. This is evidenced by the humus content, which amounted to 0.44 and 0.51%, respectively, in the supra-solonetz and solonetz horizons (Table 2).

Table 2 – Chemical composition of medium salt licks

№ cut	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
1	0-10	0,44	0,056	25,2	20	160	9,18
	20-30	0,51	0,042	25,2	4	70	9,42
	40-50	-	-	-	-	-	8,72
	70-80	-	-	-	-	-	8,38
	120-130	-	-	-	-	-	8,36

The half-meter thickness of the middle salt licks of the study point №1 is characterized by a strongly alkaline reaction of the medium (pH 8.72-9.42).

Determination of the salt profile of medium salt licks showed that in them water-soluble salts in concentrations toxic to plants (>0.1-0.3%) occur from a depth of 20 cm. The most superficial humus layer, where the salt content was 0.065%, is favorable with respect to salinity (Table 3). Based on the data of the first half meter, the studied soils can be characterized as slightly saline.

Table 3 – Ionic composition of water extract of medium solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
1	0-10	0,065	0,48	0,00	0,04	0,41	0,09	0,66	0,12	0,06
			0,029	0,000	0,001	0,02	0,002	0,008	0,003	0,002
	20-30	0,329	0,96	0,16	3,29	0,81	0,09	0,09	4,85	0,02
			0,059	0,005	0,117	0,039	0,002	0,001	0,112	0,001
	40-50	0,221	0,40	0,00	3,32	0,15	1,4	1,22	1,24	0,02
			0,024	0,000	0,118	0,007	0,028	0,015	0,028	0,001
	70-80	0,539	0,36	0,00	8,5	0,65	7,01	1,22	1,25	0,02

			0,022	0,000	0,301	0,031	0,14	0,015	0,029	0,001
	120-130	0,859	0,36	0,00	4,99	8,34	10,66	2,16	0,86	0,02
			0,022	0,000	0,177	0,4	0,213	0,026	0,02	0,001

The soils of the monitoring site №1 of the Aktogay district of the Karaganda region are solonetz, since their content of absorbed sodium at a depth of 40-50 cm is 21.42%, and absorbed magnesium in the surface horizons is 29.0 and 54.0% of the sum of absorbed bases (Table 4).

Table 4 – Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
1	0-10	5,97	2,49	0,02	0,23	8,71
		68,5	29,0	0,2	3,0	
	20-30	4,98	7,46	1,42	0,06	13,92
		36,0	54,0	10,0	0,4	
	40-50	7,96	6,97	21,42	0,06	36,41
		22,0	19,0	59,0	0,2	
	70-80	10,95	17,41	7,84	0,20	36,40
		30,1	47,8	21,5	0,5	
	120-130	12,94	12,44	52,43	0,06	77,87
		17,0	16,0	67,0	0,1	

Characteristics and forage value of land cover. When studying the biological indicators of vegetation, it was revealed that the projective coverage of the surface of solonetzic soils with vegetation is 35–40% of the total area. The type of pasture is scorzonera-sagebrush with the participation of a boy, since when determining the botanical composition of plants, scorzonera occupies – 65%, wormwood – 20% and hawthorn – 15% of the area. On solonetz buds, in addition to them, bluegrass, Tatar rhubarb and kochia are found in small quantities in the vegetation. The yield of pasture mass was –9.2 c/ha. Coordinates of the boundaries of the contour of the research point №1– N 46º20'18.7, E 074º08'47,6’’

Research conducted by the laboratory of Kazakh Research Institute of «Animal Husbandry and Feed Production» to study the chemical composition of feed in solonetzic soils showed that the content of protein in the air-dry state is 13.63%, fat – 5.11%, fiber – 32.74%, NFE -36.09% and ash – 10.30%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.60 per kilogram of feed, and the exchange energy is – 8.71 MJ (appendix).

Monitoring site № 2 is located in the Aktogay district of the Karaganda region, in the southeast 500 meters from the Almaty – Karaganda highway and from the village of Gulshat to the north 18 kilometers (Figure 4). Soil type – medium saltbush, relief – low-wave plain,

landscape aspect – greyish, water regime – atmospheric. Coordinates N 46° 721' 132", E 074° 483' 838".



A



B

Figure 4 – Structure of the profile (A) of the middle salt licks and surface condition (B)

0-16 cm, light gray, dry, weakly compacted, dusty-clumpy, loamy, pierced by roots, boiling from HCl, the transition is sharp in density and color;

17-33 cm, Dark brown with whitish spots, dry, dense, heavy loam, roots, boiling from HCl, the transition is noticeable, lumpy-prismatic;

34-58 cm, lighter than the previous one, more spots dense, lumpy, loamy, roots, boils from HCl, dry, the transition is noticeable in mechanical composition;

59-85 cm, brown, fresh, loamy, coarse sand, carbonate spots, weakly compacted, structureless, gradual transition, boiling from HCl;

86-130 cm, light brown, wet, weakly compacted, crushed stone, structureless, boiling from HCl, there are individual gypsum drusen.

The granulometric composition of the solonetzes of the middle study points №2 of the Aktogay district of the Karaganda region is characterized by sandy loam in the superficial and heavy loamy solonetz horizons. These had physical clay contents of 16.48 and 33.27%, respectively (Table 5).

Table 5 – Granulometric composition of medium salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
2	5-15	0,48	30,527	42,946	10,048	5,225	7,235	4,019	16,479
	25-35	1,40	21,542	39,108	6,085	5,274	23,124	4,868	33,266
	40-50	1,68	31,998	31,387	8,950	2,441	19,121	6,103	27,665
	70-80	2,16	24,796	34,730	7,768	22,077	6,541	4,088	32,706
	110-120	3,12	41,969	19,220	9,083	1,652	20,644	7,432	29,727

Table 6 – Chemical composition of medium salt licks

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
2	5-15	0,37	0,042	22,4	20	200	9,09
	25-35	0,37	0,042	28	8	200	9,25
	40-50	-	-		-	-	8,82
	70-80	-	-	-	-	-	8,66
	110-120	-	-	-	-	-	8,56

The study of the chemical composition of the middle salt licks of the study point №2 of the Aktogay district of the Karaganda region is characterized by a low level of fertility. This proves the humus content in the surface horizons, where it was respectively 0.37%, as well as the very strong alkalinity (pH 9.09-9.25) of the soil environment (Table 6).

The average solonetzes of the study point №2 are characterized by the fact that the salinity of the profile increases with depth and at depths of 70-80 and 110-120 cm reaches a maximum (1.092 and 1.218%). The ionic composition is dominated by sulfate and then chlorine ions (Table 7).

Table 7 - Ionic composition of water extract of medium solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
2	5-15	0,141	0,32	0,00	1,00	0,91	0,28	0,84	1,05	0,06
			0,02	0,000	0,035	0,044	0,006	0,01	0,024	0,002
	25-35	0,372	0,56	0,16	5,17	0,45	0,28	0,84	5,04	0,02
			0,034	0,005	0,183	0,022	0,006	0,01	0,116	0,001
	40-50	0,688	0,32	0,00	7,94	3,09	3,27	1,22	6,84	0,02
			0,02	0,000	0,282	0,148	0,065	0,015	0,157	0,001
	70-80	1,092	0,40	0,00	10,71	6,59	4,39	2,06	11,21	0,03

			0,024	0,000	0,38	0,316	0,088	0,025	0,258	0,001
	110-120	1,218	0,32	0,00	10,16	9,08	6,08	2,81	10,64	0,03
			0,02	0,000	0,36	0,436	0,122	0,034	0,245	0,001

Data on the composition of the absorbed bases of the soils of study point №2 showed that they are solonetz. Since in the solonetz horizon (25-35 cm) the proportion of absorbed sodium reaches 43.0% of the sum of absorbed bases (Table 8).

Table 8 - Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
2	5-15	3,98	1,99	0,92	0,22	7,11
		56,0	28,0	13,0	3,0	
	25-35	3,98	6,47	7,99	0,05	18,49
		22,0	35,0	43,0	0,3	
	40-50	14,43	5,47	11,30	0,22	31,42
		46,0	17,0	36,0	0,7	
	70-80	22,39	9,95	5,88	0,24	38,46
		58,0	26,0	15,0	0,6	
	110-120	11,94	13,93	16,33	0,22	42,42
		28,0	33,0	38,5	0,5	

Characteristics and forage value of land cover. The total projective surface coverage of solonetzic soils with vegetation is only – 45% of the total area. Pasture type – sagebrush – scorzonera with the participation of hawthorn. The botanical composition of the plants consists of wormwood – 40%, scorzonera – 30%, feather grass – 5%, feather grass – 3%, klimokoptera – 10% and hawthorn – 12% of the area. In addition to them, kochia is found in a single specimen in the vegetation cover. The yield of pasture mass is – 10.0 c/ha. Coordinates of the study point contour boundaries №2 – N 46º43'15.7'' E 074º29'037''.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 13.41%, fat – 5.23%, fiber – 32.45%, NFE - 34.55% and ash – 11.42%. The yield of feed units at natural plant moisture is – 0.50 per kilogram of feed, and the exchange energy is – 6.89 MJ.

Monitoring site № 3 is located 8 kilometers north of the city of Balkhash, Aktogay district, Karaganda region (Figure 5). Soil type – fine saltbush, crushed soil surface, relief – low-wavelength plain, landscape aspect – greyish-greenish, water regime – atmospheric. Coordinates N 46° 949' 820", E 074° 941' 162".



A



B

Figure 5 – Structure of profile (A) of fine solonetz and surface condition (B)

0-11 cm, Light gray, dry, loamy, dusty lumpy, weakly compacted, many roots, boiling from HCl, crushed stone on the surface, sharp transition in density;

12-24 cm, Dark brown, dry, prism-clumpy, dense, heavy loam, roots, boils from HCl;

25-41cm, Brown with carbonate spots, dry, dense, lumpy, loamy, small roots, carbonate spots, gradual transition;

42-69cm, Brown with a whitish tint, fresh, structureless, compacted, noted a lot of gypsum drusen, does not boil from HCl;

70-120 cm, Brown with a reddish tint, wet, clayey, structureless, manganese veins, gypsum drusen, compacted, does not boil from HCl.

An analysis of the content of the fraction of small solonetz of the study point №3 of the Aktogay district of the Karaganda region showed that they have a sandy loam composition in the above-solonetz and heavy loam in the solonetz horizons themselves. In the latter, physical clay contains 14.95 and 33.18%, respectively (Table 9).

Table 9 – Granulometric composition of small salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
3	0-10	0,98	32,801	35,286	16,966	2,828	6,059	6,059	14,946

	11-21	2,36	32,466	25,748	8,603	10,242	1,639	21,303	33,183
	30-40	1,80	43,829	30,102	6,925	1,222	4,073	13,849	19,145
	50-60	4,38	44,112	26,605	8,785	1,673	2,092	16,733	20,498
	80-90	7,86	8,487	3,386	8,248	4,341	4,775	70,762	79,878

The chemical composition of small salt licks of the study point №3 of the Aktogay district of the Karaganda region shows a low level of their fertility. The humus content of the surface horizons is 0.51% (Table 10).

Table 10 – Chemical composition of fine salt licks

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
3	0-10	0,51	0,056	19,6	12	220	9,84
	11-21	0,51	0,056	25,2	10	90	8,96
	30-40	-	-	-	-	-	8,61
	50-60	-	-	-	-	-	8,09
	80-90	-	-	-	-	-	6,68

A study of the ionic composition of the water extract and the salt content of the small salt licks of the monitoring site №3 showed that they are superficially practically unsalted. This is clearly shown by the content of water-soluble salts (0.075 and 0.133%) in layers 0-10 and 11-21 cm (Table 11). A sharp increase in the noted indicator to 1.5% is observed deeper than the first half meter in layers of 50-60 and 80-90 cm.

Table 11 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
3	0-10	0,075	0,72	0,16	0,07	0,19	0,09	0,28	0,59	0,02
			0,044	0,005	0,003	0,009	0,002	0,003	0,014	0,001
	11-21	0,133	0,64	0,16	1,37	0,02	0,28	0,19	1,52	0,04
			0,039	0,005	0,048	0,001	0,006	0,002	0,035	0,002
	30-40	0,582	0,32	0,00	4,51	4,45	1,78	1,78	5,70	0,02
			0,020	0,000	0,160	0,214	0,036	0,022	0,131	0,001
	50-60	1,237	0,28	0,00	3,84	14,6	11,13	1,41	6,18	0,02
			0,017	0,000	0,136	0,701	0,223	0,017	0,142	0,001
	80-90	1,503	0,36	0,00	24,57	1,14	1,40	3,74	20,91	0,02

			0,022	0,000	0,871	0,055	0,028	0,045	0,481	0,001

A study of the composition of small salt licks of the monitoring site №3 showed that the proportion of absorbed sodium and magnesium in them is high. Thus, for example, in the upper horizon (0-10 cm) the proportion of magnesium absorbed is 36.0%, while at a depth of 30-40 cm the proportion of sodium absorbed reaches 46.0% (Table 12). Moreover, the latter increases even more with depth.

Table 12 - Composition of absorbed bases of small solonetz

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
3	0-10	5,47	3,98	1,42	0,12	10,99
		50,0	36,0	13,0	1,0	
	11-21	12,94	2,49	2,09	0,14	17,66
		73,0	14,0	12,0	0,8	
	30-40	21,39	4,48	21,79	0,14	47,80
		45,0	9,0	46,0	0,3	
	50-60	11,94	13,43	26,95	0,05	52,37
		23,0	26,0	51,5	0,1	
	80-90	9,95	12,94	61,06	0,05	84,00
		11,8	15,4	72,7	0,06	

Characteristics and forage value of land cover. Studies of biological indicators of vegetation showed that the projective coverage of the surface of solonetzic soils with vegetation is – 40%. Pasture type – salsola -sagebrush with the participation of hawthorn and feather grass**.** When studying the botanical composition of plants, it was revealed that scorzonera occupies - 60%, wormwood – 15%, calligonum – 15% and feather grass – 10% of the area. In addition to them, the vegetation contains plants such as kochia, sedge and climocoptera. The yield of pasture mass was - 7.0 c/ha. Coordinates of the study point contour boundaries №3 – N 46º56'59,3’’; E 074º56'27,80’’.

Analysis of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 11.44%, fat – 6.72%, fiber – 33.42%, NFE -34.65% and ash – 10.53%. At the same time, the yield of feed units at natural plant moisture is – 0.51 per kilogram of feed, and the exchange energy is – 6.96 MJ.

The monitoring site №4 is also located in the Aktogay district of the Karaganda region and is located 500 meters east of the Almaty – Karaganda highway (Figure 6). Soil type – medium saltbush, soil surface - crushed stone, relief – plain, landscape aspect – greyish – yellowish, water regime – atmospheric. Coordinates N 47°199' 144", E 074° 827' 975".



A



B

Figure 6 – Structure of the profile (A) of the middle salt licks and surface condition (B)

0-13 cm, Light gray, dry, dusty-clumpy, weakly compacted, loamy, soil-crushed from the surface, many roots, boiling from HCl, transition clear in density;

14-28 cm, Brown, dry, dense, prism-columnar, heavy loam, roots, salt spots, boiling from HCl, gradual transition;

29-47 cm, Brown with a whitish tint, dry, dense, loamy, lumpy, many roots, boils from HCl, the transition is noticeable in color;

48-68 cm, Lighter than the previous one, dry, compacted, loamy, crushed stone and small stones are found, structureless, boiling transition from HCl is sharp in color;

69-120 cm, Greyish-whitish, fresh, dense, clayey, structureless, a lot of gypsum and carbonates.

A study of the middle salt licks of the study point №4 of the Aktogay district of the Karaganda region showed that in the upper horizon they have a light loamy granulometric composition (physical clay 27.34%). In the underlying horizon, the content of physical clay increases and amounts to 39.55% (Table 13), which indicates severe conditions.

Table 13 – Granulometric composition of medium salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
4	0-10	1,96	40,147	14,157	18,360	8,568	13,464	5,304	27,336
	15-25	2,90	30,299	15,324	14,830	6,591	11,123	21,833	39,547
	30-40	3,38	30,656	15,111	15,318	7,038	14,490	17,388	38,915
	50-60	2,80	51,749	14,918	9,877	4,938	9,053	9,465	23,457
	80-90	4,06	31,666	23,306	24,599	1,668	0,834	17,928	20,429

Table 14 – Chemical composition of medium salt licks

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
4	0-10	1,17	0,126	47,6	16	320	8,67
	15-25	0,91	0,112	19,6	2	80	8,46
	30-40	-	-	-	-	-	8,65
	50-60	-	-	-	-	-	8,22
	80-90	-	-	-	-	-	8,15

Compared to previous soils, in the middle salt licks of the study point №4, the humus content in the humus-accumulative horizon (0-10 cm) is slightly higher and amounts to 1.17%. With depth, it gradually decreases to 0.91% (Table 14). From the surface to a depth of 90 cm, the reaction of the soil environment of medium-sized solonetz varies from medium to highly alkaline (pH 8.15-8.67).

From the data of the ionic composition and the content of water-soluble salts of the middle salt licks of the monitoring site №4, it follows that they are not saline in the first half meter (sum of salts <0.1%). However, a high concentration of salts (1.318%) at a depth of 80-90 cm indicates that the noted soils formed on saline source rocks (Table 15).

Table 15 - Ionic composition of water extract of medium solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
4	0-10	0,095	0,44	0,00	0,04	0,87	0,65	0,47	0,14	0,08
			0,027	0,000	0,001	0,042	0,013	0,006	0,003	0,003
	15-25	0,055	0,36	0,00	0,00	0,41	0,28	0,38	0,10	0,02
			0,022	0,000	0,000	0,020	0,006	0,005	0,002	0,001
	30-40	0,078	0,56	0,04	0,00	0,50	0,28	0,38	0,39	0,02
			0,034	0,001	0,000	0,024	0,006	0,005	0,009	0,001
	50-60	0,352	0,28	0,00	0,00	4,86	3,55	0,56	1,01	0,02
			0,017	0,000	0,000	0,233	0,071	0,007	0,023	0,001

	80-90	1,318	0,32	0,00	1,29	17,78	11,87	1,03	6,47	0,02
			0,02	0,000	0,046	0,853	0,237	0,013	0,149	0,001

Data on the composition of the absorbed bases of the middle solonetzes of the monitoring site №4 showed that their content of absorbed sodium is quite high (19.5% of the CEC) in the solonetz horizon (Table 16).

Table 16 - Composition of absorbed bases of middle solonetz

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
4	0-10	13,43	4,48	0,02	0,22	18,15
		74,0	25,0	0,1	1,0	
	15-25	22,39	6,47	7,02	0,05	35,93
		62,3	18,0	19,5	0,2	
	30-40	20,4	6,97	0,77	0,05	28,19
		72,0	25,0	2,7	2,2	
	50-60	36,82	3,98	2,66	0,05	43,51
		85,0	9,0	6,0	0,1	
	80-90	12,44	14,43	3,66	0,05	30,58
		41,0	47,0	12,0	0,2	

Characteristics and forage value of land cover. The study of soil cover by vegetation showed that projective surface coverage by plants accounts for 45% of the total area. Pasture type – sagebrush - scorzoneraovo - feather grass. The botanical composition of this massif consists of wormwood – 52%, scorzonera –25%, feather grass – 10%, kochia – 8% and parmell – 5% of the area. Plants such as ferula are also found in the vegetation. The yield of pasture mass was -11.5 c/ha. Coordinates of the study point contour boundaries №4 – N 47º11'56.9’’; E 074º49'41.9’’.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 12.93%, fat – 6.44%, fiber – 32.22%, NFE - 33.38% and ash – 11.84%. At the same time, the yield of feed units at natural plant moisture is – 0.48 per kilogram of feed, and the exchange energy is – 6.74 MJ.

Monitoring site №5 in the Shet district of the Karaganda region and is located 500m northeast of the Karaganda – Almaty highway (Figure 7). Soil type – fine brackish, relief – weakly sloping plain with a southern slope, landscape aspect – greyish, water regime – atmospheric. Coordinates N 47°645' 370", E 074° 365' 029".



A



B

Figure 7 – Structure of profile (A) of fine solonetz and surface condition (B)

0-18 cm, Light grey, dusty-grain, dry, weakly compacted, loamy, many roots, boils violently from HCl, clear transition;

19-31cm, Brown, dry, dense, heavy loam, prism-like lumpy, roots, boiling from HCl, carbonate spots marked towards the bottom, noticeable transition;

32-49 cm, Brown-fawn, a lot of carbonates, dry, dense, lumpy, loamy, few roots, boils violently from HCl;

50-78 cm, Whitish due to carbonates, fresh, dense, structureless, loamy, boils violently from HCl, the transition is noticeable;

79-110 cm, Fawn-buff, fresh, compacted, structureless, manganese dots, iron veins, loamy.

Based on the granulometric composition of the solonetz, small study points №5 of the Shet district of the Karaganda region are characterized as light loamy. Physical clay in the 0-30 cm thickness averages 27.0% (Table 17). Even deeper, starting from 35 cm, the soil becomes heavy clay. Physical clay varies between 43.89 and 55.92%.

Table 17 – Granulometric composition of small salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
5	5-15	1,52	28,899	28,452	15,435	8,936	12,185	6,093	27,214
	20-30	1,96	42,697	18,543	10,200	6,120	9,384	13,056	28,560
	35-45	2,48	29,717	16,961	9,434	11,075	13,946	18,868	43,888
	60-70	2,16	22,383	19,563	10,221	4,088	38,021	5,724	47,833
	80-90	2,00	18,143	12,878	13,061	4,898	44,490	6,531	55,918

Based on the humus content in the upper horizons of small salt licks, we can state the fact that the soils in question are weakly humidified. The humus content of layers 5-15 and 20-30 cm was 1.75 and 1.36% (Table 18).

Table 18 – Chemical composition of fine salt licks

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
5	5-15	1,75	0,224	28,0	40	500	7,90
	20-30	1,36	0,098	33,6	2	100	8,56
	35-45	-	-	-	-	-	8,55
	60-70	-	-	-	-	-	8,76
	80-90	-	-	-	-	-	8,31

Data on the ionic composition and water extract salt content of the salt licks of the small monitoring site №5 showed that these soils are not saline at a depth of 0-30 cm (<0.1%). However, within a thickness of 35 to 70 cm, the degree of soil salinity changes to weak (0.298-0.356%) (Table 19).

Table 19 - Ionic composition of fine salt licks aqueous extract, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
5	5-15	0,086	0,28	0,00	0,04	0,97	0,19	0,94	0,03	0,13
			0,017	0,000	0,001	0,047	0,004	0,011	0,001	0,005
	20-30	0,039	0,44	0,00	0,00	0,07	0,19	0,28	0,03	0,02
			0,027	0,000	0,000	0,003	0,004	0,003	0,001	0,001
	35-45	0,298	0,52	0,00	2,73	1,55	0,47	1,31	3,01	0,02
			0,032	0,000	0,097	0,075	0,009	0,016	0,069	0,001
	60-70	0,356	0,44	0,00	4,62	0,82	0,47	0,75	4,64	0,02
			0,027	0,000	0,164	0,039	0,009	0,009	0,107	0,001
	80-90	0,873	0,36	0,00	4,43	8,78	6,08	1,97	5,51	0,02
			0,022	0,000	0,157	0,421	0,122	0,024	0,127	0,001

The soils of the monitoring site №5 of the Shet district of the Karaganda region are characterized by magnesium solonetzicity. This is evidenced by the proportion of magnesium absorbed, which varies in a noticeable amount within the profile from 37.0 to 42.0% of the cation exchange capacity (Table 20).

Table 20 - Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
5	5-15	8,46	5,47	0,16	0,65	14,73
		57,0	37,0	1,0	4,0	
	20-30	12,94	2,49	0,16	0,09	15,67
		83,0	16,0	1,0	0,6	
	35-45	12,94	9,95	0,53	0,09	23,50
		55,0	42,0	2,0	0,4	
	60-70	12,94	8,46	1,59	0,09	23,08
		56,0	37,0	7,0	0,4	
	80-90	27,86	6,97	1,72	0,09	36,64
		76,0	19,0	5,0	0,2	

Characteristics and forage value of land cover. The results of the field studies show that the projective covering of the soil surface by plants accounts for – 55% of the total area. Grassland type – sagebrush and feather grass involving krascheninnikovia ceratoides. A study of the botanical composition of plants showed that wormwood occupies – 50%, feather grass – 35%, krascheninnikovia ceratoides – 10% and ephedra – 5% of the area. The plants also contain single plants – Tatar rhubarb. The yield of pasture mass was – 6.0 c/ha. Coordinates of the study point contour boundaries №5 – N 47º38'43.0’’; E 074º21'54.2’’.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 12.52%, fat – 7.00%, fiber – 32.52%, NFE - 34.31% and ash – 10.54%. The yield of feed units at natural plant moisture is – 0.53 per kilogram of feed, and the exchange energy is – 7.45 MJ.

Monitoring site № 6 is located 1.5 kilometers from the village. Aksu-Ayuly to the south in the Shet district of the Karaganda region (Figure 8). Soil type – fine saltbush, relief – plain, landscape aspect – yellowish grey, water regime – atmospheric. Coordinates N 48° 756' 219", E 073° 681' 798".



A



B

Figure 8 – Structure of profile (A) of fine solonetz and surface condition (B)

0-10 cm, Dark grey, dry, compacted, dusty lumpy, loamy, plant roots, does not boil from HCl, transition is sharp in density;

11-23cm, Brownish grey, dry, dense, columnar, heavy loam, roots, does not boil from HCl, clear transition;

24-41cm, Brownish, dry, compacted, lumpy, loamy, few roots, veins of carbonates, boils violently from HCl, the transition is gradual;

42-70 cm, Dark brown with carbonate veins, dry, compacted, loamy, few roots, structureless, sharp transition;

71-130 cm, Brown with a whitish tint, fresh, compacted, loamy, accumulation of carbonates and gypsum, individual spots of manganese are found, structureless.

A study of the granulometric composition of small solonetzes of the monitoring site №6 showed that they are superficially light loamy, as well as medium loamy in the solonetz horizon. In the marked strata, the physical clay content was respectively 15.56 and 29.02% (Table 21).

Table 21 – Granulometric composition of small salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01

6	0-10	2,28	14,388	37,720	32,337	6,140	6,140	3,275	15,555
	11-21	2,12	9,931	29,179	31,876	10,217	11,034	7,765	29,015
	30-40	2,00	9,653	36,878	30,612	6,939	8,980	6,939	22,857
	50-60	2,14	6,785	25,772	33,926	9,401	19,620	4,496	33,517
	80-90	1,98	19,547	38,013	29,790	1,224	0,816	10,610	12,650

Small salt licks of the monitoring site №6 of the Shet district of the Karaganda region contain total humus in the amount of 3.73 and 2.22% in layers 0-10 and 11-21 cm (Table 22). These soils are characterized by a highly alkaline reaction of the medium throughout the profile (pH 8.19-8.64).

Table 22 – Chemical composition of fine salt licks

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
6	0-10	3,73	0,252	64,4	42	1000	8,64
	11-21	2,22	0,168	50,4	10	680	8,25
	30-40	-	-	-	-	-	8,19
	50-60	-	-	-	-	-	8,22
	80-90	-	-	-	-	-	8,24

According to the ionic composition of the water extract of small salt licks of the monitoring site №6, it is clear that in these soils the salinity increases with depth from a weak to an intense degree. Within the profile, the salt content varies from 0.128 to 1.173% (Table 23).

Table 23 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
6	0-10	0,128	0,48	0,00	0,04	1,26	0,09	0,75	0,66	0,28
			0,029	0,000	0,001	0,061	0,002	0,009	0,015	0,011
	11-21	0,476	0,40	0,00	4,99	2,30	1,78	1,13	4,45	0,33
			0,024	0,000	0,177	0,11	0,036	0,014	0,102	0,013
	30-40	0,766	0,40	0,00	10,16	2,32	4,86	1,69	5,89	0,44
			0,024	0,000	0,36	0,111	0,097	0,021	0,135	0,017
	50-60	1,150	0,36	0,00	10,53	7,85	8,23	3,00	7,23	0,28
			0,022	0,000	0,373	0,377	0,165	0,036	0,166	0,011
	80-90	1,173	0,28	0,00	2,44	15,03	11,03	2,53	4,16	0,02
			0,017	0,000	0,086	0,721	0,221	0,031	0,096	0,001

Study of the composition of the absorbed bases of the middle solonetzes of the monitoring site №6 shows the salinity of the soil from a depth of 30 cm to 60 cm, where the

proportion of absorbed sodium is, respectively, 46.0 and 51.8% of the cation exchange capacity (Table 24).

Table 24 - Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
6	0-10	13,93	4,98	0,89	1,71	21,52
		65,0	23,0	4,0	8,0	
	11-21	14,93	4,98	2,37	0,49	22,77
		66,0	22,0	10,0	2,0	
	30-40	15,42	8,96	21,02	0,45	45,85
		34,0	19,0	46,0	1,0	
	50-60	28,86	7,96	39,60	0,17	76,59
		38,0	10,0	51,8	0,2	
	80-90	12,94	9,95	0,29	0,09	23,27
		55,6	43,0	1,0	0,4	

Characteristics and forage value of land cover. The data obtained when studying the biological indicators of vegetation showed that the projective coverage of the soil with vegetation accounts for 60% of the total area. Pasture type – sagebrush-hazel-cereal. The botanical composition of plants is formed mainly from wormwood – 60%, isene – 30% and cereals – 10% of the area and consists of plants such as wormwood, isene, fescue, chiy, yarrow, cinquefoil and thistle. The yield of pasture mass is 6.5 c/ha. Coordinates of the study point contour boundaries №6 – N 48°45'20,4''; E 073°40'53,8''.

Analysis of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 12.13%, fat – 5.22%, fiber – 32.84%, NFE -34.65% and ash – 12.32%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.50 per kilogram of feed, and the exchange energy is – 7.06MJ.

The monitoring site № 7 is also located in the Shet district of the Karaganda region, east of the Karaganda-Zhezkazgan highway (Figure 9). Soil type – brackish, relief – weakly undulating plain, landscape aspect – greyish-yellowish, water regime – atmospheric. Coordinates N 48° 890' 700", E 072° 333' 273".



A



B

Figure 9 – Structure of the profile (A) of cortical solonetz and surface condition (B)

0-4cm, Light gray, dry, dusty lumpy, loose, loamy, many roots, does not boil from HCl, the transition is sharp in color and density;

5-23cm, Dark brown, dry, very dense, columnar, heavy loam, plant roots, does not boil from HCl, the transition is noticeable;

24-43cm, Gley with brown tint, wet, slightly compacted, light loam, lumpy, boiling from HCl, clear transition in color;

44-62 cm, Gley with brown spots, wet, veins and spots of carbonates, structureless, loamy, weakly compacted, does not boil from HCl, the transition is gradual;

63-120 cm, Gley with pronounced brown spots, wet, structureless, clayey, weakly compacted, does not boil from HCl.

In terms of granulometric composition, the cortical salt licks of the monitoring site №7 are characterized by a sandy loam and light clay composition in the over-solonetz and solonetz horizons. In the latter, the physical clay content was respectively 16.63 and 40.80% (Table 25).

Table 25 – Granulometric composition of cortical solonetzes

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physi-cal

									clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
7	0-7	8,58	28,965	37,782	16,627	7,001	5,688	3,938	16,627
	10-20	1,96	27,458	22,766	8,976	8,160	11,832	20,808	40,800
	25-35	3,08	15,291	23,215	48,700	0,413	0,413	11,969	12,794
	45-55	2,26	12,994	39,943	38,879	2,046	0,818	5,320	8,185
	80-90	1,96	31,089	20,767	17,952	25,296	1,224	3,672	30,192

In the chemical composition of the cortical salt licks of the monitoring site №7 of the Shet district of the Karaganda region, it is clear that their humus content is 2.07, 1.61 and 0.33% in the upper three layers (Table 26). The alkalinity of the soil environment (pH 8.39-9.23) is characterized by almost all genetic horizons of soils, except humus (pH 7.15).

Table 26 – Chemical composition of cortical solonetzes

Point №	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
7	0-7	2,07	0,126	25,2	48	290	7,15
	10-20	1,61	0,084	33,6	16	220	8,39
	25-35	0,33	0,084	28,0	6	60	9,23
	45-55	-	-	-	-	-	9,04
	80-90	-	-	-	-	-	8,55

A study of the ionic composition of the water extract of the crust salt licks of the monitoring site №7 showed that these soils are very highly saline within a thickness of 25 to 90 cm. In the latter, the salt content varies from 1.792 to 2.425% (Table 27).

Table 27 - Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
7	0-7	0,046	0,20	0,00	0,00	0,43	0,09	0,09	0,43	0,02
			0,012	0,000	0,000	0,021	0,002	0,001	0,010	0,001
	10-20	0,355	0,52	0,00	1,40	3,45	0,47	1,40	3,49	0,02
			0,032	0,000	0,050	0,166	0,009	0,017	0,080	0,001
	25-35	2,383	0,28	0,00	6,10	29,13	10,75	3,09	21,64	0,02
			0,017	0,000	0,216	1,398	0,215	0,038	0,498	0,001
	45-55	2,425	0,32	0,00	7,57	28,41	9,63	3,09	23,56	0,02
			0,020	0,000	0,269	1,364	0,193	0,038	0,542	0,001

	80-90	1,792	0,24	0,00	8,50	18,24	5,24	0,47	21,26	0,02
			0,015	0,000	0,30 1	0,876	0,10 5	0,006	0,489	0,001

The composition of the absorbed bases of the cortical solonetzes of the monitoring site №7 is dominated by absorbed sodium, the share of which in the solonetz horizon was 25.0% of the cation exchange capacity (Table 28). Moreover, with depth, its proportion increases even more and at a depth of 80–90 cm reaches 61.6% of the CEC.

Table 28 - Composition of absorbed bases of cortical solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
7	0-7	6,47	3,48	0,36	0,31	10,62
		61,0	33,0	3,0	3,0	
	10-20	4,48	6,97	3,95	0,11	15,51
		29,0	45,0	25,0	1,0	
	25-35	14,43	9,95	28,29	0,09	52,76
		27,0	18,8	54,0	0,2	
	45-55	12,94	10,95	25,25	0,09	49,22
		26,3	22,2	51,3	0,2	
	80-90	36,82	3,48	64,91	0,09	105,29
		35,0	3,3	61,6	0,09	

Characteristics and forage value of land cover. Analysis of the data obtained from field studies showed that the projective coverage of the soil with vegetation accounts for 60% of the total area. Pasture type – sagebrush-fescue-echium with the distribution of plants such as sagebrush, fescue, feather grass, vostrets, volosnets, echium, statice, camphorosma, reveller and ferula. The botanical composition consists mainly of wormwood – 60%, fescue – 20%, echium– 10%, statice 5% and camphorosm 5% of the area. The yield of pasture mass is at – 5.0 c/ha. Coordinates of the study point contour boundaries №7 – N 48º53'26,4’’; E 072º20'00,0’’.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 11.82%, fat – 6.93%, fiber – 31.93%, NFE - 32.58% and ash – 13.42%. The yield of feed units at natural plant moisture is – 0.52 per kilogram of feed, and the exchange energy is – 7.21 MJ.

The monitoring site № 8 is located in the Osakarov district of the Karaganda region and is located 600m from the village. Bakbakty in a northwestern direction, towards Astana (Figure 10). Soil type –shallow, relief – plain, landscape aspect –greenish– greyish, water regime – atmospheric. Coordinates N 50°469' 737", E 072° 687' 368".



A



B

Figure 10 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-10cm, Dark gray, fresh, dusty lumpy, loose, many plant roots, boils violently from HCl, loamy, the transition is sharp in density;

11-22cm, Dark brown, fresh, dense, columnar-prismoid, heavy loam, roots, boils violently from HCl, gradual transition;

23-36 cm, Lighter than the previous one, fresh, dense, lumpy, loamy, single roots, boils violently from HCl, the transition is gradual;

37-63cm, Brown, wet, compacted, structureless, loamy, carbonate veins, small plant roots, boils violently from HCl, gradual transition;

64-110 cm, Lighter than the previous one, wet, weakly compacted, individual dark spots are noted, clayey, structureless, boils violently from HCI; veins of carbonates.

In small salt licks of the monitoring site №8, Osakarov district, Karaganda region, the content of physical clay in layers 0-10 and 11-21 cm is 33.73 and 44.60%, respectively (Table 29). This suggests that the humus horizon has an average loamy granulometric composition. Deeper, starting from the solonetz horizon, the latter becomes heavy.

Table 29 – Granulometric composition of fine salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physi-cal clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01

8	0-10	3,94	5,726	19,738	40,808	9,577	16,240	7,912	33,729
	11-21	4,04	3,272	17,528	34,598	11,672	18,341	14,589	44,602
	25-35	3,98	1,458	26,474	14,164	14,580	20,829	22,495	57,905
	50-60	3,92	0,729	10,595	29,142	12,073	22,481	24,979	59,534
	80-90	3,90	0,333	4,766	37,045	13,319	39,958	4,579	57,856

The salt licks of the small monitoring site № 8 in the Osakarov district of the Karaganda region are characterized by a low level of fertility. This is evidenced by the humus content (2.55 and 2.06%) and the medium/strong alkaline reaction of the medium (pH 8.37 and 8.70) (Table 30).

Table 30 – Chemical composition of fine salt licks

№ cut	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
8	0-10	2,55	0,182	81,2	14	500	8,37
	11-21	2,06	0,168	39,2	2	210	8,70
	25-35	1,84	0,098	30,8	2	200	8,64
	50-60	-	-	-	-	-	8,41
	80-90	-	-	-	-	-	8,29

In the small salt licks of the monitoring site №8, the content of water-soluble salts is low, especially in the surface layers, where their sum was 0.115-0.151% (Table 31). However, deeper, the content of toxic salts gradually increases to 0.541%.

Table 31 - Ion composition of water extracts from small salt marshes, mg-eq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
8	0-10	0,115	0,60	0,00	0,22	0,85	0,37	0,66	0,62	0,02
			0,037	0,000	0,008	0,041	0,007	0,008	0,014	0,001
	11-21	0,151	0,76	0,00	0,00	1,35	0,09	0,84	1,16	0,02
			0,046	0,000	0,000	0,065	0,002	0,01	0,027	0,001
	25-35	0,264	0,76	0,00	0,52	2,58	0,19	1,22	2,44	0,02
			0,046	0,000	0,018	0,124	0,004	0,015	0,056	0,001
	50-60	0,504	0,48	0,00	5,73	2,20	1,78	2,06	4,55	0,02
			0,029	0,000	0,203	0,105	0,036	0,025	0,105	0,001
	80-90	0,541	0,40	0,00	7,57	1,28	2,62	1,69	4,93	0,02
			0,024	0,000	0,269	0,061	0,052	0,021	0,113	0,001

Small salt licks of the monitoring site №8 of the Osakarov district of the Karaganda region are characterized by magnesium solonetz. Since the proportion of absorbed magnesium in the solonetz and sub-solonetz horizons is greater than 30% of the sum of absorbed bases (Table 32).

Table 32 - Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
8	0-10	19,4	6,97	0,94	0,33	27,64
		70,2	25,2	3,4	1,2	
	11-21	15,42	11,44	3,45	0,09	30,39
		50,7	38,0	11,0	0,3	
	25-35	14,93	9,45	0,80	0,09	25,27
		59,1	37,4	3,2	0,3	
	50-60	13,93	17,91	0,78	0,09	32,70
		42,6	54,7	2,4	0,3	
	80-90	11,94	14,43	0,45	0,09	26,90
		44,4	53,6	1,7	0,3	

Characteristics and forage value of land cover. Projective vegetation coverage of this solonetz area accounts for 65% of the total area. Pasture type –wormwood– forge-fescue. The botanical composition of the plants consists of wormwood– 50%, feather grass –30%, fescue– 20% of the area. In addition to the above-mentioned plants, wheatgrass, yellow sweet clover, yarrow and rump are found in a single specimen. The yield of pasture mass is –11.0 c/ha. Coordinates of the study point contour boundaries №8 – N 50º28'10,9’’; E 072º41'14,2’’.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that in the air-dry state the content of protein is 16.62%, fat – 7.02%, fiber – 32.93%, NFE -33.52% and ash – 7.42%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.58 per kilogram of feed, and the exchange energy is – 8.23 MJ.

Monitoring site № 9 is located in the Osakarov district of the Karaganda region, 400 m west of the Pavlodar highway– Karaganda and in an easterly direction 3 kilometers from the village of Rodnikovskoye (Figure 11). Soil type – fine saltbush, relief – low wavy plain, landscape aspect – greyish– greenish, water regime – atmospheric. Coordinates N 51°040' 035", E 073° 956' 100".



A



B

Figure 11 – Structure of the profile (A) of fine solonetz and surface condition (B)

0-11cm, Dark gray, wet, granular-lumpy, loose, loamy, abundance of roots, boils violently from HCl, the transition is sharp in color and density;

12-24 cm, Dark brown, moist, prism-clumpy, dense, heavy loam, roots, boiling from HCl, transition sharp in color;

24-46 cm, Brown, fresh, lumpy, dense, clayey, boils violently from HCl, single roots, small pebbles are found, the transition is gradual;

47-84 cm, Lighter than the previous one, wet, structureless, carbonate stains, compacted, clayey, boils violently from HCl, gradual transition;

85-120 cm, Brown with a rusty tint, wet, structureless, compacted, clayey, boils violently from HCl.

Small salt licks of the monitoring site № 9 Osakarov district of the Karaganda region were formed on clayey soil-forming rocks. This is indicated by the content of physical clay, which at a depth of 90-100 cm is 57.04% (Table 33). Its maximum value was recorded in layers of 30-40 and 60-70 cm (62.14 and 64.65%). Even the humus horizon has a heavy loamy composition (54.91%).

Table 33 - Granulometric composition of small salt licks

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physi-cal clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
9	0-10	3,84	3,702	9,359	32,030	21,631	19,135	14,143	54,908
	12-22	3,98	2,166	4,936	32,910	18,746	25,411	15,830	59,988
	30-40	4,08	2,836	5,004	30,025	18,349	23,353	20,434	62,135
	60-70	4,10	0,792	27,049	7,508	22,106	38,790	3,754	64,651
	90-100	3,92	0,583	34,471	7,910	19,151	33,306	4,580	57,036

A study of the chemical composition of small salt licks of the monitoring site №9 of the Osakarov district of the Karaganda region showed that they are more fertile compared to previous soils. The humus content in the upper horizons (0-10 and 12-22 cm) was 3.39 and 2.20%, respectively (Table 34). However, in them, the alkalinity of the soil environment is still preserved to an average degree throughout the entire profile.

Table 34 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
9	0-10	3,39	0,210	64,4	28	800	8,40
	12-22	2,20	0,154	53,2	2	190	8,77
	30-40	-	-	-	-	-	8,50
	60-70	-	-	-	-	-	8,31
	90-100	-	-	-	-	-	8,34

Data on the ionic composition of the soil solution of small solonetz showed that in these soils salinity increases with depth and reaches a very strong degree in the parent rock (1.011%). In the ionic composition, chlorine ion dominates among the anions (Table 35).

Table 35 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
9	0-10	0,135	0,60	0,00	0,00	1,33	0,56	0,75	0,60	0,02
			0,037	0,000	0,000	0,064	0,011	0,009	0,014	0,001
	12-22	0,183	0,96	0,08	0,63	1,02	0,19	0,84	1,45	0,13
			0,059	0,002	0,022	0,049	0,004	0,010	0,033	0,005
	30-40	0,576	0,60	0,00	7,39	1,44	2,15	0,28	6,98	0,02
			0,037	0,000	0,262	0,069	0,043	0,003	0,161	0,001
	60-70	0,820	0,44	0,00	12,01	1,62	1,59	2,72	9,75	0,02
			0,027	0,000	0,42	0,07	0,032	0,033	0,224	0,001

					6	8				
	90-100	1,011	0,40	0,00	12,93	3,61	1,68	2,81	12,43	0,02
			0,024	0,000	0,459	0,174	0,034	0,034	0,286	0,001

A study of the composition of the absorbed bases of small solonetzes of the monitoring site №9 of the Osakarov district of the Karaganda region showed that starting from a depth of 30 cm to 100 cm, the share of absorbed sodium occupies more than half (>50% of the ECO) among all cations (Table 36).

Table 36 - Composition of absorbed bases of small solonetz

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
9	0-10	16,92	10,95	0,09	0,60	28,56
		59,2	38,3	0,3	2,1	
	12-22	22,39	4,98	2,75	0,06	30,19
		74,2	16,5	9,1	0,2	
	30-40	11,94	14,43	33,52	0,06	59,96
		20,0	24,0	55,9	0,1	
	60-70	10,95	16,42	37,40	0,06	64,83
		16,9	25,0	58,0	0,1	
	90-100	9,45	17,41	32,92	0,06	59,84
		15,8	29,1	55,0	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 70% of the total area. Pasture type – sagebrush. The botanical composition of the plants in this area consists of sagebrush – 80%, wheatgrass – 10%, feather grass –5% and fescue – 5% of the area. It is also found in a single specimen of thistle, which belongs to a number of weeds. The yield of pasture mass is – 5 c/ha. Coordinates of the study point contour boundaries №9 – N 51º02'24,2’’; E 073º57'22,5’’.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 16.00%, fat – 7.20%, fiber – 28.55%, NFE - 30.75% and ash – 14.21%. At the same time, the yield of feed units at natural plant moisture is – 0.61 per kilogram of feed, and the exchange energy is – 8.92 MJ.

The monitoring site № 10 is also located in the Osakarov district of the Karaganda region, 400m west of the Pavlodar – Karaganda highway and 70 km in a northeast direction from the city of Karaganda (Figure 12). Soil type – brackish, relief –low-wavelength plain, landscape aspect – greyish– greenish, water regime –atmospheric. Coordinates N 50° 346' 582", E 073° 289' 311".



A



B

Figure 12 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

0-5cm, grey, wet, loose, granular-clumpy, loamy, abundance of plant roots, boiling from HCl, transition noticeable in color and density;

6-17cm, Brown, wet, dense, columnar, heavy loam, roots, boiling from HCl, noticeable transition;

18-27 cm, Lighter than the previous one, wet, lumpy, clayey, roots, boils from HCl, compacted, gradual transition;

28-55 cm, Brown, wet, structureless, clay, boiling from HCl, compacted, noticeable transition;

56-110 cm, Brown with whitish spots of carbonates, wet, structureless, clayey, compacted, boils violently from HCl, gypsum drusen.

The study of the granulometric composition of the small salt licks of the monitoring site №10 showed that they are superficially medium loamy (phys. clay 38.58%). However, the subhumus horizon of the soil acquires a heavy loamy granulometric composition, which is further weighted deeper and reaches maximum values in the layer of 40-50 cm (physical clay 67.80%) (Table 37).

Table 37 – Granulometric composition of cortical solonetzes

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
10	0-5	2,54	7,306	34,004	20,111	10,671	15,596	12,313	38,580
	6-16	3,26	9,944	11,081	27,290	10,750	17,366	23,568	51,685
	18-27	4,80	4,517	24,475	13,445	30,672	20,588	6,303	57,563
	40-50	3,84	4,160	8,070	19,967	55,324	7,903	4,576	67,804
	80-90	4,70	7,807	12,865	67,996	4,197	0,420	6,716	11,333

A study of the cortical solonetzes of the monitoring site №10 in the Osakarov district of the Karaganda region showed that they are weakly humous in the upper layer A in terms of humus content (Table 38). The humus value in the marked soil layer is 2.69%.

Table 38 – Chemical composition of cortical solonetzes

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
10	0-5	2,69	0,154	47,6	18	410	8,35
	6-16	1,66	0,126	47,6	3	240	8,73
	18-27	1,00	0,098	84,0	10	290	8,82
	40-50	-	-	-	-	-	9,12
	80-90	-	-	-	-	-	8,92

A study of the salt composition of small salt licks of the monitoring site №10 showed that they are superficially weak - (0.250%) and highly saline (0.817%). However, the salt sequence is located in the range from 18 to 90 cm, where the maximum amount of salts (2.6-2.8%) is concentrated. This suggests that the soils studied are deeply saline and formed on saline soil-forming rocks (Table 39).

Table 39 - Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
10	0-5	0,250	0,52	0,00	0,07	2,90	0,09	0,38	3,01	0,02
			0,032	0,000	0,003	0,139	0,002	0,005	0,069	0,001
	6-16	0,817	0,72	0,00	0,11	10,81	0,94	1,41	9,29	0,02
			0,044	0,000	0,004	0,519	0,019	0,017	0,214	0,001
	18-27	2,555	0,64	0,08	0,78	35,18	6,83	1,97	27,79	0,02
			0,039	0,002	0,028	1,689	0,137	0,024	0,639	0,001
	40-50	2,326	0,56	0,08	2,88	30,16	4,02	1,78	27,79	0,02
			0,034	0,002	0,102	1,448	0,080	0,022	0,639	0,001

	80-90	2,800	0,44	0,00	3,66	37,43	7,29	7,97	26,25	0,02
			0,027	0,000	0,13	1,797	0,146	0,097	0,604	0,001

The soils of the monitoring site №10 of the Osakarov district of the Karaganda region are solonetz, since exchangeable sodium dominates in the composition of absorbed cations (Table 40). Its content in the solonetz horizon is 73.9% of the cation exchange capacity.

Table 40 - Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
10	0-5	12,44	5,47	51,10	0,06	69,07
		18,0	8,0	73,9	0,1	
	6-16	18,41	5,97	37,58	0,06	62,03
		29,7	9,6	60,6	0,1	
	18-27	11,94	8,46	36,80	0,21	57,41
		20,8	14,7	64,1	0,4	
	40-50	11,94	14,43	19,34	0,06	45,77
		26,1	31,5	42,3	0,1	
	80-90	12,94	14,93	22,87	0,06	50,80
		25,5	29,4	45,0	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area is –70% of the total area. Grassland type – sagebrush-forge-halophyte. The botanical composition of plants in this area consists of wormwood – 60%, feather grass – 15%, echium – 5%, statice - 10%, camphorosma – 5% and wheatgrass – 5% of the area. The yield of pasture mass is 10.5 c/ha. Coordinates of the study point contour boundaries №10 – N 50º20'47,7''; E 073º17'21,4''.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 14.41%, fat – 7.52%, fiber – 28.54%, NFE - 34.89% and ash – 11.52%. The yield of feed units at natural plant moisture is – 0.57 per kilogram of feed, and the exchange energy is – 7.93 MJ.

Ulytau region.

The monitoring site № 11 is located in the Zhanaarkin district of the Ulytau region, 5500 meters from the village of Atasu in a westerly direction (Figure 13). Soil type – fine saltbush, relief – flat, landscape aspect – greenish, water regime – atmospheric. Coordinates N 48° 639' 417", E 071° 347' 464".



A



B

Figure 13 – Structure of profile (A) of fine solonetz and surface condition (B)

0-11 cm, Dark grey, dry, dusty-lumpy, loamy, weakly compacted, many roots, does not boil from HCl, clear transition;

12-23cm, Brown, dry, lumpy, loamy, dense, roots, does not boil from HCl, the transition is clear in color;

24-43cm, Brown, dry, lumpy, loamy, dense, boils violently from HCl, single roots, noticeable transition;

44-63cm Light brown, fresh, structureless, compacted, clayey, boils violently from HCl, carbonate stains, gradual transition;

64-120 cm, Fawn, wet, structureless, weakly compacted, clayey, carbonates, boils violently from HCl.

In terms of granulometric composition, the small salt licks of the monitoring site №11 of the Zhanaarkin district of the Ulytau region are easily loamy. In the surface horizons, the physical clay content is 19.075 and 23.030% (Table 41). Moreover, as the value deepens, it increases towards weighting.

Table 41 - Granulometric composition of small solonetz

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
11	0-10	1,44	33,604	29,058	18,263	7,305	8,117	3,653	19,075
	10-20	1,00	29,677	30,323	16,970	8,081	10,101	4,848	23,030
	30-40	1,32	35,995	19,416	11,755	5,675	11,755	15,403	32,833
	50-60	1,78	31,562	15,903	8,145	4,887	12,625	26,878	44,390
	80-90	1,02	28,309	28,854	10,507	2,829	15,357	14,144	32,330

In the chemical composition of small salt licks of the monitoring site №11 of the Zhanaarkin district of the Ulytau region, it is clear that these soils contain humus in an amount of 3.98% in the humus horizon (Table 42). As it deepens downward, the humus content sharply decreases, first to 1.88%, and then to 1.31%. The fact that starting from 30 cm to the bottom of the incision, the reaction of the soil medium is very highly alkaline (pH 9.67-9.87) should be noted here.

Table 42 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
11	0-10	3,98	0,238	44,8	49	560	7,60
	10-20	1,88	0,140	22,4	4	520	8,47
	30-40	1,31	-	-	-	-	9,67
	50-60	-	-	-	-	-	9,72
	80-90	-	-	-	-	-	9,87

From the data of the ionic composition of the water extract of the middle salt licks of the monitoring site №11, it follows that these soils are characterized by weak salinity of the soil profile. In the latter, the total salt content varies from 0.167 to 0.355% (Table 43). In the anionic composition, the dominant position is occupied by sulfate and chlorine ions, but in addition to them, soda is present in a content toxic to plants at a depth of 30-90 cm.

Table 43 - Ionic composition of water extract of medium solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
11	0-10	0,167	0,20	0,00	0,00	2,27	1,31	0,66	0,49	0,02
			0,012	0,000	0,000	0,109	0,026	0,008	0,011	0,001
	10-20	0,338	0,16	0,00	0,81	3,93	0,56	0,56	3,40	0,38
			0,01	0,000	0,029	0,189	0,011	0,007	0,078	0,015
	30-40	0,350	1,44	0,80	1,22	2,21	0,19	0,19	4,26	0,23
			0,088	0,024	0,043	0,106	0,004	0,002	0,098	0,009
	50-60	0,355	1,80	1,04	1,66	1,57	0,19	0,38	4,45	0,02

			0,11	0,031	0,059	0,075	0,004	0,005	0,102	0,001
	80-90	0,250	1,20	0,80	1,00	1,30	0,09	0,19	3,20	0,02
			0,073	0,024	0,035	0,063	0,002	0,002	0,074	0,001

The soils of the monitoring site №11 are solonetzic because in them, in the solonetzic horizon, the proportion of sodium absorbed is 29.3% of the sum of the bases absorbed (Table 44). Moreover, as it deepens, the value of the noted indicator increases.

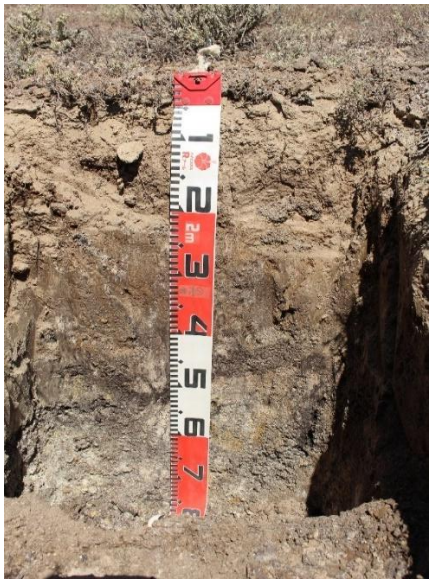
Table 44 - Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
11	0-10	8,46	2,99	0,30	0,53	12,27
		68,9	24,4	2,4	4,3	
	10-20	13,43	1,49	6,36	0,45	21,73
		61,8	6,8	29,3	2,1	
	30-40	3,48	4,48	4,37	0,04	12,37
		26,1	36,2	35,3	0,3	
	50-60	4,48	7,46	60,36	0,12	72,42
		6,2	10,3	83,3	0,2	
	80-90	3,48	4,48	56,83	0,06	64,85
		5,4	6,9	87,6	0,1	

Characteristics and forage value of land cover. A study of the projective vegetation cover showed that in this area it is no higher than 45% of the total area. Pasture type – sagebrush-wort type with chiya participation. The botanical composition of plants in this area consists of wormwood – 70%, hairwort –15% and chiya – 15% of the area. It is also found in a single copy of the wostrets, and there is contamination with the sophora. The yield of pasture mass is 6.5 c/ha. Coordinates of the study point contour boundaries №11 – N 48º38'21,9’’; E 071º20'51,2’’.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 14.63%, fat – 6.62%, fiber – 33.50%, NFE -34.03% and ash – 8.20%. The yield of feed units at natural plant moisture is – 0.57 per kilogram of feed, and the exchange energy is – 8.04 MJ.

Monitoring site № 12 is located in the Ulytau district of the Ulytau region, 200 m south of the Karaganda – Zhezkazgan highway (Figure 14). Soil type – fine saltbush, relief – flat, landscape aspect – greenish, water regime – atmospheric. Coordinates N 48° 229' 394", E 069° 306' 406".



A



B

Figure 14 – Structure of profile (A) of fine solonetz and surface condition (B)

0-11 cm, Light grey, dry, weakly compacted, loamy, dusty-lumpy, plant roots, does not boil from HCl, soil surface is crushed stone, transition is sharp in color and density;

12-28cm Solonetzic, dark brown, dry, dense, columnar, heavy loam, does not boil from HCl, few roots, clear transition;

29-42cm, mottled with black, Coal with a large accumulation of carbonate spots mixed with sand, fresh, compacted, lumpy, light clay, boils violently from HCl transition clear;

43-78 cm, Coal with a yellowish-whitish tint, fresh, loose, crushed stone and rocky, structureless, loamy, boiling from HCl, gradual transition;

79-130 cm, Coal with a whitish tint, many spots of carbonate and drusen gypsum, wet, structureless, loamy, coarse sand, crushed stone.

Small salt licks of the monitoring site №12 of the Ulytau district of the Ulytau region have a clay granulometric composition in the solonetz and sub-solonetz horizons. Here, the physical clay content is 61.6 and 42.7%, respectively (Table 45).

Table 45 - Granulometric composition of small solonetz

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
12	0-10	17,30	15,381	8,682	36,276	12,092	26,602	0,967	39,661
	15-25	3,90	12,612	5,390	20,395	10,822	19,563	31,217	61,602

	30-40	2,56	13,218	30,131	13,957	39,409	2,463	0,821	42,693
	60-70	2,02	30,190	30,618	32,660	0,816	1,225	4,491	6,532
	80-90	2,80	45,638	15,679	27,984	1,235	0,412	9,053	10,700

A study of the chemical composition of small solonetzes of the monitoring site №12 of the Ulytau district of the Ulytau region showed that as a result of illuvial processes, humus moves into the subhumus horizon, where its content is noticeably higher (2.65%) than in the humus horizon (1.31%) (Table 46).

Table 46 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
12	0-10	1,31	0,098	33,6	42	460	8,13
	15-25	2,65	0,140	39,2	12	200	8,11
	30-40	-	-	-	-	-	8,27
	60-70	-	-	-	-	-	8,14
	80-90	-	-	-	-	-	8,07

Data from small salt licks of the monitoring site № 12 showed that they are slightly saline at a depth of 0-25 cm (0.127-0.424%). However, even deeper (30-90 cm) the degree of salinity rises to a very highly saline level and reaches significant values (1.120-1.749%). In the marked unit, chlorides and sulfates dominate the composition of the anions, and there are no normal carbonates (Table 47).

Table 47 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
12	0-10	0,127	0,28	0,00	1,77	0,08	0,28	0,47	1,37	0,02
			0,017	0,000	0,063	0,004	0,006	0,006	0,032	0,001
	15-25	0,424	0,24	0,00	7,02	0,02	0,56	0,75	5,89	0,08
			0,015	0,000	0,249	0,001	0,011	0,009	0,135	0,003
	30-40	1,120	0,24	0,00	19,03	0,30	6,08	1,50	11,97	0,02
			0,015	0,000	0,675	0,015	0,122	0,018	0,275	0,001
	60-70	1,729	0,16	0,00	17,73	10,74	12,81	4,22	11,59	0,02
			0,010	0,000	0,629	0,516	0,256	0,051	0,267	0,001
	80-90	1,749	0,20	0,00	15,89	12,53	13,56	4,22	10,82	0,02
			0,012	0,000	0,563	0,601	0,271	0,051	0,249	0,001

Data on the composition of the absorbed bases of the soils of the monitoring site № 12 showed that they are solonetz. This is evidenced by the proportion of absorbed sodium in solonetz, which exceeds 20% of the sum of absorbed bases (Table 48).

Table 48 - Composition of absorbed bases of middle solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
12	0-10	7,46	2,99	2,09	0,39	12,93
		57,7	23,1	16,2	3,0	
	15-25	13,43	11,44	34,02	0,06	58,95
		22,8	19,4	57,7	0,1	
	30-40	18,91	11,44	54,84	0,06	85,25
		22,2	13,4	64,3	0,1	
	60-70	16,92	10,95	43,56	0,06	71,49
		23,7	15,3	60,9	0,1	
	80-90	16,92	10,95	51,75	0,06	79,68
		21,2	13,7	65,0	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 50% of the total area. Pasture type – echiumovo-sagebrush-ephemeral. The botanical composition of plants consists of echium – 70%, wormwood– 25% and ephemera – 5% of the area. Also found in a single specimen are bluegrass and statice. The yield of pasture mass is 7, c/ha. Coordinates of the study point contour boundaries №12 – N 48º13'45,3’’; E 069º18'22,3’’.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 14.73%, fat – 6.82%, fiber – 31.84%, NFE-34.12% and ash – 8.93%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.57 per kilogram of feed, and the exchange energy is – 7.93 MJ.

The monitoring site № 13 is also located in the Ulytau district of the Ulytau region, 200 m north of the Karaganda-Zhezkazgan highway (Figure 15). Soil type – medium saltbush, relief – plain, landscape aspect – grey with a greenish tint, water regime – atmospheric. Coordinates N 48° 122' 130", E 068° 700' 593".



A



B

Figure 15 – Structure of the profile (A) of the middle salt licks and surface condition (B)

0-13cm, Light gray, dry, dusty lumpy, loamy, weakly compacted, does not boil from HCl, many plant roots, the transition is sharp in color and density;

14-33 cm, Brown, dry, loamy, dense, prism-columnar, roots, boiling from HCl, gradual transition;

34-58 cm, Lighter than the previous one, dry, crushed stone present, lumpy, dense, loamy, boiling from HCl, the transition is noticeable;

59-73 cm, Light brown, dry, dense, very crushed, mixed with sand, carbonate stains, boils violently from HCl, the transition is gradual;

74-120 cm, Light brown, dry, structureless, carbonate spots, crushed stone and coarse sand, loamy, dense.

In terms of granulometric composition, the average solonetz of the monitoring site №13 are superficially medium loamy (phys. clay 30.59%) as well as lightly clayey (phys. clay 45.14%) in the solonetz horizon (Table 49).

Table 49 - Granulometric composition of mean solonetz

№ Point	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
13	0-10	1,94	14,216	16,031	39,160	12,237	14,277	4,079	30,594

	20-30	2,52	9,048	9,705	36,110	14,362	17,234	13,541	45,137
	40-50	2,30	12,590	14,534	35,210	11,054	15,558	11,054	37,666
	60-70	1,64	29,565	20,415	23,180	6,507	10,573	9,760	26,840
	80-90	1,90	20,673	17,757	27,319	8,563	13,863	11,825	34,251

The average solonetzes of the monitoring site №13 in the Ulytau district of the Ulytau region are characterized by a low level of fertility, as evidenced by the humus content (1.75 and 1.24%), respectively, in the surface horizons (0-10 and 20-30 cm) (Table 50).

Table 50 – Chemical composition of medium salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
13	0-10	1,75	0,126	36,4	54	1000	7,61
	20-30	1,24	0,140	25,2	6	390	7,95
	40-50	-	-	-	-	-	8,57
	60-70	-	-	-	-	-	8,66
	80-90	-	-	-	-	-	8,51

The middle solonetzes of the monitoring site №13 are characterized by the unsalinity of the soil profile. Within the latter, the salt content does not exceed 0.1% (Table 51).

Data on the composition of the absorbed bases of the middle solonetzes of the monitoring site №13 showed that these soils are characterized by magnesium solonetzicity. Since the proportion of absorbed magnesium in the 20-30 cm layer is quite high and amounts to 35.7% of the sum of absorbed bases (Table 52).

Table 51 - Ionic composition of water extract of medium solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
13	0-10	0,043	0,36	0,00	0,04	0,21	0,19	0,38	0,03	0,02
			0,022	0,000	0,001	0,010	0,004	0,005	0,001	0,001
	20-30	0,058	0,16	0,00	0,04	0,60	0,09	0,38	0,03	0,30
			0,010	0,000	0,001	0,029	0,002	0,005	0,001	0,012
	40-50	0,050	0,40	0,08	0,00	0,30	0,28	0,38	0,03	0,02
			0,024	0,002	0,000	0,014	0,006	0,005	0,001	0,001
	60-70	0,042	0,32	0,00	0,04	0,25	0,19	0,38	0,03	0,02
			0,020	0,000	0,001	0,012	0,004	0,005	0,001	0,001

	80-90	0,053	0,28	0,00	0,22	0,29	0,47	0,28	0,03	0,02
			0,017	0,000	0,008	0,014	0,009	0,003	0,001	0,001

Table 52 - Composition of absorbed bases of middle solonetz

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
13	0-10	12,94	5,97	0,14	2,01	21,06
		61,4	28,4	0,7	9,5	
	20-30	15,92	2,99	0,14	0,04	19,09
		83,4	35,7	0,7	0,2	
	40-50	14,93	4,48	0,14	0,04	19,59
		76,2	22,9	0,7	0,2	
	60-70	8,96	6,97	0,14	0,04	16,11
		55,6	43,3	0,9	0,2	
	80-90	10,95	4,98	0,11	0,04	16,07
		68,1	31,0	0,7	0,2	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 50% of the total area. Pasture type – sagebrush. The botanical composition of plants in this area consists of wormwood – 85%, Persian rose – 10% and wheatgrass – 5% of the area. The yield of pasture mass is 8.1 c/ha. Coordinates of the study point contour boundaries №13 – N 48º07'19,9''; E 068º42'02,0''.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 16.23%, fat – 6.74%, fiber – 30.63%, NFE - 31.17% and ash – 11.92%. The yield of feed units at natural plant moisture is – 0.60 per kilogram of feed, and the exchange energy is – 8.55 MJ.

Monitoring site № 14 is located in the Ulytau district of the Ulytau region, 6 kilometers west of the city of Satpayev (Figure 16). Soil type – salty light chestnut, relief – hilly, landscape aspect – grey, water regime – atmospheric. Coordinates N 47° 936' 965", E 007° 481' 389".



A



B

Figure 16 – Structure of the profile (A) of saline light chestnut soils and surface condition (B)

0-13cm, Dark grey, dry, loamy, dusty lumpy, loose, does not boil from HCl, many roots, transition sharp in color and density;

14-34cm, Dark brown with brown tint, dry, prism-columnar, dense, loamy, does not boil from HCl, roots, clear transition;

35-58 cm, Brown with whitish spots of carbonates, dry dense, loamy, boiling over from HCl, spots of carbonates, lumpy structure, gradual transition;

59-76 cm, Chestnut, dry, structureless, loamy, chestnut with a whitish tint, abundance of carbonate spots, structureless, boiling from HCl, gradual transition;

77-120 cm, Light brown with a whitish tint, fresh, structureless, dusty-crushed, loamy, compacted.

A study of the granulometric composition of salty light chestnut soils of the monitoring site №14 of the Ulytau district of the Ulytau region showed that they are superficially light loamy. In layer 0-10 cm, the content of physical clay is 20.25%. However, in the underlying solonetz horizon, the indicator value increases to 47.1%, i.e. becomes easily clayey (Table 53).

Table 53 - Granulometric composition of saline light chestnut soils

№ Point	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical

									clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
14	0-10	1,24	16,464	39,388	23,896	11,341	3,240	5,670	20,251
	20-30	2,44	10,332	19,557	22,960	9,020	14,760	23,370	47,150
	40-50	2,20	3,967	4,826	37,628	16,360	17,996	19,223	53,579
	60-70	1,98	3,203	33,544	19,588	13,875	15,915	13,875	43,665
	80-90	2,82	5,001	40,667	36,633	2,881	1,235	13,583	17,699

Data on the chemical composition of salty light chestnut soils of the monitoring site №14 of the Ulytau district of the Ulytau region show a low humus content (1.55 and 1.09%) relative to the soil-bioclimatic zone (Table 54).

Table 54 – Chemical composition of saline light chestnut soils

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
14	0-10	1,55	0,098	47,6	60	390	8,19
	20-30	1,09	0,126	25,2	4	140	8,46
	40-50	-	-	-	-	-	8,60
	60-70	-	-	-	-	-	8,52
	80-90	-	-	-	-	-	8,34

The saline light chestnut soils of the monitoring site №14 are characterized by the non-salinity of the first half-meter layer (0-50), where the salt content varies from 0.055 to 0.078% (Table 55). However, from a depth of 60 cm to the bottom of the cut, the degree of soil salinity rises first to weak (0.191%) and then to intense (0.911%).

In terms of the content of absorbed magnesium, the light chestnut soils of the monitoring site №14 are solonetzic, and in terms of absorbed sodium they are residual. The proportion of the former in the upper horizons is 27.0 and 22.0% of the sum of the absorbed bases (Table 56).

Table 55 - Ionic composition of the aqueous extract of solonetzic light chestnut soils, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
14	0-10	0,055	0,32	0,08	0,00	0,47	0,37	0,38	0,03	0,02
			0,020	0,002	0,000	0,023	0,007	0,005	0,001	0,001
	20-30	0,057	0,32	0,00	0,18	0,30	0,37	0,28	0,03	0,12
			0,020	0,000	0,007	0,014	0,007	0,003	0,001	0,005
	40-50	0,078	0,36	0,00	0,18	0,62	0,65	0,47	0,03	0,02
			0,022	0,000	0,007	0,030	0,013	0,006	0,001	0,001

	60-70	0,191	0,24	0,00	0,04	2,57	2,06	0,75	0,03	0,02
			0,015	0,000	0,001	0,123	0,041	0,009	0,001	0,001
	80-90	0,911	0,20	0,00	0,00	13,21	12,9	0,47	0,03	0,02
			0,012	0,000	0,000	0,634	0,258	0,006	0,001	0,001

Table 56 - Composition of absorbed bases of saline light chestnut soils

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
14	0-10	8,96	3,48	0,11	0,34	12,89
		69,5	27,0	0,9	2,6	
	20-30	13,93	3,98	0,11	0,04	18,05
		77,2	22,0	0,6	0,2	
	40-50	14,93	3,48	0,13	0,04	18,57
		80,4	18,7	0,7	0,2	
	60-70	13,93	2,49	0,13	0,04	16,58
		84,0	15,0	0,8	0,2	
	80-90	9,95	9,95	0,14	0,20	20,25
		49,1	49,1	0,7	1,0	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 45% of the total area. Pasture type – sagebrush-ephemeral with the participation of hawthorn. The botanical composition of plants in the solonetz area consists of wormwood – 80%, ephemera -10%, hawthorn – 7% and krascheninnikovia ceratoides – 3% of the area. Also found in vegetation are tulip, bedbug, canopy and a single specimen – hornhead. The yield of pasture mass is 8.4 c/ha. Coordinates of the study point contour boundaries №14 – N 47º56'12,3,''; E 067º28'52,7''.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 14.93%, fat – 7.32%, fiber –30.51%, NFE - 35.70% and ash – 8.32%. At the same time, the yield of feed units at natural plant moisture is – 0.59 per kilogram of feed, and the exchange energy is – 8.13 MJ.

Monitoring site № 15 is located in the Ulytau district of the Ulytau region, 4 km in a south-eastern direction from the village of Karsakbay (Figure 17). Soil type – fine saltbush, relief – flat, landscape aspect – brownish-greenish, water regime – atmospheric. Coordinates N 47° 822' 188", E 066° 737' 940".



A



B

Figure 17 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-8 cm, Light grey, dry, loamy, dusty lumpy, weakly compacted, many roots, does not boil from HCl, transition is sharp in density;

9-30 cm, Dark brown, dry, columnar, heavy loam, dense, does not boil from HCl, roots, clear transition;

31-52 cm, Brown, fresh, lumpy, loamy, boils violently from HCl, single roots, to the bottom of carbonate spots, gradual transition;

52-84cm, Light brown, fresh, structureless, clayey, compacted, boils violently from HCl, isolated spots of carbonates, the transition is sharp;

85-100 cm, Brown-fawn with whitish tints, fresh, accumulation of carbonates, gypsum drusen, structureless, compacted.

From the granulometric composition data of small solonetzes of the monitoring site №15, it follows that the studied soils are heavy loamy. This is evidenced by the content of physical clay, which in the solonetz and supra-solonetz horizons is 27.6 and 62.7%, respectively (Table 57).

Table 57 – Granulometric composition of small solonetz

№ cut	Depth, cm	A.S. N %	Fraction content in % on absolute dry soil			
			Fraction sizes in mm			
			Sand	Dust	Silt	Physical

		H2O							clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
15	0-8	1,44	3,531	29,505	39,367	9,740	12,581	5,276	27,597
	15-25	4,36	1,924	5,228	30,113	11,292	23,421	28,022	62,735
	40-50	2,94	1,051	6,635	29,672	9,891	45,333	7,418	62,642
	70-80	2,90	0,680	7,868	38,723	35,427	15,242	2,060	52,729
	90-100	3,10	9,536	14,510	47,884	2,064	23,117	2,890	28,070

In the chemical composition of the small salt licks of the monitoring site №15 of the Ulytau district of the Ulytau region, a very low humus content is observed, only 0.87% in the low-power humus horizon (Table 58). These soils are distinguished by medium and strong alkalinity of the soil environment (pH 8.13-9.48), which makes them unfavorable for many plants.

Table 58 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
15	0-8	0,87	0,070	25,2	70	390	8,28
	15-25	1,41	0,112	25,2	8	210	8,77
	40-50	-	-	-	-	-	9,48
	70-80	-	-	-	-	-	8,52
	90-100	-	-	-	-	-	8,13

From the data on the saline composition of small solonetzes of the monitoring site № 15, it follows that these soils are characterized by practical unsalinity of the upper 0-25 cm layer (0.064-0.155%). Within the profile of the studied soil as a whole, there is a tendency for the salinity of soils to gradually increase with depth (Table 59).

The soils of the monitoring site №15 of the Ulytau district of the Ulytau region are characterized by solonetzicity in exchangeable sodium and solonetzicity in exchangeable magnesium. The share of the latter in the composition of absorbed cations is quite high and amounts to 44.7 and 39.4% in the solonetz and suprasolonetz horizons, respectively (Table 60).

Table 59 - Ionic composition of fine solonetz water extract, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
15	0-8	0,064	0,32	0,08	0,15	0,47	0,19	0,47	0,25	0,03

			0,020	0,002	0,005	0,023	0,004	0,006	0,006	0,001
	15-25	0,155	1,20	0,16	0,11	0,77	0,19	0,56	1,31	0,02
			0,073	0,005	0,004	0,037	0,004	0,007	0,030	0,001
	40-50	0,241	1,72	0,32	0,07	1,36	0,28	0,38	2,48	0,02
			0,105	0,010	0,003	0,065	0,006	0,005	0,057	0,001
	70-80	0,546	0,44	0,00	0,04	7,56	2,43	2,06	3,52	0,02
			0,027	0,000	0,001	0,363	0,049	0,025	0,081	0,001
	90-100	0,878	0,36	0,00	0,07	12,67	10,19	2,34	0,53	0,03
			0,022	0,000	0,003	0,608	0,204	0,029	0,012	0,001

Table 60 – Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
15	0-8	7,46	4,98	0,13	0,08	12,65
		59,0	39,4	1,0	0,6	
	15-25	13,43	14,43	4,44	0,01	32,31
		41,5	44,7	13,7	0,1	
	40-50	6,97	24,38	5,08	0,01	36,45
		19,12	66,9	13,94	0,03	
	70-80	21,39	9,45	0,27	0,01	31,13
		68,7	30,4	0,87	0,03	
	90-100	16,92	12,94	0,15	0,07	30,08
		56,25	43,02	0,5	0,23	

Characteristics and forage value of land cover. Projective vegetation coverage in this area is only 35% of the total area. Pasture type – sagebrush-scorzonera. The botanical composition of plants in this area consists of wormwood – 80% scorzonera-20% of the area and is found in a single specimen of bluegrass. The yield of pasture mass is 6.8 c/ha. Coordinates of the study point contour boundaries №15 – N 47º49'06,9''; E 066º44'55,9''.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 16.62%, fat – 6.82%, fiber – 30.40%, NFE - 31.79% and ash – 11.10%. The yield of feed units at natural plant moisture is – 0.56 per kilogram of feed, and the exchange energy is – 8.02 MJ.

Monitoring site № 16 is located in the Ulytau district of the Ulytau region, 7 km in a north-eastern direction from the village of Zhezdy towards the regional center of Ulytau (Figure 18). Soil type – brackish fine surface crushed stone, relief – hilly, landscape aspect – greyish-greenish, water regime – atmospheric. Coordinates N 48° 105' 711", E 067° 043' 747".



A



B

Figure 18 – Structure of profile (A) of fine solonetz and surface condition (B)

0-11cm, Light grey, dry, loose, loamy, dusty lumpy, plant roots, does not boil from HCI, transition is sharp in color and density;

12-22cm, Dark brown, dry, prismatic-blocky, heavy loam, very dense, boiling from HCl, roots, clear transition;

23-38 cm, light brown, fresh, lumpy, light loam, single roots, boiling from HCl, gradual transition, compacted;

39-65 cm, lighter than the previous one, fresh, clayey, compacted, boiling from HCl, a layer of light whitish tint is noted across the soil horizon, the transition is sharp in color, structureless;

66-130 cm, yellowish-grey, fresh, structureless, sandy loam, compacted, boiling from HCl.

The study of the granulometric composition of the small salt licks of the monitoring site №16 showed that these soils have a heavy granulometric composition. The content of physical clay in surface horizons is 36.0 and 53.0%, respectively. (Table 61).

Table 61 – Granulometric composition of small solonetz

№ cut	Depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil
			Fraction sizes in mm

			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
16	0-10	16,68	18,051	44,023	1,920	11,522	18,243	6,241	36,006
	10-20	5,68	11,578	14,631	20,780	8,906	16,115	27,990	53,011
	25-35	1,70	5,493	23,296	28,077	7,731	15,870	19,532	43,133
	50-60	1,74	4,010	34,928	23,611	4,071	13,841	19,540	37,452
	80-90	2,34	8,007	17,039	26,623	10,240	33,586	4,505	48,331

Like the previous soil in the small salt licks of the monitoring site №16, located in the Ulytau district of the Ulytau region, there is also a very low humus content (0.87%) in the humus over-solonetz horizon (Table 62). However, in the underlying layer of 10-20 cm it increases slightly and amounts to 1.04%. Also noteworthy is the very strongly alkaline reaction of the medium (pH 9.02-9.09) of the surface layers of small solonetz.

Table 62 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
16	0-10	0,87	0,07	22,4	20	260	9,02
	10-20	1,04	0,084	47,6	2	130	9,09
	25-35	0,58	0,042	64,4	4	60	9,08
	50-60	-	-	-	-	-	8,75
	80-90	-	-	-	-	-	8,30

In the soil solution of the small salt licks of the monitoring site № 16, water-soluble salts from the surface are present (Table 63). Moreover, with depth its content increases and reaches a maximum at a depth of 80-90 cm (1.744%). This suggests that the marked soils were formed on saline soil-forming rocks.

Analysis of the composition of the absorbed bases of the soils of the monitoring site №16 showed that these soils are solonetz. This is clearly shown by the percentage of sodium absorbed, which in the solonetz horizon was 30.4% of the cation exchange capacity (Table 64).

Table 63 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth,	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General	From						

	cm		in HCO_3^-	normal carbonates in CO_3^{2-}						
16	0-10	0,139	0,48	0,00	0,52	1,08	0,19	0,75	1,10	0,04
			0,029	0,000	0,018	0,052	0,004	0,009	0,025	0,002
	10-20	0,315	1,16	0,24	3,10	0,59	0,19	0,56	4,09	0,02
			0,071	0,007	0,110	0,028	0,004	0,007	0,094	0,001
	25-35	0,543	0,76	0,08	8,13	0,25	0,47	1,22	7,39	0,06
			0,046	0,002	0,288	0,012	0,009	0,015	0,170	0,002
	50-60	0,906	0,44	0,00	10,71	3,63	0,84	1,22	12,70	0,02
			0,027	0,000	0,380	0,174	0,017	0,015	0,292	0,001
	80-90	1,744	0,32	0,00	6,46	19,34	7,01	1,22	17,85	0,04
			0,020	0,000	0,229	0,928	0,14	0,015	0,411	0,002

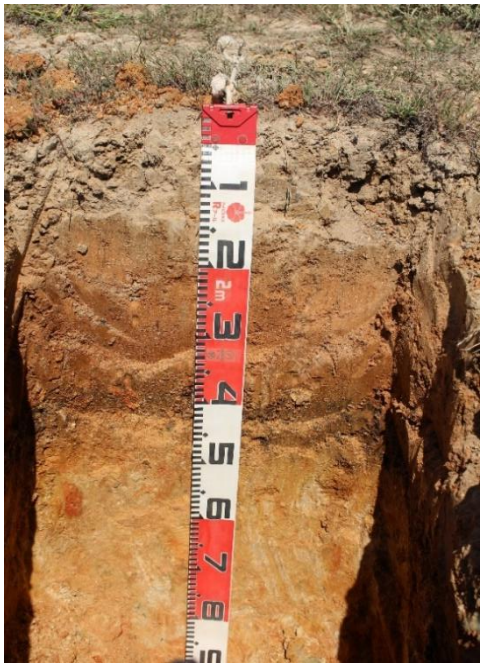
Table 64 – Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
16	0-10	5,97	2,99	0,62	0,03	9,61
		62,1	31,1	6,5	0,3	
	10-20	8,46	6,47	6,54	0,01	21,49
		39,4	30,1	30,4	0,1	
	25-35	5,97	4,48	10,95	0,01	21,42
		27,9	20,9	51,1	0,1	
	50-60	10,45	3,48	2,97	0,01	16,92
		61,8	20,6	17,5	0,1	
	80-90	11,44	9,45	2,36	0,07	23,32
		49,1	40,5	10,1	0,3	

Characteristics and forage value of land cover. Projective vegetation coverage in this area also accounts for - 35% of the total area. Pasture type –echiumovo– sagebrush-scorzonera. The botanical composition of plants in this area consists of echium – 40%, wormwood - 30% and scorzonera – 30% of the area. It is also found in a single specimen of camphorosma. The yield of pasture mass is 7.5 c/ha. Coordinates of the study point contour boundaries №16 – N 48º06'20,7''; E 067º02'36,9''.

A study of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 14.93%, fat – 6.22%, fiber – 30.28%, NFE -33.54% and ash – 12.22%. The yield of feed units at natural plant moisture is – 0.55 per kilogram of feed, and the exchange energy is – 7.72 MJ.

Monitoring site № 17 is located in the Ulytau district of the Ulytau region, 300m north of the Ulytau – Arkalyk highway (Figure 19). Soil type – brackish, relief – saucer-shaped plain, landscape aspect – brownish-greenish, water regime – atmospheric. Coordinates N48°841'375", E 067°061'471".



A



B

Figure 19 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

0-5 cm, Light grey, dry, slightly compacted, loamy, dusty-clumpy, pierced by roots, does not boil away from HCl, transition is sharp;

6-22cm, Dark brown, dry, dense, heavy, loam, prismatic-columnar, roots, does not boil from HCI, the transition is clear in color;

23-38 cm, Light brown with a brick tint, fresh, lumpy, dense, loamy, does not boil from HCI, the transition is noticeable;

39-58 cm, Brown with dark interlayer, wet, compacted, clayey, does not boil from HCI, structureless, noticeable transition;

59-130 cm, Brick with an abundance of gypsum accumulations, wet, structureless, does not boil from HCI, weakly compacted, loamy.

In terms of granulometric composition, the cortical solonetz of the monitoring site №17 are medium clay in the solonetz horizon (10-20 cm). It has a physical clay content as high as 62.18% (Table 65).

Chemical composition data from cortical solonetzes of the monitoring site №17 of the Ulytau district of the Ulytau region showed that these soils have a low level of fertility, which is confirmed by humus data (1.73 and 1.38%) in surface horizons (0-5 and 10-20 cm) (Table 66).

Table 65 - Granulometric composition of cortical solonetz

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
17	0-5	1,46	14,492	30,302	26,791	12,178	11,772	4,465	28,415
	10-20	2,86	4,303	17,048	16,471	14,000	19,354	28,824	62,178
	25-35	2,22	10,841	37,206	14,727	4,091	9,409	23,727	37,226
	40-50	3,04	9,653	37,541	31,353	18,564	0,413	2,475	21,452
	100-110	1,40	15,396	50,527	26,369	0,811	6,491	0,406	7,708

Table 66 – Chemical composition of cortical solonetzes

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
17	0-5	1,73	0,112	33,6	40	240	7,48
	10-20	1,38	0,084	39,2	14	80	5,68
	25-35	0,77	0,056	33,6	4	80	5,45
	40-50	-	-	-	-	-	6,45
	100-110	-	-	-	-	-	7,59

The cortical salt licks of the monitoring site №17 in solution contain easily soluble salts from a depth of 10 cm, i.e. starting from the solonetz horizon. The salt horizon is located at a depth of 40-50 cm, where the salt content is 1.117% (Table 67).

Table 67 - Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
17	0-5	0,037	0,24	0,00	0,11	0,17	0,09	0,09	0,31	0,02
			0,015	0,000	0,004	0,008	0,002	0,001	0,007	0,001
	10-20	0,110	0,28	0,08	1,22	0,24	0,09	0,19	1,45	0,02
			0,017	0,002	0,043	0,012	0,002	0,002	0,033	0,001
	25-35	0,192	0,12	0,00	3,07	0,05	0,09	0,09	3,01	0,04
			0,007	0,000	0,109	0,002	0,002	0,001	0,069	0,001
	40-50	1,117	0,12	0,00	8,31	9,34	3,93	2,81	11,01	0,02

			0,007	0,000	0,295	0,448	0,079	0,034	0,253	0,001
	100-110	0,590	0,12	0,00	5,73	3,61	0,56	0,94	7,94	0,02
			0,007	0,000	0,203	0,173	0,011	0,011	0,183	0,001

The study of the composition of the absorbed bases of the soils of the monitoring site №17 showed that they are solonetz, since the content of absorbed sodium in a layer of 10-20 cm reaches 26.1% of the sum of the absorbed bases (Table 68).

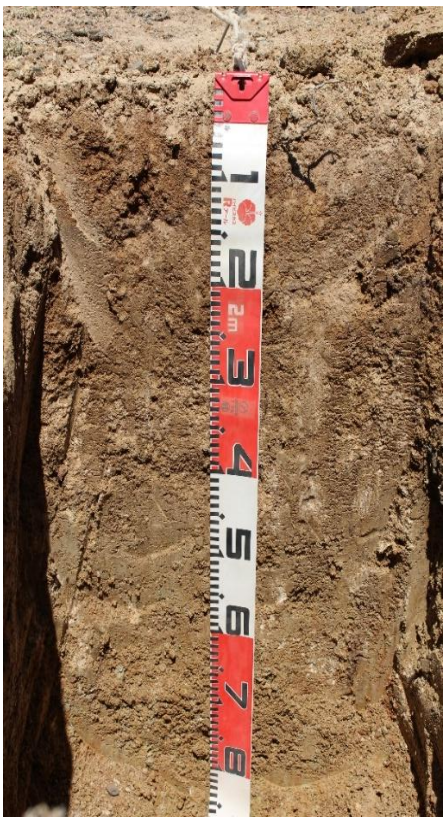
Table 68 - Composition of absorbed bases of cortical solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
17	0-5	8,96	3,48	0,46	0,00	12,91
		69,4	27,0	3,6	0,00	
	10-20	11,94	9,45	7,61	0,18	29,18
		40,9	32,4	26,1	0,6	
	25-35	7,46	5,47	24,30	0,04	37,26
		20,0	14,7	65,2	0,1	
	40-50	11,44	10,95	27,51	0,04	49,93
		22,9	21,9	55,1	0,1	
	100-110	9,95	6,47	35,04	0,04	51,50
		19,3	12,6	68,0	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 55% of the total area. Pasture type – echiumovo-scorzoneraovo-sagebrush. The botanical composition of plants in this area consists of echium – 60%, scorzonera -35%, wormwood– 15%, knotweed -5% and bluegrass - 5% of the area. Wild onions are also found in a single specimen. The yield of pasture mass is 6, c/ha. Coordinates of the study point contour boundaries №17 – N 48º50'23,7''; E 067º03'41,1''.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 13.63%, fat – 7.00%, fiber – 30.50%, NFE -34.89% and ash – 10.72%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.56 per kilogram of feed, and the exchange energy is – 7.78 MJ.

Monitoring site № 18 is located in the Ulytau district of the Ulytau region, 30 km east of the village of Ulytau, towards the village of Boztumsyk – Shubarkol (Figure 20). Soil type – brackish, relief – inter-hill valley, landscape aspect – greenish-brown, water regime – atmospheric. Coordinates N 48° 689' 067", E 067° 344' 075".



A



B

Figure 20 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

0-6 cm, Light brown, dry, lumpy, loamy, weakly compacted, plant roots, boiling from HCl, the transition is sharp in structure;

7-22cm, Dark brown, dry, prism-columnar, clayey, dense, roots, boiling from HCl, clear transition in color;

23-34cm, Brown, wet, lumpy, compacted, gypsum stains, clayey, does not boil from HCl, the transition is clear in color;

35-56 cm, Lighter than the previous one with a high gypsum content, wet, compacted, clayey, structureless, does not boil from HCl, the transition is gradual;

57-130 cm, brown with a gley tint, wet, compacted, clayey, structureless, does not boil, large accumulation of gypsum.

The cortical salt licks of the monitoring site №18 are characterized by a light clay heavy granulometric composition in a layer of 10-20 cm, where the content of physical clay was 41.14% of the cation exchange capacity (Table 69).

The cortical solonetzes of the monitoring site №18 of the Ulytau district of the Ulytau region are also characterized by a low level of fertility, as evidenced by the humus content in its upper horizons (0.48 and 1.51%) (Table 70).

Table 69 - Granulometric composition of cortical solonetz

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
18	0-6	2,52	13,480	17,993	29,134	11,900	18,876	8,617	39,393
	10-20	1,80	23,544	18,208	17,108	8,554	14,257	18,330	41,141
	20-30	5,98	10,891	8,275	59,562	14,040	0,425	6,807	21,272
	40-50	6,78	6,179	7,144	35,615	47,200	0,429	3,433	51,062
	90-100	6,88	4,167	0,258	9,880	6,443	11,168	68,729	86,340

Table 70 – Chemical composition of solonetz cortices

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
18	0-6	0,48	0,056	14,0	19	260	8,21
	10-20	1,51	0,098	33,6	12	80	7,13
	20-30	0,48	0,056	33,6	1	110	7,88
	40-50	-	-	-	-	-	7,58
	90-100	-	-	-	-	-	7,28

In the soil solution of the cortical solonetz of the monitoring site № 18, water-soluble salts are present in maximum amounts (1.069-1.607%) within a thickness of 20 to 100 cm (Table 71). In a low-power humus horizon (0-6 cm), the salt content is 0.095%, i.e. is not unsalted.

Table 71 - Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
18	0-6	0,095	0,16	0,00	1,40	0,03	0,09	0,19	1,29	0,02
			0,010	0,000	0,050	0,001	0,002	0,002	0,030	0,001
	10-20	0,358	0,16	0,00	5,91	0,10	0,37	0,66	5,12	0,02
			0,010	0,000	0,210	0,005	0,007	0,008	0,118	0,001
	20-30	1,607	0,24	0,00	15,52	10,58	9,35	4,03	12,93	0,02
			0,015	0,000	0,550	0,508	0,187	0,049	0,297	0,001
	40-50	1,423	0,24	0,00	18,29	5,05	2,06	1,78	19,73	0,02
			0,015	0,000	0,648	0,243	0,041	0,022	0,454	0,001

	90-100	1,069	0,08	0,00	16,81	1,28	0,56	0,94	16,66	0,02
			0,005	0,000	0,596	0,061	0,011	0,011	0,383	0,001

The composition of the absorbed cations of the cortical solonetzes of the monitoring site № 18 is dominated by exchangeable sodium. Its share in relation to other cations is 26.7 and 52.5%, respectively, in the solonetz and suprasolonetz horizons (Table 72).

Table 72 - Composition of absorbed bases of cortical solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
18	0-6	8,96	4,98	5,09	0,04	19,07
		47,0	26,1	26,7	0,2	
	10-20	10,45	9,45	22,04	0,04	41,97
		24,9	22,5	52,5	0,1	
	20-30	14,93	17,41	12,01	0,04	44,39
		33,6	39,2	27,1	0,1	
	40-50	19,4	15,92	19,10	0,04	54,45
		35,6	29,2	35,1	0,1	
	90-100	30,35	9,95	31,90	0,04	72,23
		42,0	13,8	44,1	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 45% of the total area. Pasture type – sagebrush-scorzoneraov-echiumovy. The botanical composition of plants in this area consists of wormwood – 60%, scorzonera - 25% and echium –15% of the area. Also found in a single specimen are bluegrass, sagebrush, tas-scorzonera, calligonum, statice, parmella. The yield of pasture mass is 6.0 c/ha. Coordinates of the study point contour boundaries №18 – N 48º41'20,8''; E 067º20'39,1''.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 16.32%, fat – 6.13%, fiber –32.74%, NFE-34.11% and ash – 11.52%. At the same time, the yield of feed units at natural plant moisture is – 0.56 per kilogram of feed, and the exchange energy is – 8.21 MJ.

Monitoring site № 19 is located in the Ulytau district of the Ulytau region, from the Boztumsyk highway towards the village of Betbulaka, 200 meters from the grader highway (Figure 21). Soil type – fine saltbush, relief – flat, landscape aspect – greenish-dark grey, water regime – atmospheric. Coordinates N 48° 838' 903", E 067° 932' 118".



A



B

Figure 21 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-10cm, Dark gray, dry, dusty lumpy, loamy, loose, many roots, boiling from HCl, KIK crushed stone surface, sharp transition in density;

11-28 cm, Dark brown, dry, heavy loam, very dense, columnar, roots, fine crushed stone, boiling from HCl, gradual transition;

29-40 cm, lighter than the previous one, dry, loamy, lumpy-prismatic, dense, sparse spots of carbonates, boiling from HCl, the transition is sharp in color;

41-57 cm, whitish with brown tint, carbonate layer, fresh, loamy, structureless, compacted, boils violently from HCl, the transition is noticeable;

58-110 cm, Greenish with a brown tint, fresh, clayey, a lot of gypsum, there are gypsum drusen, some spots of manganese.

The granulometric composition data of the small salt licks of the monitoring site №19 showed that the indicated soils have a heavy granulometric composition in the solonetz horizon. Here the physical clay content reaches 71.6% (Table 73).

The small salt licks of the monitoring site №19 in the Ulytau district of the Ulytau region contain 1.17% humus in their surface horizon, which increases slightly in the solonetz horizon (1.25%) (Table 74).

Table 73 – Granulometric composition of small solonetz

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
19	0-10	4,58	3,186	6,686	23,056	8,384	38,566	20,122	67,072
	15-25	4,52	3,687	4,985	19,690	9,636	23,041	38,961	71,638
	30-40	3,92	4,996	14,654	60,366	6,661	1,249	12,073	19,983
	45-55	4,62	2,118	1,426	75,068	8,807	2,097	10,484	21,388
	80-90	1,02	2,324	5,941	10,911	75,571	1,212	4,041	80,824

Table 74 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
19	0-10	1,17	0,112	50,4	8	440	8,49
	15-25	1,25	0,098	25,2	2	270	8,72
	30-40	-	-	-	-	-	8,20
	45-55	-	-	-	-	-	8,17
	80-90	-	-	-	-	-	8,15

In the soil solution of small solonetzes of the monitoring site № 19 water-soluble salts in the maximum amount (1.576-2.014%) are present in the range from 30 to 90 cm, i.e. these soils are salty and very highly saline (Table 75). The most favorable are surface horizons, where the salt content is 0.096 and 0.126%, respectively.

Table 75 - Ionic composition of the aqueous extract of fine salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
19	0-10	0,096	0,56	0,08	0,11	0,68	0,28	0,47	0,58	0,02
			0,034	0,002	0,004	0,033	0,006	0,006	0,013	0,001
	15-25	0,126	1,04	0,16	0,59	0,09	0,19	0,19	1,33	0,02
			0,063	0,005	0,021	0,004	0,004	0,002	0,031	0,001
	30-40	1,576	0,44	0,00	6,10	17,56	11,78	2,63	9,67	0,02
			0,027	0,000	0,216	0,843	0,236	0,032	0,222	0,001
	45-55	1,808	0,40	0,00	9,24	18,30	11,31	2,91	13,7	0,02
			0,024	0,000	0,328	0,878	0,226	0,035	0,315	0,001
	80-90	2,014	0,36	0,00	10,7	19,8	7,39	2,63	20,88	0,02

					1	3				
			0,022	0,000	0,38	0,952	0,148	0,032	0,48	0,001

Small solonetzes of the monitoring site №19 in the Ulytau district of the Ulytau region in the soil-absorbing complex of the solonetz horizon (15-25 cm) contain 19.0% absorbed sodium (Table 76).

Table 76 - Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mEq/%				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
19	0-10	25,87	8,95	0,71	0,10	35,63
		72,6	25,1	2,0	0,3	
	15-25	23,38	8,95	7,60	0,04	39,96
		58,5	22,4	19,0	0,1	
	30-40	16,92	13,43	2,99	0,02	33,36
		50,7	40,2	9,0	0,1	
	45-55	16,92	11,94	4,11	0,04	33,00
		51,3	36,2	12,4	0,1	
	80-90	19,9	12,94	59,19	0,04	92,06
		21,6	14,0	64,3	0,1	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 60% of the total area. Pasture type – sagebrush. The botanical composition of plants in this area consists of wormwood – 80%, scorzonera – 10%, feather grass –5% and climacopter –5% of the area. Also found in a single specimen are ruminus hairwort and tulip. The yield of pasture mass is 8.0 c/ha. Coordinates of the study point contour boundaries №19 – N 48º50'20,0’’; E 067º55'55,6’’.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 17.30%, fat – 6.82%, fiber – 30.12%, NFE - 34.48% and ash – 8.12%. The yield of feed units at natural plant moisture is – 0.57 per kilogram of feed, and the exchange energy is – 8.23 MJ.

Monitoring site № 20 is located in the Ulytau district of the Ulytau region from the village of Malshybay towards the city of Satpayev, 5 kilometers in a southwestern direction (Figure 22). Soil type – fine saltbush, relief – undulating plain, landscape aspect – greyish-greenish, water regime – atmospheric. Coordinates N 48° 374' 403", E 067° 854' 285".



A



B

Figure 22 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-8cm, Light gray, dry, loose, loamy, dusty lumpy, small plant roots, boils violently from HCl, the transition is sharp in color and density;

9-22 cm, Dark brown, dry, dense, heavy loam, prism-columnar, roots, boils violently from HCl, gradual transition;

23-37 cm, Brown with single carbonate spots, dry, dense, lumpy, loamy, carbonate spots, boiling from HCl, the transition is sharp in color;

38-54cm, Brown with whitish tints, large accumulation of carbonates, loamy, dense, structureless, boiling from HCl, clear transition;

55-100 cm, light brown, dry, loamy, dense, structureless, found in sand and crushed stone, gypsum and carbonate drusen, abundance of sand and crushed stone, boils violently from HCl.

From the granulometric composition data of small solonetzes of the monitoring site №20 it follows that these soils have a heavy composition. The latter can be traced in the solonetz horizon, where physical clay reaches 48.5% (Table 77).

Examination of the chemical composition of the small salt licks of the monitoring site №20 shows a low humus content (2.05 and 1.72%) in the surface horizons (0-8 and 10-20 cm) (Table 78).

Table 77 – Granulometric composition of small solonetz

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
20	0-8	2,44	10,209	20,500	33,620	18,450	11,480	5,740	35,670
	10-20	3,56	9,146	12,049	30,278	10,784	21,153	16,591	48,528
	25-35	3,40	7,019	12,236	33,540	12,008	20,704	14,493	47,205
	40-50	3,06	11,162	22,406	12,379	8,253	21,869	23,932	54,054
	80-90	2,76	17,359	20,527	39,079	2,879	9,461	10,695	23,036

Table 78 – Chemical composition of salt licks of small

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
20	0-8	2,05	0,154	28,0	60	620	7,31
	10-20	1,72	0,112	30,8	6	240	7,92
	25-35	1,34	0,098	22,4	4	130	8,76
	40-50	-	-	-	-	-	8,62
	80-90	-	-	-	-	-	8,16

The ionic composition of the water extract of small salt licks of the monitoring site № 20 is shown by the fact that, according to the data of the first half meter, these soils are slightly saline (sum of salts 0.136-0.204%). The anionic composition lacks normal carbonates and sulfates dominate (Table 79).

Table 79 – Ionic composition of fine solonetz water extract, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
20	0-8	0,204	0,28	0,00	0,07	2,69	1,68	1,13	0,06	0,17
			0,017	0,000	0,003	0,129	0,034	0,014	0,001	0,007
	10-20	0,074	0,40	0,00	0,07	0,64	0,19	0,84	0,06	0,02
			0,024	0,000	0,003	0,031	0,004	0,010	0,001	0,001
	25-35	0,152	0,56	0,00	0,07	1,70	0,37	1,78	0,16	0,02
			0,034	0,000	0,003	0,081	0,007	0,022	0,004	0,001
	40-50	0,136	0,52	0,00	0,07	1,47	0,47	1,41	0,17	0,02
			0,032	0,000	0,003	0,071	0,009	0,017	0,004	0,001
	80-90	0,949	0,28	0,00	0,22	13,63	12,16	1,78	0,17	0,02
			0,017	0,000	0,008	0,654	0,243	0,022	0,004	0,001

The soils of the monitoring site №20 are characterized by magnesium solonetz. Its share is significantly high in the solonetz horizon and amounts to 29.78% of the sum of absorbed bases (Table 80).

Table 80 – Composition of absorbed bases of small solonetzes

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
20	0-8	16,42	3,48	0,17	0,24	20,31
		80,85	17,13	0,84	1,18	
	10-20	17,41	7,46	0,17	0,01	25,05
		69,5	29,78	0,68	0,04	
	25-35	18,91	6,47	0,02	0,01	25,41
		74,42	25,46	0,08	0,04	
	40-50	15,42	6,97	0,01	0,01	22,42
		68,8	31,1	0,05	0,05	
	80-90	13,43	12,94	0,05	0,01	26,44
		50,79	49,0	0,18	0,03	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 60% of the total area. Pasture type – sagebrush. The botanical composition of the plants in this area consists of wormwood – 90%, hay –5%, feather grass –2% and climate copters - 3% of the area. The yield of pasture mass is 78 c/ha. Coordinates of the study point contour boundaries №20 – N 48º22'27,8’’; E 067º51'15,7’’.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 17.22%, fat – 4.63%, fiber – 30.44%, NFE-31.57% and ash – 12.82%. The yield of feed units at natural plant moisture is – 0.50 per kilogram of feed, and the exchange energy is – 7.14 MJ.

Akmola region

The monitoring site № 21 is located in the Astrakhan district of the Akmola region, south of 300 m from the Astana – Atbasar highway and from the village of Ornek, 600 m to the north (Figure 23). Soil type – brackish, relief – flat, landscape aspect – greyish-greenish, water regime – atmospheric. Coordinates N 51° 313' 935", E 070° 209' 884".

0-4 cm, Dark grey, dry, loamy, layered-lumpy, weakly compacted, rootlets, does not boil from HCl, transition clear in density and structure;

5-22cm, Dark brown, dry, heavy loam, dense, columnar, roots, does not boil from HCl, the transition is clear in color;

23-40 cm, Lighter than the previous one, brown, wet, lumpy, compacted, separated carbonate spots, boils violently from HCl, gradual transition;

41-74 cm, dark brown, wet, structureless, compacted, carbonate stains, clay, boils violently from HCl;



A



B

Figure 23 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

75-120 cm, Dark brown with a whitish tint, wet, compacted, structureless, clayey, many spots of carbonates and gypsum drusen.

The cortical salt licks of the monitoring site №21 have a heavy granulometric composition, starting from the solonetz horizon. In the latter, the physical clay content is 74.4% (Table 81).

Table 81 – Granulometric composition of cortical solonetz

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
21	0-4	1,82	8,800	38,236	30,964	5,704	11,000	5,296	22,000
	10-20	3,80	4,262	17,152	4,158	31,185	24,948	18,295	74,428
	25-35	4,16	3,255	11,603	30,885	29,633	21,703	2,922	54,257
	50-60	3,72	2,555	11,446	75,197	5,816	1,246	3,739	10,802
	90-100	3,24	9,115	21,848	59,115	4,134	1,654	4,134	9,921

Data on the chemical composition of the cortical salt licks of the monitoring site №21 of the Astrakhan district of the Akmola region show a humus content of 2.20% in the humus and 1.64% in the subhumus horizons (Table 82). Starting from a depth of 10 cm deep, the reaction of the soil environment varies from medium to highly alkaline.

Table 82 – Chemical composition of cortical solonetzes

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
21	0-4	2,20	0,140	50,4	62	600	7,70
	10-20	1,64	0,098	36,4	20	330	8,32
	25-35	0,93	0,070	25,2	6	250	8,83
	50-60	-	-	-	-	-	8,63
	90-100	-	-	-	-	-	8,50

The cortical salt licks of the monitoring site №21 are both salt marshes and salt marshes. The maximum mass of easily soluble salts is concentrated in the underlying layers in an amount of 1.2-1.8% (Table 83). The anionic composition is dominated by both chlorides and sulfates.

Table 83 - Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
21	0-4	0,133	0,52	0,00	0,30	1,08	0,28	0,56	0,91	0,14
			0,032	0,000	0,010	0,052	0,006	0,007	0,021	0,005
	10-20	0,755	0,56	0,00	6,65	4,75	0,09	1,59	10,25	0,02
			0,034	0,000	0,236	0,228	0,002	0,019	0,236	0,001
	25-35	1,779	0,56	0,08	11,45	15,88	4,96	4,69	18,23	0,02
			0,034	0,002	0,406	0,762	0,099	0,057	0,419	0,001
	50-60	1,517	0,40	0,08	7,02	15,88	7,67	2,91	12,7	0,02
			0,024	0,002	0,249	0,762	0,153	0,035	0,292	0,001
	90-100	1,222	0,36	0,00	3,14	14,81	5,80	2,44	10,06	0,02
			0,022	0,000	0,111	0,711	0,116	0,03	0,231	0,001

The cortical salt licks of the monitoring site №21 of the Astrakhan district of the Akmola region are distinguished by a high proportion of absorbed sodium and magnesium. As follows

from the table, the share of the latter in layers 10-20 and 25-35 cm is 18.03 and 56.67%, respectively, as well as 41.65 and 16.94% (Table 84).

Table 84 – Composition of absorbed cortical solonetz bases

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
21	0-4	8,96	3,98	0,20	0,47	13,61
		65,8	29,4	1,4	3,4	
	10-20	6,47	14,43	4,60	0,01	25,51
		25,36	56,57	18,03	0,04	
	25-35	21,89	8,96	22,03	0,01	52,89
		41,39	16,94	41,65	0,02	
	50-60	11,94	9,95	18,37	0,01	40,27
		29,65	24,71	45,62	0,02	
	90-100	9,95	10,95	9,79	0,01	30,70
		32,41	35,67	31,89	0,03	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 65% of the total area. Pasture type –sagebrush-forge-fescue. The botanical composition of the plants in this area consists of wormwood – 60%, feather grass –20%, fescue – 10% and hay - 10% of the area. Also found in a single specimen is the wheatgrass, gimlet, and statice. The yield of pasture mass is 6.1 c/ha. Coordinates of the study point contour boundaries №21 - N 51º18'50,2''; E 070º12'35,7''.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 12.52%, fat – 6.32%, fiber – 32.23%, NFE -34.04% and ash – 12.21%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.51 per kilogram of feed, and the exchange energy is – 8.23 MJ.

The monitoring site № 22 is also located in the Astrakhan district of the Akmola region, from the Astana – Atbasar highway to the southwest, 400 meters and from the regional center of Astrakhanovka to the south, 5 km (Figure 24). Soil type – brackish, relief – low-wave plain, landscape aspect – light greyish, water regime – atmospheric. Coordinates N 51° 600' 993", E 069° 850' 032".

0-5cm, Dark gray, dry, lumpy, loamy, slightly compacted, plant roots, boiling from HCl, transition noticeable in density;

6-17 cm, Brown, fresh, columnar, heavy loam, light veins of salts noted, dense, roots, boiling from HCl, transition noticeable in color;

18-34 cm, brown with whitish spots of carbonates, fresh, slightly compacted, loamy, boils violently from HCl, lumpy, gradual transition;



A



B

Figure 24 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

35-62 cm, Brownish, moist, loamy, weakly compacted, structureless, carbonate stains, boils violently from HCl, gradual transition;

63-130 cm, Dark brown, wet, loamy, structureless, boiling from HCl, weakly compacted.

The granulometric composition data of the cortical solonetz of the monitoring site №22 show that they are heavy in the solonetz and easily loamy in the suprasolonetz horizons. In the latter, the physical clay content reached 30.4 and 39.7%, respectively (Table 85).

Table 85 – Granulometric composition of cortical solonetz

Sampling location	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
22	0-5	2,66	12,739	41,648	15,204	6,164	11,095	13,150	30,409
	7-17	3,20	4,773	36,550	19,008	11,570	11,157	16,942	39,669
	20-30	2,12	8,132	40,785	36,780	4,495	4,904	4,904	14,303
	50-60	2,82	9,117	62,070	14,818	9,467	1,646	2,881	13,995
	80-90	2,02	11,615	67,973	8,981	2,449	6,532	2,449	11,431

The chemical composition of the cortical salt licks of the monitoring site №22 of the Astrakhan district of the Akmola region shows a relatively low level of their fertility. This is due not only to the humus content, but also to the alkaline reaction of the soil environment

throughout the soil profile. If the first in the surface horizons is 1.97 and 1.76%, then the second (pH) in the indicated places is 8.71 and 8.76, respectively (Table 86).

Table 86 – Chemical composition of cortical solonetzes

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
22	0-5	1,97	0,196	56,0	50	330	8,71
	7-17	1,76	0,154	64,4	12	80	8,76
	20-30	0,82	0,070	36,4	11	70	8,83
	50-60	-	-	-	-	-	8,63
	80-90	-	-	-	-	-	8,63

In the soil solution of the crust salt licks of the monitoring site № 22 there are easily soluble salts in concentrations toxic to plants, starting from the surface, i.e. are salt marshes and very highly saline (Table 87). Salt content above 1.0% is accumulated within depths of 7 to 60 cm.

Table 87 – Ionic composition of the aqueous extract of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
22	0-5	0,707	0,96	0,16	5,73	4,23	0,19	0,84	9,87	0,02
			0,059	0,005	0,203	0,203	0,004	0,010	0,227	0,001
	7-17	1,965	0,48	0,00	14,22	15,87	3,37	2,16	25,03	0,02
			0,029	0,000	0,504	0,762	0,067	0,026	0,576	0,001
	20-30	2,106	0,52	0,08	12,01	19,72	5,89	2,06	24,27	0,02
			0,032	0,002	0,426	0,947	0,118	0,025	0,558	0,001
	50-60	1,194	0,36	0,00	4,25	13,3	4,68	1,41	11,81	0,02
			0,022	0,000	0,151	0,638	0,094	0,017	0,272	0,001
	80-90	0,643	0,24	0,00	0,89	8,38	4,68	0,94	3,88	0,02
			0,015	0,000	0,031	0,402	0,094	0,011	0,089	0,001

The soils of the monitoring site №22 are solonetzic, since the percentage of sodium absorbed in the solonetzic and supra-solonetzic horizons is 20.13 and 23.82%, respectively (Table 88).

Table 88 – Composition of absorbed solonetz bases

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
22	0-5	10,95	3,98	4,69	0,07	19,69
		55,61	20,21	23,82	0,36	
	7-17	23,88	12,94	9,30	0,07	46,19
		51,7	28,02	20,13	0,15	
	20-30	9,95	12,44	7,82	0,07	30,28
		32,86	41,08	25,83	0,23	
	50-60	12,44	11,94	1,12	0,07	25,57
		48,65	46,7	4,38	0,27	
	80-90	36,32	4,98	2,28	0,07	43,65
		83,21	11,41	5,22	0,16	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 65% of the total area. Pasture type – sagebrush-fescueovo-covy. The botanical composition of plants in this area consists of wormwood – 64%, fescue – 15%, feather grass – 15% and echium – 6% of the area. The yield of pasture mass is 7.0 c/ha. Coordinates of the study point contour boundaries №22 – N 51º36'03,6''; E 069º50'59,6''.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 13.00%, fat – 6.52%, fiber –32.73%, NFE - 32.66% and ash – 11.82%. At the same time, the yield of feed units at natural plant moisture is – 0.49 per kilogram of feed, and the exchange energy is – 6.88 MJ.

The monitoring site № 23 is located in the Atbasar district of the Akmola region and is located from the Atbasar – Kokshetau highway in the eastern direction, 700 km and from the village. Borisovki to the southwest at 500 m (Figure 25). Soil type – meadow saltbush shallow, relief – flat, landscape aspect – greenish, water regime – ground. Groundwater lies close to the soil surface. Coordinates N 51° 883' 090", E 068° 529' 880".

0-10 cm, Dark grey, dry, granular-lumpy, loamy, compacted, abundance of roots, boiling from HCl, transition sharp;

11-27 cm, Dark brown, moist, nutty-prismate, dense, heavy loam, roots, boils from HCl, gradual transition;

27-42 cm, Brown, wet, lumpy, slightly compacted, single roots, clayey, boiling from HCl, the transition is noticeable in color;

43-72cm, Brown, wet, structureless, weakly compacted, clayey, boiling from HCl, sharp in color transition;

72-120 cm, Brown with a yellowish tint, wet, clayey, structureless, weakly compacted, boiling from HCl.



A



B

Figure 25 – Structure of the profile (A) of meadow salt licks and surface condition (B)

Analysis of the granulometric composition of the meadow solonetz of the monitoring site №23 showed that the studied soils have a heavy composition in the solonetz horizon, where the physical clay content is 72.3% (Table 89).

Table 89 – Granulometric composition of meadow salt licks

№ Point	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
23	0-10	1,24	8,364	4,557	3,645	5,670	46,983	30,78	83,435

								2	
	15-25	0,90	7,326	18,406	2,018	13,724	20,585	37,941	72,250
	30-40	1,10	14,156	3,741	14,965	12,942	13,347	40,849	67,139
	60-70	1,18	30,662	4,574	12,143	10,929	10,524	31,168	52,621
	90-100	3,00	37,505	1,052	7,423	6,186	8,247	39,588	54,021

Data on the chemical composition of the meadow salt licks of the study point № 23 in the Atbasar district of the Akmola region show a relatively high humus content in the upper horizon (4.02%), which is associated with the conditions of the meadow soil-forming process (Table 90). However, a limiting factor in their fertility is the salinity of the entire profile and soloneness. The presence of the latter demonstrates not only absorbed sodium, but also a high level of alkalinity of the soil environment (pH 8.46-9.22).

Table 90 – Chemical composition of meadow salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
23	0-10	4,02	0,280	50,4	40	500	7,92
	15-25	2,91	0,196	36,4	2	260	8,46
	30-40	-	-	-	-	-	8,98
	60-70	-	-	-	-	-	9,10
	90-100	-	-	-	-	-	9,22

Salt content data from the over-salt and solonetz horizons (0.405 and 0.996% respectively) of the monitoring site's meadow salt licks № 23 showed that these soils are medium - and intensively saline (Table 91). The anionic composition contains sulfates and chlorides in toxic concentrations, but also bicarbonates and normal carbonates. It is known that the presence of the latter (>0.8 and 0.03 mEq per 100 g of soil) causes high alkalinity of the soil environment.

Table 91 - Ionic composition of the water extract of meadow salt licks, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
23	0-10	0,405	0,52	0,00	3,55	2,39	1,12	1,22	4,09	0,03
			0,032	0,000	0,126	0,115	0,022	0,015	0,094	0,001
	15-25	0,996	0,72	0,16	5,73	8,80	1,40	1,88	11,95	0,02
			0,044	0,005	0,203	0,422	0,028	0,023	0,275	0,001
	30-40	0,829	1,28	0,40	5,91	5,52	0,28	1,41	11,00	0,02
			0,078	0,012	0,210	0,265	0,006	0,017	0,253	0,001
	60-70	0,716	1,16	0,32	5,73	4,13	0,09	0,84	10,06	0,02
			0,071	0,010	0,203	0,198	0,002	0,010	0,231	0,001
	90-100	0,653	1,04	0,32	5,73	3,40	0,09	0,94	9,11	0,02
			0,063	0,010	0,203	0,163	0,002	0,011	0,210	0,001

The meadow salt licks of the monitoring site № 23 contain in noticeable quantities not only absorbed sodium, but also magnesium. Their proportion in the 15-25 cm layer is 19.10 and 30.66% of the sum of the absorbed bases (Table 92).

Table 92 – Composition of absorbed bases of grassland solonetz

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil	CEC, mEq

		Calcium	Magnesium	Sodium	Potassium	per 100g of soil
23	0-10	23,88	8,96	3,84	0,14	36,82
		64,86	24,33	10,43	0,38	
	15-25	24,38	14,93	9,30	0,07	48,68
		50,1	30,66	19,10	0,14	
	30-40	8,96	10,95	14,49	0,07	34,47
		25,99	31,77	42,04	0,2	
	60-70	6,47	8,46	9,30	0,07	24,30
		26,63	34,81	38,27	0,29	
	90-100	4,98	9,95	14,55	0,07	29,55
		16,85	33,67	49,24	0,24	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 80% of the total area, which is due to the close occurrence of groundwater. Pasture type – grass-wormwood. The botanical composition of plants in this area consists of wheatgrass – 30%, rump – 25%, ratite –15% and wormwood - 10% of the area. Also found in a single specimen is elecampane, knotweed, plantain, and fescue. The yield of pasture mass is 16.5 c/ha. Coordinates of the study point contour boundaries №23 – N 51º53'06.8’’; E 068º31'03.9’’.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 12.63%, fat – 5.64%, fiber – 32.62%, NFE - 34.76% and ash – 11.63%. The yield of feed units at natural plant moisture is – 0.51 per kilogram of feed, and the exchange energy is – 7.31 MJ.

The monitoring site № 24 is located in the Sandyktau district of the Akmola region and is located from the Atbasar – Kokshetau highway to the southeast, 4 km and from the village of Vladimirovka, 1.5 km to the southeast (Figure 26). Soil type – fine brackish meadow, relief – low wave plain, landscape aspect – green, water regime –ground. Coordinates N 52° 323' 206", E 068° 611' 116".

0-12 cm, brown, wet, loamy, granular-lumpy, compacted, abundance of plant roots, boiling from HCl, transition clear in color and density;

13-32cm, Dark brown, fresh, heavy loam, columnar, dense, salt spots, boiling from HCl, roots, gradual transition;

33-56 cm, Darker than the previous one with a grayish tint, wet, loamy, lumpy, compacted, roots, individual salt spots noted, boiling from HCl, gradual transition;



A



B

Figure 26 – Structure of the profile (A) of the salt licks of small meadow and surface condition (B)

57-78 cm, Greyish-dark, moist, loamy, structureless, compacted, boiling from HCl, individual roots, salt spots, transition sharp in color;

79-120 cm, Light brown, wet, clayey, structureless, boils violently from HCl, weakly compacted.

Analysis of the granulometric composition of the soils of the monitoring site №24 showed that small meadow salt licks have a heavy composition. The physical clay content in the solonetz horizon reaches 62.01 and 64.29% (Table 93).

Table 93 – Granulometric composition of small grassland solonetz

№ cut	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
24	0-10	8,50	4,481	5,027	28,41	13,115	16,61	32,35	62,077

					5		2	0	
	20-30	3,56	3,837	6,159	25,715	14,102	24,886	25,301	64,289
	40-50	3,66	3,633	5,024	20,345	11,625	26,157	33,216	70,999
	70-80	3,56	3,567	21,775	11,613	10,369	18,664	34,011	63,044
	90-100	3,52	6,198	4,664	18,242	22,803	15,755	32,338	70,896

If compared with previous soils, the meadow small salt licks of the monitoring site №24 in the Sandyktau district of the Akmola region are characterized by a high level of humus, which in the upper horizons was 5.03 and 4.66%, respectively (Table 94).

Table 94 – Chemical composition of small meadow salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
24	0-10	5,03	0,336	53,2	62	1000	8,24
	20-30	4,66	0,322	39,2	6	260	8,22
	40-50	-	-	-	-	-	8,45
	70-80	-	-	-	-	-	8,34
	90-100	-	-	-	-	-	8,34

The small meadow salt licks of the monitoring site №24 are practically not saline. Since the salt content in the first half meter varies from 0.090 to 0.143% (Table 95). These soils practically lack normal carbonates.

Table 95 - Ionic composition of the water extract of small meadow salt licks, mEq/%

№ cut	Sample	Sum of	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			Genera	From						

	depth, cm	salts, %	l in HCO_3^-	normal carbonates in CO_3^{2-}						
24	0-10	0,109	0,60	0,00	0,04	0,90	0,47	0,75	0,16	0,16
			0,037	0,000	0,001	0,043	0,009	0,009	0,004	0,006
	20-30	0,090	0,56	0,00	0,11	0,65	0,28	0,84	0,17	0,02
			0,034	0,000	0,004	0,031	0,006	0,01	0,004	0,001
	40-50	0,143	0,64	0,00	0,11	1,40	0,19	1,50	0,44	0,02
			0,039	0,000	0,004	0,067	0,004	0,018	0,01	0,001
	70-80	0,179	0,64	0,04	0,85	1,30	0,47	1,41	0,89	0,02
			0,039	0,001	0,03	0,062	0,009	0,017	0,021	0,001
	90-100	0,205	0,52	0,00	0,96	1,79	0,37	1,97	0,91	0,02
			0,032	0,000	0,034	0,086	0,007	0,024	0,021	0,001

The soils of the monitoring site №24 of the Sandyktau district of the Akmola region are characterized by magnesium solonetz. This is due to the high content of absorbed magnesium, which in the solonetz and supra-solonetz horizons amounted to 44.2 and 22.3% of the ECO total (Table 96).

Table 96 – Composition of absorbed solonetz bases

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
24	0-10	24,88	7,46	0,09	1,06	33,49
		74,3	22,27	0,27	3,16	
	20-30	26,87	21,39	0,03	0,07	48,36
		55,56	44,2	0,1	0,14	
	40-50	24,88	18,41	0,71	0,07	44,07
		56,46	41,77	1,61	0,16	

	70-80	25,37	20,4	1,68	0,07	47,52
		53,39	42,93	3,53	0,15	
	90-100	19,4	11,44	1,60	0,07	32,51
		59,67	35,19	4,92	0,22	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 85% of the total area. Pasture type – cereal-grass. The botanical composition of plants in this area consists of wheatgrass - 30%, ratite - 16%, rump –15%, yarrow – 10%, wormwood – 10%, knotweed – 10% and fescue – 9% of the area. The yield of pasture mass is 17.0 c/ha. Coordinates of the study point contour boundaries №24 – N 52º19'23,4''; E 068º36'40,1''.

A study of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 16.63%, fat – 3.93%, fiber – 32.72%, NFE -33.42% and ash – 10.14%. The yield of feed units at natural plant moisture is – 0.50 per kilogram of feed, and the exchange energy is – 6.91 MJ.

The monitoring site № 25 is located in the Zerendinsky district of the Akmola region from the Atbasar – Kokshetau highway to the west, 800 m, and from the village of Aidarly to the southeast, 600 m (Figure 27). Soil type – fine saltbush, relief – flat, landscape aspect – yellowish– light grey, water regime – atmospheric. Coordinates N 53° 046' 727", E 069° 140' 717".

0-9cm, Dark gray, wet, granular-clumpy, loamy, slightly compacted, many roots, does not boil from HCl, the transition is sharp in density;

10-21cm, Dark brown, fresh, columnar-prismate, dense, heavy loam, roots, does not boil from HCl, the transition is gradual;

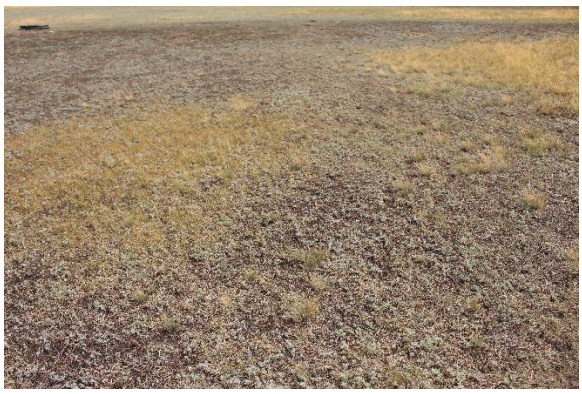
22-43 cm, Lighter than the previous one, fresh, lumpy, loamy, small roots, does not boil from HCl, the transition is noticeable;

44-78 cm, Light brown with whitish veins, fresh, structureless, loamy, fine sand, dense, does not boil from HCl;

79-120 cm, Brown, fresh, structureless, veins of salts and spots of carbonates, loamy, dense, boils violently from HCl.



A



B

Figure 27 – Structure of the profile (A) of fine solonetzes and surface condition (B)

The small salt licks of the monitoring site №25 are characterized by a heavy granulometric composition, since the physical clay content of the 10-20 cm layer is 56.4% (Table 97).

Table 97 – Granulometric composition of small solonetz

№ cut	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
25	0-9	3,52	7,898	11,671	29,022	13,267	18,657	19,486	51,410
	10-20	3,60	5,207	8,071	30,290	13,278	18,257	24,896	56,432
	30-40	3,52	9,660	10,32	25,29	14,925	19,48	20,315	54,726

				3	0		6		
	50-60	3,52	19,196	14,055	48,093	7,048	6,633	4,975	18,657
	90-100	3,32	19,963	41,560	9,930	2,482	21,101	4,965	28,548

From the data on the chemical composition of small salt licks of the monitoring site №25 of the Zerendinsky district of the Akmola region it follows that they are low-humus. In them, the humus content is 4.22% in the supra-solonetz humus and 3.93% in the solonetz horizons proper (Table 98).

Table 98 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
25	0-9	4,22	0,280	61,6	70	990	6,88
	10-20	3,93	0,238	25,2	16	330	7,86
	30-40	-	-	-	-	-	8,50
	50-60	-	-	-	-	-	8,33
	90-100	-	-	-	-	-	8,19

A study of the salt composition of the small salt licks of the monitoring site № 25 showed that their surface horizons (0-9 and 10-20 cm) are practically unsalted (0.083 and 0.106%). However, deeper than the above horizons, soil salinity increases to 0.909% (Table 99).

Table 99 - Salt composition of small solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3	From normal carbonates						

			-	in CO_3^{2-}						
25	0-9	0,106	0,24	0,00	0,00	1,27	0,37	0,56	0,39	0,18
			0,015	0,000	0,000	0,061	0,007	0,007	0,009	0,007
	10-20	0,083	0,52	0,16	0,00	0,60	0,19	0,28	0,62	0,03
			0,032	0,005	0,000	0,029	0,004	0,003	0,014	0,001
	30-40	0,264	0,72	0,00	2,07	1,28	0,47	0,66	2,91	0,03
			0,044	0,000	0,073	0,061	0,009	0,008	0,067	0,001
	50-60	0,909	0,44	0,00	3,66	9,93	5,05	3,00	5,95	0,03
			0,027	0,000	0,130	0,477	0,101	0,036	0,137	0,001
	90-100	0,813	0,36	0,00	2,70	9,11	3,93	2,25	5,09	0,90
			0,022	0,000	0,096	0,438	0,079	0,027	0,117	0,035

Table 100 – Composition of absorbed bases of small solonetz

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
25	0-9	21,39	10,95	0,03	1,17	33,54
		63,77	32,65	0,09	3,49	
	10-20	24,38	11,44	1,29	0,07	37,18
		65,57	30,77	3,47	0,19	
	30-40	21,89	11,44	2,80	0,07	36,20
		60,47	31,60	7,73	0,2	
	50-60	10,95	22,89	1,68	0,07	35,59
		30,77	64,31	4,72	0,2	
	90-100	11,44	21,89	1,94	0,07	35,34
		32,37	61,94	5,49	0,2	

Like the soils of the previous point, the small solonetzes of the monitoring area № 25 are also characterized by magnesium solonetization. Among the cations, its proportion in the upper horizons varies from 30.77 to 32.65% of the sum of the bases absorbed (Table 100).

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 75% of the total area. Grassland type – sagebrush-type grassland. The botanical composition of plants in this area consists of wormwood – 70%, fescue - 20% and wheatgrass – 10% of the area. Also found in a single specimen is calligonum, cinquefoil, and reveler. The

yield of pasture mass is 8.5 c/ha. Coordinates of the study point contour boundaries №25 – N 53º02'48,4''; E 069º08'26,5''.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 15.81%, fat – 4.41%, fiber – 30.22%, NFE -34.46% and ash – 11.32%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.58 per kilogram of feed, and the exchange energy is – 7.51 MJ.

The monitoring site № 26 is located in the Burabay district of the Akmola region and is located from the Kokshetau - Astana highway 600 m to the north-east and from the village of Kenesary 500 m to the north (Figure 28). Soil type – southern chernozem solonetzic, relief – plains, landscape aspect – green, water regime – atmospheric. Coordinates N 53° 116' 890", E 069° 859' 629".



A



B

Figure 28 – Structure of the profile (A) of the saline salt marshes of the southern chernozems and surface condition (B)

0-6 cm, Dark grey, wet, loamy, granular-lumpy, loose, abundance of roots, boiling from HCl, transition clear in density;

7-21cm, Dark brown, wet, heavy loam, columnar, dense, roots, boils from HCl, the transition is noticeable in color;

22-37 cm, Dark brown, moist, heavy loam, compacted, lumpy, marked with individual spots of carbonates, single roots, boiling from HCl, clear transition;

38-66 cm, Brown, wet, heavy loam, compacted, structureless, abundance of carbonate stains, boils violently from HCl, clear transition;

67-120 cm, Dark brown, wet, heavy loam, compacted, structureless, interspersed with carbonates, boils violently from HCl.

From the data of the fraction of small solonetzes of the monitoring site № 26, it is clear that they have a heavy composition of the solonetz horizon, where the content of physical clay is 38.5 and 32.4% (Table 101).

Table 101 – Granulometric composition of small salt licks

№ cut	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
26	0-6	3,42	9,236	14,144	38,103	18,223	12,011	8,283	38,517
	10-20	3,60	5,041	23,174	39,419	10,373	13,278	8,714	32,365
	25-35	3,60	10,809	27,780	34,855	11,618	9,544	5,394	26,556
	50-60	3,44	4,805	26,429	21,955	17,813	20,713	8,285	46,810
	80-90	3,14	5,369	18,645	42,123	14,454	13,215	6,195	33,863

From the data on the chemical composition of the solonetzic salt marshy southern chernozems of the monitoring site № 26 of the Burabay district of the Akmola region, it follows that these soils are weakly humidified. This is evidenced by the humus content in the humus horizon, which is 3.51% (Table 102). With depth, the noted value decreases first to 2.21%, and then to 1.52%.

Table 102 – Chemical composition of solonetzic saltmarsh southern chernozems

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
26	0-6	3,51	0,238	95,2	66	1000	8,29
	10-20	2,21	0,210	44,8	10	240	8,14
	25-35	1,52	0,196	25,2	8	170	8,27
	50-60	-	-	-	-	-	8,21
	80-90	-	-	-	-	-	8,19

From the data on the content of water-soluble salts of the saline-like saline-like southern chernozems of the monitoring site № 26, it appears that these soils are superficially weakly and highly saline. In the topsoil the salt content is 0.170 and 0.789% (Table 103). From 25 to 90 cm, the salt concentration varies from 1.118 to 1.610%.

Table 103 - Saline composition of solonetzic salt marshes of southern chernozems, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
26	0-6	0,170	0,52	0,00	0,33	1,59	0,65	0,66	0,92	0,20
			0,032	0,000	0,012	0,076	0,013	0,008	0,021	0,008
	10-20	0,789	0,52	0,00	3,29	8,25	4,21	1,88	5,95	0,03
			0,032	0,000	0,117	0,396	0,084	0,023	0,137	0,001
	25-35	1,118	0,44	0,00	4,10	12,59	6,64	3,09	7,37	0,03
			0,027	0,000	0,145	0,604	0,133	0,038	0,17	0,001
	50-60	1,610	0,48	0,00	6,83	17,45	7,01	4,50	13,22	0,03
			0,029	0,000	0,242	0,838	0,140	0,055	0,304	0,001
	80-90	1,506	0,48	0,00	7,76	15,2	6,73	4,41	12,27	0,03
			0,029	0,000	0,275	0,730	0,135	0,054	0,282	0,001

The southern chernozems of the monitoring site № 26 have not only salt marshes, but also medium saltiness. Since the latter shows the proportion of sodium absorbed, which in the solonetz horizon is 12.01% of the sum of the bases absorbed (Table 104).

Table 104 – Composition of absorbed bases of solonetzic saltmarsh southern chernozems

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
26	0-6	25,37	6,97	1,31	2,01	35,66
		71,14	19,55	3,67	5,64	
	10-20	34,33	10,95	6,19	0,06	51,53
		66,62	21,25	12,01	0,12	
	25-35	12,94	19,9	2,07	0,06	34,97
		37,0	56,90	5,9	0,2	
	50-60	14,43	19,9	3,21	0,06	37,60
		38,38	52,92	8,54	0,16	
	80-90	15,42	18,41	3,59	0,06	37,48
		41,14	49,12	9,58	0,16	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 70% of the total area. Pasture type – wheatgrass-swan-fescue. The botanical composition of plants in this area consists of wheatgrass – 70%, quinoa – 15%, fescue –10% and bedbug – 5% of the area. Also found in a single specimen is ruminaceae hairwort. The yield of pasture mass is 9.0 c/ha. Coordinates of the study point contour boundaries №26 – N 53º07'00,2’’; E 069º51'20,9’’.

A study conducted to study the chemical composition of feed on solonetzic salty soils showed that the content of protein in the air-dry state is 12.13%, fat – 5.44%, fiber –33.00%, NFE -37.96% and ash – 8.73%. At the same time, the yield of feed units at natural plant moisture is – 0.54 per kilogram of feed, and the exchange energy is – 7.49 MJ.

The monitoring site № 27 is located in the Enbekshil district of the Akmola region and is located from the highway of the city of Makinsk – Aksu to the northwest, 400 m and from the village of Birsuat to the south, 10 km (Figure 29). Soil type – fine saltbush, relief – flat, landscape aspect –greyish-green, water regime – atmospheric. Coordinates N 52° 667' 836", E 070° 861' 389".



A



B

Figure 29 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-6 cm, Dark grey, dry, granular-lumpy, loamy, weakly compacted, abundance of roots, does not boil from HCl, transition is sharp in density;

7-22 cm, Dark brown, wet, heavy loam, dense, nutty-clumpy, roots, does not boil from HCl, the transition is noticeable in color;

22-41cm, Dark brown, wet, clayey, lumpy, single spots of carbonates, boiling from HCl, single small roots, gradual transition;

42-59 cm, Brown, wet, clayey, structureless, carbonate stains, boils violently from HCl, gradual transition, compacted;

60-120 cm, Lighter than the previous one, wet, clayey, structureless, compacted, boils violently from HCl.

The granulometric composition data of the small salt licks of the monitoring site № 27 showed that they have a heavy composition, especially in the solonetz horizon. Here the physical clay content is 65.5% (Table 105).

Table 105 – Granulometric composition of small salt licks

№ cut	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
27	0-6	3,64	12,848	22,395	22,001	13,699	17,850	11,208	42,756
	10-20	1,64	10,960	4,860	18,707	13,827	24,400	27,247	65,474
	30-40	3,50	7,088	4,207	62,176	20,725	3,731	2,073	26,528
	45-55	3,26	7,608	6,802	72,359	9,097	1,240	2,894	13,231
	80-90	3,16	6,939	3,015	21,066	9,500	43,784	15,696	68,980

In the chemical composition of small salt licks of the monitoring site № 27 of the Enbekshil district of the Akmola region, it is clear that the humus content in the low-power humus horizon is 3.11%, and in the subhumus horizon 1.33% (Table 106). The peculiarity of the studied soils also lies in the alkalinity of the soil environment (pH 8.89-9.03) starting from the solonetz horizon.

Table 106 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
27	0-6	3,11	0,182	64,4	50	770	7,56
	10-20	1,33	0,112	47,6	2	350	8,89
	30-40	-	-	-	-	-	8,57
	45-55	-	-	-	-	-	8,61

	80-90	-	-	-	-	-	9,03

A study of the content of water-soluble salts of small salt licks of the monitoring site №27 showed that they are slightly saline in the low-power humus horizon (sum of salts 0.197%). While in the underlying horizon the indicator value increases to 0.536%, which indicates average salinity (0.536%). Even deeper, the salt concentration rises to 1.4% (Table 107).

Table 107 - Salt composition of small solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
27	0-6	0,197	0,64	0,16	0,26	1,86	0,09	0,56	1,96	0,14
			0,039	0,005	0,009	0,089	0,002	0,007	0,045	0,005
	10-20	0,536	1,20	0,24	2,11	4,55	0,47	0,94	6,42	0,03
			0,073	0,007	0,075	0,218	0,009	0,011	0,148	0,001
	30-40	1,173	0,56	0,04	2,29	14,49	4,39	2,16	10,76	0,03
			0,034	0,001	0,081	0,695	0,088	0,026	0,247	0,001
	45-55	1,379	0,48	0,04	2,03	17,65	6,55	1,31	12,27	0,03
			0,029	0,001	0,072	0,847	0,131	0,016	0,282	0,001
	80-90	0,702	1,04	0,24	2,29	6,88	0,28	0,66	9,24	0,03
			0,063	0,007	0,081	0,330	0,006	0,008	0,213	0,001

The soils of the monitoring site №27 of the Enbekshil district of the Akmola region are solonetz. In them, the proportion of absorbed sodium and magnesium in a layer of 10-20 cm reaches 19.36 and 45.47%, respectively (Table 108).

Table 108 – Composition of absorbed bases of small solonetz

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
27	0-6	13,43	8,46	1,41	1,08	24,38
		55,09	34,7	5,78	4,43	
	10-20	9,95	12,94	5,51	0,06	28,46
		34,96	45,47	19,36	0,21	
	30-40	14,43	9,45	2,81	0,06	26,75
		53,94	35,33	10,51	0,22	
	45-55	14,43	8,46	2,82	0,01	25,72
		56,10	32,9	10,96	0,04	
	80-90	8,46	10,45	19,27	0,06	38,24
		22,12	27,33	50,39	0,16	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 55% of the total area. Type of pasture – isene-wormwood with the participation of sweet clover. The botanical composition of plants in this area consists of isene – 70%, wormwood – 20% and sweet clover – 10% of the area. Also found in a single specimen are feather grass, horse sorrel, quinoa, wormwood, skerda, dandelion and statice. The yield of pasture mass is 7.6 c/ha. Coordinates of the study point contour boundaries №27 – N 52º40'04.0''; E 070º51'40.4''.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 15.53%, fat – 5.62%, fiber – 31.60%, NFE - 34.39% and ash – 9.92%. The yield of feed units at natural plant moisture is – 0.56 per kilogram of feed, and the exchange energy is – 7.89 MJ.

The monitoring site № 28 is located in the Akkol district of the Akmola region and is located from the highway of the city of Makinsk – Aksu, 1 km to the west and from the village of Kyrykuduk, 400 m to the east (Figure 30). Soil type – fine saltbush, relief – flat, landscape aspect –greyish-green, water regime – atmospheric. Coordinates N52°511'532", E071°651'485".



A



B

Figure 30 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-7 cm, Dark grey, dry, granular-lumpy, loamy, loose, abundance of roots, does not boil from HCl, the transition is noticeable in color;

8-22 cm, Dark brown, dry, nutty-columnar, heavy loam, dense, roots, does not boil from HCl, the transition is noticeable in color;

23-38 cm, Light brown, dry, lumpy, dense, isolated spots of carbonates, boiling from HCl, clayey, gradual transition;

39-58 cm, Brown, fresh, structureless, dense, clayey, carbonate spots and individual gypsum drusen, boils violently from HCl, the transition is gradual;

59-120 cm, Darker than the previous one, wet, structureless, compacted, clayey, carbonate spots, abundance of gypsum drusen, boils violently from HCl.

Analysis of the fraction of small salt licks of the monitoring site № 28 showed that these soils are heavy loamy. This is evidenced by the physical clay content, which reaches 36.9% in the solonetz horizon (Table 109).

Table 109 – Granulometric composition of small solonetz

№ cut	Sample depth,	A.S.N %	Fraction content in % on absolute dry soil
			Fraction sizes in mm

	cm	H2O	Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
28	0-7	1,46	21,514	32,616	20,702	8,119	9,336	7,713	25,167
	10-20	1,60	16,850	19,736	26,423	10,569	16,667	9,756	36,992
	25-35	1,62	13,661	19,252	8,538	10,978	22,769	24,802	58,548
	40-50	1,36	16,342	24,858	6,083	8,921	28,792	15,004	52,717
	80-90	1,50	18,071	6,686	40,203	12,995	0,812	2,437	16,244

The chemical composition of the salt licks of the small monitoring site № 28 of the Akkol district of the Akmola region showed that they are relatively highly enriched with organic matter in the surface horizon, where the humus content was 4.78% (Table 110).

Table 110 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
28	0-7	4,78	0,308	75,6	110	870	8,21
	10-20	2,36	0,210	36,4	6	600	8,90
	25-35	0,92	0,084	47,6	2	240	9,25
	40-50	-	-	-	-	-	8,99
	80-90	-	-	-	-	-	8,59

Data on the ionic composition and salt content of the small salt licks of the monitoring site №28 showed that they were slightly saline from the surface to a depth of 40 cm. In the noted interval, the salt concentration varies from 0.084 to 0.158% (Table 111). Account should be

taken here of the fact that, as it deepens downwards, the degree of salinization of the small salt licks increases to an intensive (0.877%).

Table 111 - Salt composition of small solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
28	0-7	0,106	0,36	0,00	0,00	1,10	0,37	0,47	0,37	0,25
			0,022	0,000	0,000	0,053	0,007	0,006	0,009	0,010
	10-20	0,084	0,44	0,00	0,00	0,70	0,19	0,19	0,73	0,03
			0,027	0,000	0,000	0,034	0,004	0,002	0,017	0,001
	25-35	0,158	1,56	0,24	0,00	0,45	0,28	0,38	1,32	0,03
			0,095	0,007	0,000	0,021	0,006	0,005	0,030	0,001
	40-50	0,426	0,84	0,16	0,78	4,53	0,28	1,03	4,81	0,03
			0,051	0,005	0,028	0,218	0,006	0,013	0,111	0,001
	80-90	0,877	0,52	0,08	1,96	10,44	4,68	0,84	7,37	0,03
			0,032	0,002	0,069	0,501	0,094	0,010	0,170	0,001

Small salt licks of the monitoring site № 28 of the Akkol district of the Akmola region are characterized by a high content of absorbed magnesium and sodium. Moreover, a significant share of them is observed in a layer of 25-35 cm and amounts to 46.46 and 21.82% (Table 112).

Table 112 – Composition of absorbed bases of small solonetz

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
28	0-7	18,91	4,48	0,96	2,36	26,71
		70,8	16,77	3,59	8,84	
	10-20	15,92	10,45	3,03	0,89	30,29
		52,56	34,5	10,0	2,94	
	25-35	9,45	13,93	6,54	0,06	29,98
		31,52	46,46	21,82	0,2	
	40-50	10,45	9,95	8,69	0,06	29,15
		35,85	34,13	29,81	0,21	
	80-90	14,43	7,96	11,35	0,06	33,80
		42,69	23,55	33,58	0,18	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 75% of the total area. Pasture type –sagebrush-fescue-wheatgrass. The botanical composition of plants in this area consists of wormwood – 60%, wheatgrass - 35% and fescue – 5% of the area. Also found in a single specimen are hiccups, wheatgrass, bedbugs and thistles. The yield of pasture mass is 7.5 c/ha. Coordinates of the study point contour boundaries №28 – N 52º30'41,7''; E 071º39'05,4''.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 13.11%, fat – 7.42%, fiber – 30.93%, NFE -33.50% and ash – 11.92%. The yield of feed units at natural plant moisture is – 0.55 per kilogram of feed, and the exchange energy is – 7.62 MJ.

The monitoring site № 29 is located in the Ermentau district of the Akmola region and is located from the highway to the south of the 200 m grader highway Bestobe – Seleti and from the village of Seleti to the north 12 km (Figure 31). Soil type – brackish, relief – flat, landscape aspect –greyish-greenish, water regime – atmospheric. Coordinates N 52° 223' 521", E 072° 742' 756".



A



B

Figure 31 – Structure of the profile (A) of cortical solonetzes and surface condition (B)

0-4 cm, Dark grey, dry, dusty-lumpy, loose, loamy, plant roots, boiling from HCl, individual coarse crushed stone noted, soil surface crushed, transition clear;

5-18 cm, Dark gray, dry, nutty-columnar, loamy, dense, plant roots, boiling from HCl, isolated spots of carbonates, crushed stone found, clear transition in color;

19-35 cm, Light brown, fresh, clumpy, loamy, compacted, individual root species, carbonate spots found, isolated accumulation of gypsum drusen, boiling from HCl, gradual transition;

36-65 cm, Lighter than the previous one, fresh, structureless, loamy, compacted, boils violently from HCl, large spots of carbonates and gypsum drusen, the transition is gradual;

66-120 cm, Brown, fresh, structureless, compacted, clayey, boils violently from HCl, accumulation of gypsum drusen and individual spots of carbonates.

The cortical salt licks of the monitoring site №29 are distinguished by their light and medium loamy granulometric composition. This is evidenced by the physical clay content, which reaches 23.5% in the solonetz layer (Table 113).

Table 113 – Granulometric composition of cortical solonetz

№ cut	Sample depth, cm	A.S.N % H2O	Fraction content in % on absolute dry soil						
			Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
29	0-4	2,22	24,443	29,740	13,091	6,545	14,318	11,863	32,727
	5-15	1,38	27,317	36,990	12,168	4,056	10,951	8,518	23,525
	20-30	2,88	31,734	25,021	30,066	2,471	5,354	5,354	13,180
	40-50	2,06	44,456	10,619	17,153	12,252	13,886	1,634	27,772
	80-90	3,12	36,705	12,097	29,315	14,864	4,129	2,890	21,883

Data on the chemical composition of cortical salt licks of the monitoring site №29 of the Ermentau district of the Akmola region showed a low humus content in the surface horizons, only 1.81 and 1.17%, respectively (Table 114). These soils are also characterized by a very high and high alkalinity of the soil environment (pH 9.15-8.42) throughout the studied profile.

Table 114 – Chemical composition of cortical solonetzes

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
29	0-4	1,81	0,14	25,2	30	410	9,15
	5-15	1,17	0,14	39,2	6	80	8,79
	20-30	0,90	0,08	33,6	6	170	8,52
	40-50	-	-	-	-	-	8,61
	80-90	-	-	-	-	-	8,42

In the soil solution of the cortical solonetzes of the monitoring site № 29 water-soluble salts in a noticeable amount (0.295%) are present starting from the solonetz horizon (5-15 cm). The maximum salts are kept at a depth of 20-30 cm, where it reaches 1.116% (Table 115).

Table 115 - Salt composition of cortical solonetz, mEq/%

№ cut	Sample depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
29	0-4	0,095	0,56	0,04	0,07	0,66	0,09	0,28	0,89	0,03
			0,034	0,001	0,003	0,031	0,002	0,003	0,02	0,001
	5-15	0,295	0,40	0,00	0,96	2,99	0,65	0,47	3,20	0,03
			0,024	0,000	0,034	0,143	0,013	0,006	0,074	0,001
	20-30	1,116	0,36	0,00	6,83	10,68	6,73	4,78	6,33	0,03
			0,022	0,000	0,242	0,512	0,135	0,058	0,146	0,001
	40-50	0,799	0,28	0,00	6,65	5,86	4,77	1,41	6,58	0,03
			0,017	0,000	0,236	0,281	0,095	0,017	0,151	0,001
	80-90	0,921	0,28	0,00	6,10	8,30	6,17	2,81	5,66	0,03
			0,017	0,000	0,216	0,398	0,123	0,034	0,13	0,001

A study of the composition of the absorbed bases of the cortical solonetzes of the monitoring site №29 of the Ermentau district of the Akmola region showed that they have magnesium solonetzicity. However, the proportion of sodium absorbed is also high. If the proportion of absorbed magnesium in the 5-15 cm layer reaches 31.7%, then absorbed sodium – 9.83% (Table 116).

Table 116 – Composition of absorbed cortical solonetz bases

Point №	Depth, cm	Absorbed bases in mg-eq/100 g soil				CEC, mEq per 100g of soil
		Calcium	Magnesium	Sodium	Potassium	
29	0-4	11,44	4,98	2,01	0,81	19,24
		59,46	25,88	10,45	4,21	
	5-15	10,95	5,97	1,85	0,06	18,83
		58,15	31,7	9,83	0,32	
	20-30	13,93	14,43	2,55	0,05	30,96
		44,99	46,61	8,24	0,16	
	40-50	12,94	10,95	2,84	0,03	26,76
		48,36	40,92	10,61	0,11	
	80-90	15,92	9,95	1,02	0,07	26,96
		59,05	36,91	3,78	0,26	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 65% of the total area. Pasture type – sagebrush-fescue-covy. The botanical composition of plants in this area consists of wormwood – 70%, feather grass – 15%, fescue - 10%, and thin-legged – 5% of the area. Also found in a single specimen are wheatgrass, cloves, yellow alfalfa and statice. The yield of pasture mass is 6.6 c/ha. Coordinates of the study point contour boundaries №29 – N 52º13'24,7''; E 072º44'34,1''.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 14.13%, fat – 6.93%, fiber – 33.41%, NFE -33.46% and ash – 9.13%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is – 0.55 per kilogram of feed, and the exchange energy is – 7.75 MJ.

The monitoring site № 30 is also located in the Erementau district of the Akmola region and is located from the Astana – Pavlodar highway, 400 m and from the city of Ermentau, 25 km to the northeast (Figure 32). Soil type – fine saltbush, relief – flat, landscape aspect – greyish-green, water regime – atmospheric. Coordinates N 51° 683' 408", E 073° 408' 963".



A



B

Figure 32 – Structure of the profile (A) of fine solonetzes and surface condition (B)

0-9 cm, Dark grey, dry, granular-lumpy, loamy, loose, root-permeated, HCl-free, transition sharp in density;

10-21cm, Greyish-brown, dry, prismatic-columnar, there is an accumulation of salts, dense, heavy loam, does not boil from HCl, permeated with roots, the transition is noticeable in color;

22-36 cm, Dark brown with a pronounced lingueness of the humus horizon, fresh, lumpy, loamy, boiling from HCl, interspersed with carbonates, compacted, gradual transition;

37-65 cm, Brown, wet, structureless, weakly compacted, clayey, carbonate stains, boiling from HCl, gradual transition;

66-120 cm, Light brown, wet, structureless, clayey, weakly compacted, carbonates and druze of gypsum, sand and crushed stone are found.

The granulometric composition data of the small salt licks of the monitoring site № 30 showed that they are heavy loam in the first half of the profile. In the upper horizons, the physical clay content is 43.3 and 50.1% (Table 117).

Table 117 – Granulometric composition of small solonetz

№	Sample	A.S.N	Fraction content in % on absolute dry soil

cut	depth, cm	% H2O	Fraction sizes in mm						
			Sand		Dust			Silt	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
30	0-9	4,82	19,500	13,259	23,955	11,767	21,433	10,086	43,286
	10-20	3,40	19,752	9,441	20,704	13,665	25,259	11,180	50,104
	25-35	3,70	17,217	5,109	19,938	9,138	40,291	8,307	57,736
	50-60	3,68	16,445	2,575	15,365	19,934	40,698	4,983	65,615
	80-90	3,70	20,104	13,853	57,736	3,323	1,661	3,323	8,307

The chemical composition of the small salt licks of the monitoring site № 30 of the Erementau district of the Akmola region shows a comparatively high humus (5.09%) in a low-power humus horizon (Table 118).

Table 118 – Chemical composition of fine salt licks

№ Point	Depth, cm	Types of analysis					
		Total humus, %	Gross nitrogen, %	Movable forms, mg/kg			pH
				Nitrogen	Phosphorus	Potassium	
30	0-9	5,09	0,294	44,8	20	810	8,26
	10-20	3,20	0,238	33,6	4	420	8,57
	25-35	1,00	0,154	19,6	4	190	8,88
	50-60	-	-	-	-	-	8,97
	80-90	-	-	-	-	-	8,79

Table 119 – Salt composition of small solonetz, mEq/%

№ cut	Sample	Sum	Alkalinity	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+

	depth, cm	of salts, %	General in HCO_3^-	From normal carbonates in CO_3^{2-}						
30	0-9	0,132	0,48	0,00	0,11	1,26	0,28	0,47	1,00	0,11
			0,029	0,000	0,004	0,061	0,006	0,006	0,023	0,004
	10-20	0,758	0,48	0,00	1,33	9,33	3,27	1,22	6,61	0,04
			0,029	0,000	0,047	0,448	0,065	0,015	0,152	0,002
	25-35	1,782	0,52	0,04	4,40	21,39	2,81	2,72	20,76	0,03
			0,032	0,001	0,156	1,027	0,056	0,033	0,477	0,001
	50-60	1,338	0,48	0,08	6,28	13,40	2,71	1,22	16,2	0,03
			0,029	0,002	0,223	0,643	0,054	0,015	0,373	0,001
	80-90	1,736	0,40	0,04	12,19	14,61	6,92	2,53	17,72	0,03
			0,024	0,001	0,432	0,701	0,138	0,031	0,408	0,001

A study of the saline composition of the soil solution of small salt licks of the monitoring site № 30 showed that they are saline from a depth of 10 cm to 90 cm. A sharp increase in salt content to 1.78% is observed in the thickness from 25 to 90 cm (Table 119).

The small salt licks of the monitoring site №30 are characterized by salinity throughout the entire profile. It is especially evident from 25 to 60 cm, where the proportion of absorbed sodium and magnesium is, respectively, 24.73-45.39% and 33.28-37.45% of the sum of absorbed bases (Table 120).

Table 120 – Composition of absorbed solonetz bases

Point №	Depth, cm	Absorbed bases in mg-eq/%				ЕКО, мг-экв на 100г почвы
		Calcium	Magnesium	Sodium	Potassium	
30	0-9	19,4	6,47	1,75	1,27	28,89
		67,15	22,39	6,06	4,4	
	10-20	25,87	11,44	5,13	0,17	42,61
		60,71	26,85	12,04	0,4	
	25-35	19,4	15,42	11,46	0,06	46,34
		41,86	33,28	24,73	0,13	
	50-60	7,46	16,42	19,9	0,06	43,84
		17,02	37,45	45,39	0,14	
	80-90	16,42	6,97	3,57	0,08	27,04
		60,72	25,78	13,20	0,3	

Characteristics and forage value of land cover. Projective vegetation coverage in this area accounts for 65% of the total area. Pasture type –sagebrush-fescue- saltwort. The botanical composition of plants in this area consists of wormwood – 60%, aescue – 30% and saltwort – 10% of the area. Also found in a single specimen is ratite, nanea, slender-legged, and borage. The yield of pasture mass is 7.3 c/ha. Coordinates of the study point contour boundaries №30 –N 51º41'00.2''; E 073º24'31.7''.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 12.52%, fat – 6.24%, fiber –32.74%, NFE - 35.53% and ash – 9.43%. At the same time, the yield of feed units at natural plant moisture is – 0.56 per kilogram of feed, and the exchange energy is – 7.75 MJ.

Aktobe Region

Monitoring site № 31. Soil: Steppe deep salt marsh heavy loamy on loam. Located in the Khromtau district of the Aktobe region (Figure 33). Coordinates: N 50.280431º, E 57.736493º. Height above u.m. = 334 m. Wavy plain within the floodplain terrace. Vegetation of forbs-forge fescue-wormwood: blue wormwood sp, fescue sol, feather grass sol, caragana sol, yarrow sol, onion sol. Closure 50 %, Height 15-30 cm. Depth 65 cm. A+B = 55 cm. Boiling from 40 cm. Carbonates – sharply defined spots from 55 cm. Plaster sand from 55 cm. Horizons A1 0-5, AB 5-18, B_1^{CH} 18-35, B_2^{CH} 35-55, C_1 55-bottom.

0-5 cm, Dark brown, greyish, dry, slightly compacted, strongly radiculate, powdery-clumpy, medium loamy

5-18 cm, Dark brown, dry, compacted, with roots granular-clumpy, medium loamy

18 - 35 cm, Dark brownish, dry, dense, blocky-nutty, clayey

35 - 55 cm, Brown, dry, dense, clayish with single roots, sharply costose-clumpy

55-bottom, Inhomogeneously coloured, fresh, dense, brown with whitish spots of carbonates and gypsum, unstructured, heavy loamy



Figure 33 – Deep steppe saltbush heavy loamy on loam

Table 121 – Chemical and physico-chemical properties of steppe solonetzes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
31	0-5	4,41	0,28	0,32	19,8	6,44	0,4	0,78	27,42	7
	7-17	2,46	0,21	0,19	16,34	7,92	0,13	0,19	24,58	7,24
	21-31	1,94	0,21	0,16	13,37	18,32	2,21	0,21	34,11	8,24
	40-50	1,22	0,112	1,84	8,42	18,32	2,9	0,21	29,85	8,82
	55-65			1,71						8,36

Table 122 - Granulometric composition of steppe solonetzes

№ cut	Depth, cm	Fraction content in % on dry soil
		fraction size in mm

		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
31	0-5	7,35	19,94	31,63	9,45	21,36	10,27	41,08
	7-17	6,44	17,22	29,96	10,67	24,63	11,08	46,38
	21-31	4,57	9,41	25,35	12,47	28,26	19,95	60,67
	40-50	4,03	11,66	24,80	10,33	23,56	25,63	59,52
	55-65	4,27	17,26	54,10	18,17	3,72	2,48	24,37

Table 123 – Composition of water-soluble salts in steppe salt licks, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
31	0-5	0,034	0,015	0,000	0,005	0,005	0,004	0,002	0,001	0,003
			0,24	0,00	0,15	0,1	0,19	0,19	0,04	0,07
	7-17	0,105	0,01	0,000	0,004	0,065	0,009	0,011	0,004	0,002
			0,16	0,00	0,11	1,36	0,47	0,94	0,17	0,05
	21-31	0,17	0,046	0,002	0,005	0,074	0,007	0,013	0,024	0,001
			0,76	0,08	0,15	1,55	0,37	1,03	1,03	0,02
	40-50	0,29	0,051	0,005	0,009	0,147	0,006	0,014	0,063	0,001
			0,84	0,16	0,26	3,06	0,28	1,13	2,73	0,02
	55-65	1,211	0,022	0,000	0,017	0,849	0,137	0,093	0,091	0,002
			0,36	0,00	0,48	17,68	6,83	7,69	3,95	0,06

The profile is powerful (up to 65 cm), the humus horizon is pronounced (A+B ≈ 55 cm). In the upper horizons, exchangeable Na is low (0.13–0.40 mEq/100 g), but increases sharply in the illuvial part (to 2.2–2.9) (Table 121). The proportion of physical clay increases from 41–46 % at the top to 60 % at the B horizons, then decreases in the parent rock (Table 122). Salinisation is observed from 55 cm (Table 123). This is a typical salt licorice with a pronounced sodium and clay maximum.

Characteristics and forage value of land cover. Relief – wavy-hilly plain point located above the floodplain terrace, landscape aspect – grayish-green, water regime – atmospheric. At the monitoring site, when studying the biological indicators of vegetation, it was revealed that the projective coverage of the soil surface with vegetation does not exceed 50% of the total area. Pasture type – sagebrush-forge-typchak, botanical composition of plants showed that sagebrush occupies – 65%, feather grass – 20% and fescue – 15%. In the composition of the grass stand,

the dominant plant is wormwood, feather grass and fescue are subdominant, and the presence of plants such as, canopy, onion, yarrow, sweet clover and gulthemia is also noted. At the same time, the yield of pasture mass was 9.5 c/ha.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 14.73 %, fat – 5.64 %, fiber – 33.26 %, NFE – 36.32 % and ash – 9.42%. At the same time, the yield of feed units at natural plant moisture is 0.53 per kilogram of feed, and the exchange energy is – 6.94 MJ.

Monitoring site №32. Soil: Chestnut, slightly salty, light loamy on the sand. Located in the Khromtau district of the Aktobe region (Figure 34). Coordinates: N 50.254651^{o}, E 57.953029^{o}. Height above u.m. = 416 m. Wavy high plain. Vegetation of forbs-wormwood-fescue: fescue sp, wormwood sp, yarrow sol, poppy-leg sol, silene sol, cinquefoil sol, feather grass sol, erythematosus sol, field bindweed sol, gypsophila. Closedness 60 %. Height 20-25 cm. Depth 75, A+B = 40 cm. Boiling from 20 cm. No visible carbonates – were found. Horizons A 0-5, AB 5-20, B_2^{CH} 20-40, C_1 40-60, C_2 60-bottom

0-5 cm, Greyish-brown, dry, compacted, radiculate powdery-clumpy, light loamy

5-20 cm, Brown, grayish, dry, compacted with roots, weakly lumpy, light loamy

20-40 cm, Brown (brownish), dense, dry, nutty, sandy loam

40-60 cm, Cream sand with gypsum crystals

60-bottom, Slightly darker than the previous coarse sand



Figure 34 – Chestnut slightly saline medium loamy on sand

Table 124 – Chemical and physico-chemical properties of chestnut weakly saline soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
32	0-5	4,15	0,224	0,23	11,88	2,48	0,4	0,05	14,81	7,04
	7-17	1,93	0,14	0,16	9,9	2,48	0,4	0,1	12,88	7
	25-35	0,84	0,126	0,16	6,44	0,99	0,4	0,21	8,04	7,12
	45-55	0,51	0,126	0,49	6,93	1,98	0,4	0,21	9,52	7,03
	65-75			0,16						7

Table 125 - Granulometric composition of chestnut weakly saline soil

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
32	0-5	60,14	9,60	12,51	4,84	10,49	2,42	17,75
	7-17	70,07	5,74	6,85	3,23	10,88	3,23	17,33
	25-35	71,70	11,42	4,82	1,61	6,83	3,62	12,06
	45-55	66,69	16,43	4,82	2,01	4,02	6,03	12,05
	65-75	68,70	18,05	3,61	0,40	4,82	4,42	9,64

Table 126 – Composition of water-soluble salts in chestnut slightly saline soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
32	0-5	0,103	0,01	0,000	0,005	0,064	0,004	0,016	0,001	0,004
			0,16	0,00	0,15	1,33	0,19	1,31	0,04	0,09
	7-17	0,105	0,007	0,000	0,003	0,069	0,007	0,014	0,001	0,004
			0,12	0,00	0,07	1,44	0,37	1,13	0,04	0,09
	25-35	0,016	0,005	0,000	0,004	0,003	0,002	0,001	0,001	0,001
			0,08	0,00	0,11	0,06	0,09	0,09	0,04	0,02
	45-55	0,045	0,01	0,000	0,004	0,021	0,002	0,007	0,001	0,001
			0,16	0,00	0,11	0,44	0,09	0,56	0,04	0,02

	65-75	0,068	0,005	0,000	0,004	0,043	0,004	0,01	0,001	0,001
			0,08	0,00	0,11	0,9	0,19	0,84	0,04	0,02

Humus content in the upper horizon is 4.15%, rapidly decreasing downwards. Underlain by sand with gypsum with 40 cm The soil is slightly alkaline (pH about 7) (Table 124). Light particle size distribution (up to 70% of sand fraction) (Table 125). The exchangeable Na throughout the profile is consistently low (0.4 mEq). at the top the physical clay is about 18%, down it decreases to 10%. The soils are practically unsalted (Table 126). The soloneticity is weakly expressed in the surface horizon.

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – greenish grey, water regime – atmospheric. The total projective covering of the soil surface with vegetation was 55% of the total area. Grassland type – fescue-wormwood-variegated. The botanical composition of plants consists of fescue – 50%, wormwood – 35% and forbs – 15%. In addition to them, there are: yarrow, cinquefoil, eryngium, feather grass, thin-legged grass, rock and resin. The yield of pasture mass is 10.5 c/ha

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 13.91 %, fat – 5.82 %, fiber – 34.00 %, NFE – 35.20 % and ash – 8.52%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is 0.60 per kilogram of feed, and the exchange energy is – 8.96 MJ.

Monitoring site № 33. Soil: Meadow-desert salt marsh clayey saltbush on heavy loam. Located in the Khromtau district of the Aktobe region (Figure 35). Coordinates: N 50.297157º, E 58.080788º. A complex surface, a tumbled-wavy plain, part plowed. Among sunflower crops, bald spots – solonetz spots. Vegetation wormwood-forge-comforosm: comforosm sp, cop, feather grass sp-sol, scorzonera sol, volos sp, izen sol, parmelia sol. Closedness 75-80 %. Height 10-15 cm. Depth 70 cm. A+B = 30 cm. Boiling 15 cm. Gypsum with 50 sand. Carbonates – from 30 to 50 cm whitish spots. Horizons A_1^{CH} 0-5, B_1^{CH} 5-15, B_2 15-30, C_1^K 30-50, C_2 50-bottom.





Figure 35 – Meadow-desert salt marsh saltbush clayey on heavy loam

0-5 cm, Light grey, radiculate, dry, dense, clumpy-hazelous, clayey

5-15 cm, Brown, dry, very dense, nutty, clayey

15-30 cm, Greyish-bright brown, fresh, dense, cingulate-clumpy, heavy loamy

30-50 cm, Bright brown, fresh, compacted, heavy loamy

50-bottom, Reddish brown, fresh, compacted with gypsum inclusion, heavy loamy.

Table 127 – Chemical and physico-chemical properties of meadow-desert salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
33	0-5	3,16	0,238	0,16	17,33	6,44	1,63	0,36	25,76	7,52
	5-15	2,35	0,21	0,16	20,3	12,38	5,82	0,21	38,71	7,96
	17-27	1,92	0,126	1,00	11,39	13,86	14,62	0,21	40,08	8,48
	35-45	0,90	0,098	4,59	12,38	15,35	18,18	0,21	46,12	8,47
	60-70			1,46						8,18

Table 128 - Granulometric composition of meadow-desert salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil			
		fraction size in mm			
		Sand	Dust	Silt	Physical clay

		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
33	0-5	10,87	16,56	22,68	12,78	25,57	11,55	49,90
	5-15	7,18	3,66	22,60	10,05	27,21	29,30	66,56
	17-27	9,65	1,74	25,86	9,75	27,14	25,86	62,75
	35-45	5,75	9,19	34,61	13,76	33,35	3,34	50,45
	60-70	8,16	11,09	65,27	4,18	4,18	7,11	15,48

The upper horizons are brownish grey, heavy loamy and fissured. Humus 4.2 % in the upper horizon, reduced to 1 %. Carbonates and gypsum are developed with 30–50 cm. The soil is alkaline (pH 7.5–8.5) (Table 127). Physical clay increases to 66 % in B1, remaining high (50–62 %) and deeper (Table 128). Severe salinity in the lower horizons (up to 1.7 % of salts) (Table 129). Upper humus layer with Na ≈ 1.6, below — sharp increase: 5.8–14.6–18.2 in horizons B. This is a salt licorice with pronounced sodium accumulation in the illuvial horizon.

Table 129 – Composition of water-soluble salts in meadow-desert salt marshes, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
33	0-5	0,127	0,02	0,000	0,008	0,065	0,002	0,011	0,019	0,001
			0,32	0,00	0,22	1,36	0,09	0,94	0,85	0,03
	5-15	0,094	0,034	0,002	0,014	0,017	0,002	0,001	0,025	0,001
			0,56	0,08	0,41	0,34	0,09	0,09	1,11	0,02
	17-27	0,530	0,037	0,002	0,288	0,011	0,013	0,011	0,168	0,002
			0,6	0,08	8,13	0,22	0,65	0,94	7,31	0,05
	35-45	1,292	0,032	0,000	0,675	0,147	0,036	0,084	0,319	0,001
			0,52	0,00	19,03	3,05	1,78	6,94	13,87	0,02
	60-70	1,715	0,017	0,000	0,766	0,366	0,125	0,107	0,332	0,001
			0,28	0,00	21,61	7,63	6,26	8,81	14,43	0,02

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – greenish grey, water regime – atmospheric. Projective coverage of the soil surface with vegetation is 80%. Type of pasture – comphorosmic-sagebrush-quaff. When studying the botanical composition of plants, it was revealed that komforosma occupies – 40%, wormwood –

35, and feather grass – 25% of the total area. In addition to them, the grass stand contains: hairsucker and canopy in a single specimen. The yield of pasture mass was 11.0 c/ha.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 17.00%, fat – 7.13%, fiber – 30.25%, NFE– 35.20% and ash – 8.52 %. The yield of feed units at natural plant moisture is 0.61 per kilogram of feed, and the exchange energy is – 8.55 MJ.

Monitoring site №34. Soil: Chestnut medium salty heavy loamy on clay. Located in the Khromtau district of the Aktobe region (Figure 36). Coordinates: N 50.219143º, E 58.194353º. Height above u.m. = 407 m. Gently undulating plain. Cut on the gentle slope 3° of the northern exposition. Vegetation of forbs and forksbill wormwood is fescue: fescue cop, feather grass sol, sp, wormwood sp, crown vetch sol. Closedness 90-95 %. Height 25-30 cm. The soil surface is broken by deep cracks up to 10 cm wide, 30-40 cm deep. Depth 60 cm. A+B = 40 cm. Boiling with 40 slight swelling. Carbonates – small veins with 40 cm No salt. Horizons A_1^D 0-5, B_1^{CH} 5-20, B_2^{CH} 20-40, C_1^K 40-bottom.

0-5 cm, Brownish-grey, dry, compacted, strongly radiate, dusty-clumpy, heavy loamy

5-20 cm, Darkish brown, dry, dense, lumpy, clayey

20-40 cm, Brown, dry, very dense, blocky, clayey

40-bottom, Chocolate, fresh, dense, structureless, clay.



Figure 36 – Chestnut medium saline heavy loamy on clay

Table 130 – Chemical and physico-chemical properties of chestnut medium saline soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
34	0-5	4,22	0,266	0,16	26,73	4,95	0,25	1,04	32,97	7,41
	7-17	2,58	0,182	0,16	27,23	8,91	0,08	0,21	36,43	7,49
	25-35	1,49	0,126	0,16	23,76	8,42	2,32	0,21	34,71	8,15
	50-60	1,08	0,14	0,19	20,3	13,37	2,73	0,21	36,61	8,16

Table 131 - Granulometric composition of chestnut medium saline soil

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
34	0-5	7,20	3,92	22,12	7,93	25,04	33,80	66,76
	7-17	4,80	4,57	16,71	10,44	20,46	43,02	73,92
	25-35	4,90	5,53	17,58	10,88	27,21	33,91	72,00
	50-60	3,51	7,34	10,93	10,93	60,56	6,73	78,22

Table 132 – Composition of water soluble salts in chestnut medium saline soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
34	0-5	0,074	0,02	0,000	0,007	0,028	0,009	0,006	0,002	0,003
			0,32	0,00	0,18	0,59	0,47	0,47	0,08	0,08
	7-17	0,065	0,017	0,000	0,005	0,026	0,006	0,006	0,005	0,001
			0,28	0,00	0,15	0,55	0,28	0,47	0,21	0,02
	25-35	0,129	0,032	0,000	0,046	0,011	0,006	0,007	0,027	0,001
			0,52	0,00	1,29	0,23	0,28	0,56	1,18	0,02
	50-60	0,378	0,027	0,000	0,21	0,007	0,028	0,011	0,095	0,001
			0,44	0,00	5,91	0,14	1,4	0,94	4,13	0,02

Humus 4.2% in the upper horizon, reduced to 1%. The soil is dense, carbonates with 40 cm Alkaline reaction (pH 7.4–8.1). Above, the sodium content is low (0.08–0.25), but rises to 2.3–2.7 in B2–C1 (Table 130). The proportion of physical clay is very high (67–78 %), increasing with depth (Table 131). The soils are practically weakly saline from a depth of 50 cm (Table 132). Soloneteness is expressed in the middle part of the profile, the soil is heavy in terms of grain composition.

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – straw-greenish-grey, water regime – atmospheric. Projective coverage of the soil surface with vegetation is 90%. Grassland type – fescue-forge-wormwood-variegated. Determination of the botanical composition of plants showed that fescue occupies – 45%, feather grass – 25%, wormwood – 20%, and forbs – 10% of the total area. In addition to them, grass stands include; zopnik, yarrow, breast, eryngium with the participation of meadowsweet. The yield of pasture mass was 14.5 c/ha.

Determination of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 18.53%, fat – 6.82%, fiber – 31.52%, NFE – 30.87 % and ash – 9.63 %. The yield of feed units at natural plant moisture is 0.57 per kilogram of feed, and the exchange energy is – 8.23 MJ.

Monitoring site №35. Soil: Steppe salt marsh salt marsh heavy loamy on crushed loam. Located in. Abay in the Khromtau district of the Aktobe region (Figure 37). Coordinates: N 50.205311º, E 58.325471º. Wavy plain. Vegetation wormwood-fescue with crushed stone: fescue sp, wormwood sp, parmelia sol, sallow-capped moss sp, izen sp. Closedness 45-50 %. Depth 50 cm. A+B = 35 cm. Boiling from 20 cm. Crushed stone from 35 cm is strong. Horizons B^{P} 0-5, B_1^{CH} 5-20, B_2^{CH} 20-35, C 35-bottom

0-5 cm, Gray, dry, dense, radiculate, dusty-clumpy, light loamy

5-20 cm, Brown (darkish), dry, very dense, blocky with vertical columnar, clayey

20-35 cm, Bright brown, dry, compacted, dusty-clumpy, medium loamy

35-bottom, Whitish-yellow-brown fresh with a lot of stones, medium loamy.



Figure 37 – Steppe saltmarsh saltmarsh heavy loamy on crushed loam

Table 133 – Chemical and physico-chemical properties of steppe salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
35	0-5	1,27	0,126	0,16	8,42	1,98	0,13	0,19	10,72	6,83
	7-17	1,84	0,126	0,32	19,31	3,96	6,47	0,21	29,95	7,98
	23-33	1,57	0,112	4,79	18,32	7,92	11,81	0,21	38,26	8,75
	40-50	1,12	0,07	5,69	18,32	6,93	8,43	0,21	33,89	8,63

Table 134 - Granulometric composition of steppe salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
35	0-5	7,59	43,74	23,53	8,92	14,20	2,03	25,15

	7-17	4,06	27,29	18,72	4,99	14,56	30,37	49,93
	23-33	7,33	21,88	17,07	9,16	22,07	22,49	53,72
	40-50	9,69	26,80	22,00	9,55	19,93	12,04	41,51

Table 135 – Composition of water-soluble salts in salt licks of steppe salt marshes, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
35	0-5	0,062	0,012	0,000	0,005	0,027	0,004	0,005	0,007	0,002
			0,20	0,00	0,15	0,57	0,19	0,38	0,30	0,05
	7-17	0,151	0,046	0,007	0,045	0,016	0,002	0,011	0,03	0,001
			0,76	0,24	1,26	0,34	0,09	0,94	1,31	0,02
	23-33	0,505	0,037	0,002	0,275	0,01	0,017	0,014	0,151	0,002
			0,6	0,08	7,76	0,22	0,84	1,13	6,56	0,05
	40-50	0,592	0,039	0,000	0,334	0,002	0,039	0,013	0,162	0,003
			0,64	0,00	9,42	0,04	1,96	1,03	7,03	0,08

Humus is low (1.3–1.8%). With 35 cm crushed stone, salinity (0.5–0.6% salts in the lower horizons). The soil is alkaline (pH to 8.7) (Table 133). Physical clay increases from 25% at the top to 54% at the mid-horizons (Table 134). The soils are saline from a depth of 20 cm, where the sum of the salts is 0.5 % (Table 135). In soil with 7 cm, the solonetz horizon is well defined.

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – straw grey, water regime – atmospheric. The total projective coverage of the soil surface with vegetation is 45-50%. Grassland type – sagebrush-fescue-senic. In percentage terms, wormwood – 50%, fescuea – 25% and hay – 15-10% of the total area participate in grass. Among the grass stand there are: goiter, yarrow, breast, eryngium with the participation of meadowsweet. The yield of pasture mass was 7.5 c/ha.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 16.33%, fat – 7.30%, fiber – 32.82%, NFE– 31.52% and ash – 9.42%. The yield of feed units at natural plant moisture is 0.55 per kilogram of feed, and the exchange energy is – 8.24 MJ. Height above cm. 385 m.

Monitoring site № 36. Soil: Meadow-chestnut strongly saline salt marsh heavy loamy on loam. Located in the Karagalinsky district of the Aktobe region (Figure 38). Coordinates: N 50.400845°, E 57.37545°. Height above u.m. = 262 m. Floodplain terrace of the river. Zhaksa

Kargaly. Vegetation of forbs-fescue-wormwood: wormwood sp, fescue sp, feather grass sol, bedstraw, breastplate sl, silene, yellow alfalfa, limonium un. Closedness 65-70 %. Height 20-25 cm. Depth 65 cm, A+B = 35, Boiling 35. Carbonates – with 15 cm of vein, 35-50 whitish coating. Horizons A_1^{S} 0-3, B_1^{CH} 3-15, B_2 15-35, C_1^{K} 35-50, C_2^{K} 50-bottom

0-3 cm, Greyish darkish brown, dry, weakly compacted, strongly radiculate, clumpy-powdery, medium loamy

3-15 cm, Dark brown grayish, fresh, dense, sharply ribbed-clumpy, heavy loamy

15-35 cm, Grayish dirty brown, fresh, dense, blocky, heavy loamy

35-50 cm, Whitish-dirty-brown, fresh, compacted, with carbonates, structureless, heavy loamy

50-bottom, Dirty yellow-brown with dark smudges, compacted, with carbonates, structureless, heavy loamy.



Figure 38 – Meadow-chestnut strongly saline heavy loamy on loam

The top is greyish-brown with humus content up to 3.9% (Table 136). Below are carbonate inclusions. The soil is heavy loamy and clayey (Table 137). The salt content rises sharply from 37 cm (to 1.2% and above) (Table 138). The soil solution reaction is slightly alkaline (pH 7.5–8.6). Physical clay increases from 45% to 66% in B2, then subsides. The soils are already saline from a depth of 35 cm. Clear illuvial-solonetz differentiation is characteristic.

Table 136 – Chemical and physico-chemical properties of meadow chestnut highly saline salt marsh soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
36	0-3	3,92	0,266	0,16	18,32	9,9	0,15	0,69	29,06	7,49
	4-14	3,18	0,238	0,16	19,31	10,89	0,62	0,38	31,2	7,45
	20-30	2,24	0,224	3,62	12,38	15,35	4,25	0,21	32,19	8,63
	37-47	0,79	0,112	11,64	17,32	10,89	3,17	0,21	31,59	8,52
	55-65			16,17						8,66

Table 137 - Granulometric composition of meadow-chestnut highly saline salt marsh soil

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
36	0-3	10,35	13,81	31,33	10,72	23,08	10,72	44,52
	4-14	7,56	11,30	31,46	9,94	27,74	12,01	49,68
	20-30	8,14	7,73	17,82	17,41	23,21	25,69	66,31
	37-47	7,00	5,21	24,21	24,21	36,10	3,28	63,59
	55-65	3,26	0,68	55,83	27,92	10,26	2,05	40,23

Table 138 – Composition of water-soluble salts in meadow chestnut highly saline salt marsh soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
36	0-3	0,089	0,02	0,000	0,007	0,039	0,006	0,008	0,006	0,004
			0,32	0,00	0,18	0,81	0,28	0,66	0,27	0,11
	4-14	0,103	0,017	0,000	0,007	0,052	0,004	0,009	0,013	0,001
			0,28	0,00	0,18	1,08	0,19	0,75	0,57	0,04
	20-30	0,158	0,056	0,002	0,035	0,021	0,002	0,01	0,032	0,001
			0,92	0,08	1,00	0,44	0,09	0,84	1,41	0,02
	37-47	1,247	0,024	0,000	0,151	0,704	0,174	0,056	0,138	0,001

			0,4	0,00	4,25	14,66	8,7	4,59	6,00	0,02
	55-65	1,156	0,02	0,000	0,21	0,583	0,118	0,068	0,157	0,001
			0,32	0,00	5,91	12,14	5,89	5,63	6,84	0,02

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – greyish green, water regime – atmospheric.

Projective coverage of the soil surface with vegetation is 45-50% of the total area. Pasture type – sagebrush-variegated-cereal. In percentage terms, wormwood – 60%, forbs – 20%, fescue and feather grass – 10% of the total area participate in grass stand. Among the grass stand there are: bedstraw, yarrow, breast, resin, yellow alfalfa, statice, witwort and meadowsweet. The yield of pasture mass was 15.1 c/ha. Chemical analysis of the feed showed that the content of protein in the air-dry state was 12.20%, fat – 8.23%, fiber – 33.81%, NFE – 35.87% and ash – 6.83%. The yield of feed units at natural plant moisture is 0.57 per kilogram of feed, and the exchange energy is – 7.74 MJ.

Monitoring site №37. Soil: Steppe saltbush heavy loamy. Located in the Alginsky district of the Aktobe region (Figure 39). Coordinates: N 50.182491º, E 57.049101º. Wavy plain. The cut is on a gentle descent to the river. Vegetation is ishen-sagebrush with bluegrass: wormwood cop, izen sol-sp, feather grass, onion bluegrass sol, statice sol. Closedness 50-60%. Height 15-20 cm. Depth 60. A+B = 27. Boiling 27. Carbonates – white-eye 27-43 cm. Horizons A_1 0-3, A 3-15, B^{CH} 15-27, C_1^K 27-43, C_2 43-bottom.



Figure 39 – Steppe saltbush (chestnut solonetzic) heavy loamy

0-3 cm, Brown greyish layered strongly radiate powdery lumpy medium loamy

3-15 cm, Brown, dry, compacted, powdery-clumpy, medium loamy

15 - 27 cm, Dark rachis, dry, very dense, blocky-nutty, clayey

27-43 cm, Dirty dark brown, dry, with white eyes, very dense blocky, clayey

43-bottom, Yellow-brown, dry, dense, blocky, heavy loamy.

Table 139 – Chemical and physico-chemical properties of steppe solonetzes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
37	0-3	3,18	0,224	0,16	13,86	6,44	0,28	0,65	21,23	7,31
	4-14	1,76	0,182	0,23	13,86	7,43	0,15	0,21	21,65	7,4
	16-26	1,67	0,14	0,32	14,85	10,89	3,41	0,21	29,36	8,5
	30-40	1,23	0,14	1,52	4,46	3,96	5,94	0,21	14,57	8,94
	50-60			1,84						8,99

Table 140 - Granulometric composition of steppe solonetzes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
37	0-3	16,53	26,60	24,55	11,05	14,32	6,96	32,32
	4-14	16,05	24,59	21,29	13,10	17,61	7,37	38,08
	16-26	15,91	18,88	13,71	8,72	19,52	23,26	51,51
	30-40	13,73	20,93	12,82	9,10	18,61	24,81	52,52
	50-60	15,17	18,17	17,28	5,35	22,22	21,81	49,38

Table 141 – Composition of water-soluble salts in steppe salt licks, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates						

				in CO_3^{2-}						
37	0-3	0,033	0,02	0,000	0,004	0	0,004	0,001	0,001	0,004
			0,32	0,00	0,11	0	0,19	0,09	0,06	0,09
	4-14	0,089	0,01	0,000	0,007	0,05	0,007	0,009	0,006	0,001
			0,16	0,00	0,18	1,04	0,37	0,75	0,25	0,02
	16-26	0,108	0,063	0,005	0,012	0,001	0,002	0,001	0,027	0,001
			1,04	0,16	0,33	0,02	0,09	0,09	1,18	0,03
	30-40	0,231	0,076	0,005	0,026	0,06	0,002	0,005	0,063	0,001
			1,24	0,16	0,74	1,24	0,09	0,38	2,73	0,02
	50-60	0,301	0,063	0,005	0,073	0,068	0,002	0,009	0,084	0,001
			1,04	0,16	2,07	1,42	0,09	0,75	3,67	0,02

Humus to 3.2% in the upper horizon, reduced to 1.2% (Table 139). Physical clay increases from 32–38% to 52% in BC horizons (Table (Table 140). The soil is dense and salinity is noticeable from 15 cm (Table 141) pH 7.3 to 8.9. Above Na 0.15–0.28, in the middle part of the profile it reaches 3.4–5.9. The solonetz structure is clearly defined from a depth of 15 cm.

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – greyish, water regime – atmospheric. Projective covering of the soil surface with vegetation accounts for 55% of the total area. Pasture type – sagebrush-hazel-mint. Wormwood – 75%, slough – 10%, bluegrass – 10% of the total area takes part in the grass stand. In the botanical composition, grass stands include; yarrow, Fescue, statice, wheatgrass, and feather grass. The yield of pasture mass was 11.0 c/ha.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 13.82%, fat – 6.82%, fiber – 32.44%, NFE – 33.22% and ash – 10.42%. The yield of feed units at natural plant moisture is 0.52 per kilogram of feed, and the exchange energy is – 7.37 MJ.

Monitoring site № 38. Soil: Saltmarsh saltmarsh heavy loamy on crushed-sandy sediment. Located in the Temir district of the Aktobe region (Figure 40). Coordinates: N 50.050770º, E 58.702365º. High floodplain terrace of the river. Karaobda. Vegetation complex, sagebrush-comforosmic, feather grass, section under sagebrush-comforosmic vegetation. There are bare spots: comforosma cop, wormwood sp, feather grass sol, fescue sol, keireuk ip. Closedness 40-50%.



Figure 40 – Saltmarsh saltmarsh heavy loamy on crushed-sand sediment

Height 5-15 cm. Depth 55. A+B = 33 cm No boiling. Salts with 20 cm crust on crushed stone, Crushed stone with 20 cm. Horizons A_1 0-5, B_1^{CH} 5-20, B_2^{CH} 20-33, C_1^{SH} 33-bottom.

0 - 5 cm, Light grey, strata iridescent-clumpy, with medium loamy pores, with rootlets

5-20 cm, Brown, dry, dense, nutty, clayey

20-33 cm, Reddish-brown, dry, compacted, heavy loamy, blocky with salts

33-bottom, Lighter than the previous one, crushed stone-sandy sediment

Humus is low (2.4% above, below <1%). The soil is saline (0.5% salts per 20-30 cm) pH up to 9.2. At the top, Na is low (0.23), but in B1–B2 rises to 3.6-4.1, then falls again (1.3–0.3) (Table 142). The soil is practically not saline (Table 143). Physical clay grows up to 33% in the average horizon, but decreases lower (Table 144). The solonetess is pronounced and there is a salt marsh effect.

Table 142 – Chemical and physico-chemical properties of salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
38	0-5	2,44	0,168	0,16	7,92	5,94	0,23	0,16	14,25	7,34

	7-17	1,3	0,126	0,16	12,87	7,92	3,56	0,15	24,5	8,58
	21-31	0,72	0,042	0,26	11,39	4,46	4,05	0,15	20,05	8,03
	45-55	0,24	0,028	0,32	7,43	4,95	1,32	0,15	13,85	9,22
	60-70	1,6	0,056	0,16	7,92	5,94	0,31	0,22	14,39	7,44

Table 143 - Granulometric composition of salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
38	0-5	38,58	26,28	18,58	3,23	8,89	4,44	16,56
	7-17	34,11	21,12	11,40	2,04	16,69	14,65	33,37
	21-31	49,09	18,71	6,93	2,45	6,52	16,30	25,27
	45-55	46,59	25,82	7,71	3,25	11,77	4,87	19,88
	60-70	32,91	30,60	16,62	3,65	10,54	5,68	19,86

Table 144 – Composition of water-soluble salts in salt marshes, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
38	0-5	0,042	0,012	0,000	0,001	0,016	0,002	0,001	0,008	0,001
			0,2	0,00	0,04	0,34	0,09	0,09	0,37	0,02
	7-17	0,112	0,032	0,005	0,001	0,045	0,002	0,001	0,03	0,001
			0,52	0,16	0,04	0,95	0,09	0,09	1,30	0,02
	21-31	0,565	0,017	0,000	0,007	0,366	0,022	0,008	0,145	0,001
			0,28	0,00	0,18	7,62	1,12	0,66	6,29	0,02
	45-55	0,168	0,027	0,002	0,007	0,086	0,013	0,006	0,029	0,001
			0,44	0,08	0,18	1,79	0,65	0,47	1,28	0,02
	60-70	0,018	0,007	0,000	0,001	0,004	0,002	0,001	0,001	0,001
			0,12	0,00	0,04	0,09	0,09	0,09	0,04	0,02

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – grey, water regime – atmospheric. The point is on the floodplain terrace.

Projective coverage of the soil surface with vegetation is 50%. Wormwood-camphorosmo-Fescue grass stand with meadowsweet. When studying the botanical composition of plants, it was revealed that it occupies wormwood – 55%, camphorosma – 30% and Fescue – 15% of the total area. In addition to them, the grass stand contains; bluegrass, thin-legged, yarrow, isen, lalemantia, meadowsweet, reveler and feather grass. The yield of pasture mass was 11.3 c/ha.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 16.83%, fat – 6.92%, fiber – 31.26%, NFE –33.09% and ash – 8.93%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is 0.58 per kilogram of feed, and the exchange energy is – 8.17 MJ.

Monitoring site №39. Soil: Chestnut, slightly salty, light loamy on sandy loam. Located in the Temir district of the Aktobe region in the Kiikbulak tract (Figure 41). Coordinates: N 50.014829º, E 57.701498º. Wavy plain. Vegetation of wormwood: wormwood shrenka cop, wormwood estrogen sol, bluegrass meadow yip, fescue sol, wheatgrass sol. Closedness 40%. Height 15-25. Depth 65. A+B = 27. No boiling. There are no carbonates. Horizons A_1 0-3, B_1^{CH} 3-16, B_2^{CH} 16-27, C_1 27-45, C_2 45-bottom

0 - 3 cm, Light grey, dry, weakly compacted, sparsely rooted, not strongly clumpy dusty, light loamy, sandy loam

3-16 cm, Dark brown, dry, dense, with sparse roots, coarsely lumpy, light loamy

16-27 cm, Brown, dry, dense, sharply ribbed-clumpy, light loamy

27-45 cm, Bright brown, dry, dense, dusty-blocky, sandy loam

45-bottom, Brown, with dark deposits, dry, dense, structureless, medium loamy, sandy loam

.



Figure 41 – Chestnut, slightly salty, light loamy on sandy loam

Humus is low (about 1%), Na is consistently low (0.31 at all depths) (Table 145). Physical clay fluctuates around 20–23 %, drops to 16–19 % at the bottom (Table 146). Salts not available (Table 147). The profile is light, slightly salty.

Table 145 – Chemical and physico-chemical properties of chestnut lightly saline soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
39	0-3	1,05	0,112	0,16	7,92	4,95	0,31	0,15	13,33	7,51
	5-15	0,99	0,084	0,19	9,41	4,46	0,31	0,15	14,33	7,51
	16-26	0,96	0,07	0,16	7,43	1,98	0,31	0,15	9,87	7,03
	30-40	0,58	0,07	0,16	6,93	2,48	0,31	0,15	9,87	7,47
	55-65			0,81						7,73

Table 146 - Granulometric composition of chestnut weakly saline soil

№ cut	Depth, cm	Fraction content in % on dry soil			
		fraction size in mm			
		Sand	Dust	Silt	Physical clay

		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
39	0-3	31,38	30,43	16,25	0,81	11,38	9,75	21,94
	5-15	36,32	26,75	14,21	0,81	10,96	10,96	22,73
	16-26	36,99	26,08	14,61	0,41	10,55	11,36	22,32
	30-40	45,56	30,12	8,51	0,41	4,46	10,94	15,81
	55-65	44,83	26,39	10,13	2,03	4,46	12,16	18,65

Table 147 – Composition of water-soluble salts in chestnut lightly saline soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
39	0-3	0,028	0,005	0,000	0,001	0,014	0,004	0,002	0,001	0,001
			0,08	0,00	0,04	0,3	0,19	0,19	0,02	0,02
	5-15	0,028	0,005	0,000	0,001	0,014	0,004	0,002	0,001	0,001
			0,08	0,00	0,04	0,3	0,19	0,19	0,02	0,02
	16-26	0,077	0,002	0,000	0,000	0,054	0,013	0,006	0,001	0,001
			0,04	0,00	0,00	1,13	0,65	0,47	0,02	0,02
	30-40	0,016	0,005	0,000	0,001	0,005	0,002	0,001	0,001	0,001
			0,08	0,00	0,04	0,11	0,09	0,09	0,02	0,02
	55-65	0,042	0,01	0,000	0,000	0,021	0,007	0,002	0,001	0,001
			0,16	0,00	0,00	0,44	0,37	0,19	0,02	0,02

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – grey, water regime – atmospheric.

Projective coverage of the soil surface with vegetation is 40-45% of the total area. Pasture type – sagebrush. In percentage terms, Shrenk's sagebrush – 90% and tarragon – 10% of the total area participate in grass stand. The following are found in single quantities as part of the grass stand: bluegrass, cinquefoil, wheatgrass, feather grass, yarrow, resin grass. The yield of pasture mass was 6.0 c/ha.

Determination of the chemical composition of plants growing on solonetzic soils showed that the content of protein in the air-dry state is 16.73%, fat – 5.82%, fiber – 31.12%, NFE – 32.12% and ash – 11.10%. The yield of feed units at natural plant moisture is 0.59 per kilogram of feed, and the exchange energy is – 8.35 MJ.

Monitoring site №40. Soil: Chestnut, slightly salty on sandy loam. Located in the Khobdin district of the Aktobe region (Figure 42). Coordinates: N 50.086763o, E 56.618554o. A wavy, almost flat plain. Vegetation ephemeral sagebrush: sagebrush cop1, bluegrass sol, feather grass un. Closedness 35-40 %. Height 20-25 cm. Depth 65 cm. A+B = 30 cm. No boiling. There are no carbonates. Horizons A_1 0-3, AB 3-15, B_1^{CH} 15-30, C_1 30-50, C_2 50-bottom

0-3 cm, Gray, dry, loose, layered, dusty-clumpy, radiculate, light loamy

3-15 cm, Greyish dark brown, dry, compacted, dusty-clumpy, medium loamy

15-30 cm, Dark brown, dry, dense, not strongly lumpy, medium loamy

30-50 cm, Brown, dry, compacted, dusty-blocky, light loamy

50-bottom, Brown almost like the previous sandy loam



Figure 42 – Chestnut slightly salty on sandy loam

Table 148 – Chemical and physico-chemical properties of chestnut lightly saline soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
40	0-3	1,70	0,14	0,16	5,94	0,99	0,31	0,38	7,62	7,65

	4-14	1,21	0,112	0,19	7,92	1,49	0,31	0,22	9,94	7,56
	17-27	0,94	0,098	0,16	7,92	3,96	0,31	0,15	12,34	6,79
	35-45	0,56	0,098	0,16	9,41	2,97	0,31	0,15	12,84	7,23
	55-65			0,32						7,44

Table 149 - Granulometric composition of chestnut weakly saline soil

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
40	0-3	39,64	34,49	12,12	3,64	6,06	4,04	13,74
	4-14	35,20	36,88	10,12	4,05	8,91	4,86	17,81
	17-27	35,90	31,28	11,75	2,84	8,91	9,32	21,07
	35-45	46,31	26,50	6,90	3,25	6,49	10,55	20,29
	55-65	51,62	23,66	7,70	5,67	2,03	9,32	17,02

Table 150 – Composition of water-soluble salts in chestnut lightly saline soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
40	0-3	0,024	0,012	0,000	0,000	0,005	0,002	0,001	0,001	0,004
			0,2	0,00	0,00	0,11	0,09	0,09	0,02	0,09
	4-14	0,035	0,007	0,000	0,000	0,017	0,006	0,001	0,001	0,003
			0,12	0,00	0,00	0,36	0,28	0,09	0,02	0,08
	17-27	0,052	0,005	0,000	0,000	0,034	0,007	0,005	0,001	0,001
			0,08	0,00	0,00	0,71	0,37	0,38	0,02	0,02
	35-45	0,052	0,002	0,000	0,000	0,036	0,007	0,005	0,001	0,001
			0,04	0,00	0,00	0,75	0,37	0,38	0,02	0,02
	55-65	0,052	0,005	0,000	0,001	0,032	0,007	0,005	0,001	0,001
			0,08	0,00	0,04	0,68	0,37	0,38	0,02	0,02

The top is gray, loose sandy loam, then light loamy horizons. The soil is low humus (1.7%), exchangeable Na is low (0.15-0.31) throughout, but its relative content reaches 3-4% of the sum of the bases (Table 148). The mechanical composition is light (up to 50% sand) (Table

149). There is no salinity (Table 150). Physical clay increases from 14 to 21% in the middle part, then decreases. The soil is classified as slightly saline.

Characteristics and forage value of land cover. Relief – undulating plain, landscape aspect – greyish green, water regime – atmospheric. The total projective coverage of the soil surface with vegetation is 35-40%. Pasture type – sagebrush-ephemeral. Participation in wormwood grass – 90%, bluegrass – 10% of the total area. The grass stand contains ragweed, feather grass, yarrow and tarragon wormwood in a single specimen. The yield of pasture mass was 9.0 c/ha.

A study of the chemical composition of plants growing in solonetzic soils showed that the content of protein in the air-dry state is 16.32%, fat – 3.62%, fiber – 30.61%, NFE – 38.25% and ash – 8.71%. The yield of feed units at natural plant moisture is 0.59 per kilogram of feed, and the exchange energy is – 7.92 MJ.

West Kazakhstan region

Monitoring site №41. Soil: Saltmarsh saltmarsh heavy loamy on clay. Located in the Syrymsky district of the West Kazakhstan region (Figure 43). Coordinates: N 50.506914º, E 52.26408º. Flat plain with microrelief. Vegetation wormwood with feather grass: wormwood cop1, feather grass sol, limonium sol, fescue sol, breastplate un. Closedness 50-60 %. Height 15-25 cm. Depth 60 cm. A+B = 30 cm. Boiling from 30 cm. No carbonate. Salts veins at 30 – bottom. Horizons A_1 0-5, AB 5-15, B_1^{CH} 15-30, C_1^{SH} 30-45, C_2^{SH} 45-bottom.

0-5 cm, Greyish-light brown, dry, compacted, radiculate, dusty-clumpy, light loamy.

5-15 cm, Light brown, dry, compacted, dusty-clumpy, medium loamy.

15-30 cm, Brown, fresh, dense, lumpy-blocky, heavy loamy

30-45 cm, Light brown, light, compacted, obscurely blocky, heavy loamy

45-bottom, Brightly light brown, fresh, compacted, structureless, clayey

.



Figure 43 – Saltmarsh saltmarsh heavy loamy on clay

Table 151 – Chemical and physico-chemical properties of salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
41	0-5	2,19	0,168	0,23	7,43	5,45	0,21	0,88	13,97	7,56
	5-15	1,07	0,112	0,19	9,9	14,85	1,54	0,24	26,53	7,66
	17-27	1,73	0,084	4,85	19,8	12,87	2,33	0,15	35,15	8,12
	33-43	0,69	0,056	6,27	2,97	8,42	4,85	0,15	16,39	8,55
	50-60			0,16						8,53

Table 152 - Granulometric composition of salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
41	0-5	2,16	13,65	55,32	10,58	13,83	4,47	28,88
	5-15	1,42	11,68	57,26	10,15	14,62	4,87	29,65
	17-27	1,08	5,54	36,27	10,84	23,76	22,51	57,11
	33-43	0,64	4,12	39,34	24,43	29,81	1,66	55,90
	50-60	1,04	7,93	74,07	11,59	4,14	1,24	16,97

Table 153 – Composition of water-soluble salts in salt marshes, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
41	0-5	0,045	0,012	0,000	0,009	0,009	0,004	0,002	0,003	0,005
			0,20	0,00	0,26	0,19	0,19	0,19	0,14	0,14

	5-15	0,099	0,005	0,000	0,038	0,023	0,007	0,006	0,016	0,003
			0,08	0,00	1,07	0,48	0,37	0,47	0,71	0,08
	17-27	0,487	0,020	0,000	0,282	0,005	0,015	0,011	0,153	0,001
			0,32	0,00	7,94	0,11	0,75	0,94	6,67	0,02
	33-43	1,376	0,024	0,002	0,472	0,406	0,118	0,022	0,333	0,001
			0,40	0,08	13,3	8,47	5,89	1,78	14,48	0,02
	50-60	1,557	0,020	0,000	0,4	0,649	0,178	0,07	0,241	0,001
			0,32	0,00	11,27	13,52	8,88	5,72	10,49	0,02

The top is grayish-brown and light loamy, followed by heavy horizons. Humus 2.2%, reduced to < 1%, pH 7.5-8.6. Na from a surface of 0.2, then rises to 1.5-2.3 and reaches 4.9 in a horizon of 33-43 cm (Table 151). The soil is dense, the physical clay rises to 57% and 56% in the middle part of the profile, then falls (Table 152).salination is strong (up to 1.5% dense residue) (Table 153). The soloneness is pronounced, with a sodium maximum in the middle horizons.

Characteristics and feed value of the vegetation cover . The relief is a flat plain, with a gray landscape aspect and an atmospheric water regime. The total projective cover of the soil surface by vegetation is 50%. The pasture type is wormwood–feather grass–fescue. In the plant community composition: wormwood accounts for 60%, fescue for 25%, and feather grass for 15% of the total area. Other species found in the herbage include bluegrass, statice (Limonium), Grudnitsa (possibly Lactuca tatarica or related species), couch grass, and meadow grass. The pasture yield is 7.5 c/ha.

A study conducted to study the chemical composition of feed on solonetzic soils showed that the content of protein in the air-dry state is 16.53 %, fat – 5.72 %, fiber – 28.66 %, NFE – 37.13 % and ash – 8.72%. At the same time, the yield of feed units at natural plant moisture is 0.53 per kilogram of feed, and the exchange energy is – 7.63 MJ.

Monitoring Site No. 42. Soil: Meadow-steppe solonetz, solonchak type, on heavy loam. Located in the Syrym District of the West Kazakhstan Region (Figure 44). Coordinates: N

50.506914º, E 52.264068º. Flat low plain. Vegetation: wormwood–camphorosma — camphorosma cop1, saltwormwood sol, keireuk sol, stipa sol, limonium un. Canopy density 40–45%. Height 5–20 cm. Depth 60 cm. A + B = 30 cm. Effervescence from 30 cm. Carbonates – none. Salts from 30 cm – white veins, moderate; from 45 cm – spots to the bottom.. Horizons $A_1$0-3, AB 3-10, B^{CH} 10-20, B_2^{CH} 20-30, C_1^{SH}30-45, C_2^{SH} 45-bottom.



Figure 44 – Meadow-steppe saltmarsh saltbush on heavy loam

0-3 cm, Brownish-light grey, dry with roots, not strongly clumpy-dusty, light loamy

3-10 cm, Light brown dry, radiculate, fragile, lumpy-dusty, light loamy

10-20 cm, Dirty dark brown, fresh with very dense, blocky, divided vertically separately, clayey

20-30 cm, Brown, fresh, compacted, obscurely blocky, heavy loamy

30-45 cm, Dark brown with white veins of salts, fresh, compacted, structureless, heavy loamy

45-bottom, Yellow-brown, fresh with whitish salt spots, heavy loamy.

Table 154 – Chemical and physico-chemical properties of meadow-steppe salt marshes

№ cut	Sample depth,	Humus, %	Total nitroge	CO_2, %	Absorbed bases, mg-eq/100 g	pH of water.

	cm		n, %		Ca	Mg	Na	K	Amount	
42	0-3	1,72	0,14	0,19	6,44	2,97	0,23	0,81	10,45	7,27
	3-10	1,29	0,098	0,49	6,93	9,41	0,66	0,55	17,55	7,98
	10-20	1,47	0,126	0,19	3,47	11,88	8,99	0,15	24,49	8,38
	20-30	0,98	0,07	0,68	7,42	8,41	13,66	0,15	29,64	8,55
	32-42	0,51	0,042	5,72	8,42	4,95	17,21	0,15	30,73	8,57
	50-60			0,16						8,68

Table 155 - Granulometric composition of meadow-steppe salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
42	0-3	1,95	24,52	49,16	8,94	10,56	4,88	24,38
	3-10	0,20	36,52	37,32	8,92	11,76	5,27	25,96
	10-20	0,70	25,13	25,69	7,87	15,75	24,86	48,48
	20-30	0,44	9,03	41,94	7,89	17,44	23,26	48,59
	32-42	0,29	8,95	60,78	22,07	5,83	2,08	29,98
	50-60	0,17	16,33	70,63	6,23	2,08	4,57	12,88

Table 156 – Composition of water-soluble salts in meadow-steppe salt marshes, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
42	0-3	0,026	0,012	0,000	0,005	0	0,002	0,001	0,001	0,004
			0,20	0,00	0,15	0,01	0,09	0,09	0,06	0,1
	3-10	0,044	0,012	0,000	0,007	0,012	0,002	0,001	0,01	0,001
			0,20	0,00	0,18	0,24	0,09	0,09	0,42	0,02
	10-20	0,313	0,051	0,005	0,118	0,034	0,004	0,002	0,103	0,001
			0,84	0,16	3,32	0,71	0,19	0,19	4,49	0,02
	20-30	0,649	0,037	0,002	0,262	0,116	0,004	0,006	0,224	0,001
			0,60	0,08	7,39	2,42	0,19	0,47	9,73	0,02
	32-42	1,731	0,027	0,002	0,328	0,829	0,159	0,055	0,333	0,001
			0,44	0,08	9,24	17,27	7,95	4,5	14,48	0,02

	50-60	1,662	0,024	0,002	0,321	0,79	0,155	0,051	0,32	0,001
			0,40	0,08	9,05	16,45	7,76	4,22	13,91	0,02

The upperparts are brownish grey and light loamy. From a depth of 10 cm – dense heavy loamy horizons. Humus 1.7%, pH slightly alkaline (7.3-8.6). Na 0.23-0.66 on top, then a sharp increase: 9-13.7-17.2 mEq in B and BC horizons (Table 154). The physical clay increases to 48–49% in the middle of the profile, then decreases. from 30 cm (Table 155). There is strong salinity up to 1.7%, including soda (Table 156). A classic example of a solonetz.

Characteristics and feed value of the vegetation cover. The relief is a flat plain, with a gray landscape aspect and an atmospheric water regime. The projective cover of the soil surface by vegetation is 50%. The herbage is of the wormwood–Camphorosma–statice type. The botanical composition analysis showed that wormwood accounts for 60%, fescue for 25%, and feather grass for 15% of the total area. Other species present in the herbage include bluegrass (Poa), Koeleria, statice (Limonium), Grudnitsa (possibly Lactuca tatarica), wheatgrass (Agropyron), and couch grass (Elytrigia repens). The pasture yield amounts to 8.0 c/ha.

Analysis of the data obtained, when determining the chemical composition of growing plants on solonetzic soils, shows that the content of protein in the air-dry state is 15.52%, fat – 6.00%, fiber – 27.89%, NFE – 38.25% and ash – 9.22%. Moreover, on these types of pastures, the yield of feed units at natural plant moisture is 0.56 per kilogram of feed, and the exchange energy is – 7.88 MJ.

Monitoring Site No. 43 Soil: Steppe solonetz, solonchak type, heavy loam. Located in the Syrym District of the West Kazakhstan Region (Figure 45). Coordinates: N 50.585831º, E 52.170676º. Flat plain with a complex vegetation cover. The soil profile was studied under wormwood vegetation. Vegetation: common wormwood cop1, green wormwood sol, feather grass (stipa tirsa) sol, fescue sol, statice (limonium) un. Canopy density: 40–50%. Height: 10–15 cm (feather grass up to 30 cm). Depth: 60 cm. A + B horizons: 35 cm. Effervescence begins at 35 cm. Salts: from 35 cm — fine specks. Horizons: A_1 0–3, AB 3–10, B^{CH} 10–20, B_2 20–35, C_1^{SH} 35–50, C_2 50–bottom.

0-3 cm, Grayish-light brown, dry, loose, radiculate, dusty-unusual-clumpy, light loamy

3-10 cm, Brown, dry, lamellar-clumpy with roots, medium loamy

10-20 cm, Dirty dark brown, dry, very dense, columnar-blocky, clayey

20-35 cm, Brown, fresh, compacted, blocky-clumpy, heavy loamy

35-50 cm, Brown, bright, fresh, compacted, obscurely lumpy, heavy loamy

50-bottom, Yellow-brown, weakly moistened with salt veins, compacted, structureless, heavy loamy.



Figure 45 – Steppe saltbush heavy loamy

Table 157 – Chemical and physico-chemical properties of steppe salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
43	0-3	1,68	0,112	0,16	9,41	3,47	0,25	0,54	13,67	6,85
	3-10	1,24	0,098	0,19	6,93	10,4	0,12	0,42	17,87	7,25
	10-20	1,68	0,098	0,36	3,96	14,85	6,22	0,15	25,18	8,23
	22-32	0,93	0,098	4,85	6,93	7,17	15,39	0,15	29,64	8,67
	37-47	0,43	0,056	7,92	12,87	7,92	3,88	0,15	24,82	8,48
	50-60			0,23						8,56

Table 158 - Granulometric composition of steppe salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
43	0-3	1,71	49,50	19,52	10,98	13,82	4,47	29,27
	3-10	0,96	43,37	23,17	11,38	16,66	4,47	32,51
	10-20	0,68	8,52	33,17	12,02	14,93	30,68	57,63

	22-32	0,31	32,57	14,09	7,04	18,65	27,35	53,04
	37-47	1,72	17,64	51,70	20,27	5,79	2,90	28,95
	50-60	1,51	5,60	47,07	33,86	10,32	1,65	45,83

Table 159 – Composition of water-soluble salts in steppe saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
43	0-3	0,042	0,007	0,000	0,003	0,019	0,004	0,002	0,002	0,005
			0,12	0,00	0,07	0,4	0,19	0,19	0,08	0,14
	3-10	0,042	0,005	0,000	0,003	0,021	0,002	0,002	0,005	0,003
			0,08	0,00	0,07	0,44	0,09	0,19	0,23	0,08
	10-20	0,216	0,049	0,010	0,068	0,026	0,004	0,002	0,066	0,001
			0,8	0,32	1,92	0,54	0,19	0,19	2,87	0,02
	22-32	0,42	0,056	0,005	0,164	0,05	0,002	0,002	0,145	0,001
			0,92	0,16	4,62	1,05	0,09	0,19	6,29	0,02
	37-47	1,05	0,022	0,000	0,197	0,505	0,118	0,039	0,169	0,001
			0,36	0,00	5,54	10,53	5,89	3,19	7,33	0,02
	50-60	1,083	0,024	0,000	0,295	0,413	0,108	0,035	0,206	0,001
			0,4	0,00	8,31	8,61	5,42	2,91	8,97	0,02

The top layer is grayish-brown, light loam, with dense, heavy horizons below. Humus content is low (1.2-1.7%). pH 6.8-8.7. Na increases from 0.25 to 6.2 and 15.4 in horizons B1–B2 (maximum), then decreases (Table 157). Physical clay reaches 57% in the middle of the profile (Table 158). Strong salinity in the lower part of the profile (up to 1.0-1.1% salts) (Table 159). Strong salinity and heavy mechanical composition.

Characteristics and forage value of the vegetation cover. Relief – undulating plain, aspect of the landscape – grey, water regime – atmospheric. The projective cover of the soil surface by vegetation is 40–45%. The grass stand is wormwood–bluegrass. During the study of the botanical composition of plants, it was revealed that wormwood occupies – 60%, camphorosma – 25%, statice – 15%, and salsola– 10% of the total area. Also present in the grass

stand are: bluegrass, fescue, feather grass, wheatgrass, and couch grass. The pasture biomass yield amounted to 9.6 c/ha.

Determination of the chemical composition of plants growing on saline soils showed that the protein content in the air-dry state is 16.00%, fat – 6.93%, fiber – 29.63%, NFE – 32.26%, and ash – 12.50%. The yield of feed units at natural plant moisture content is 0.62 per kilogram of feed, and the metabolic energy is 9.06 MJ.

Monitoring site No. 44. Soil: Steppe clay loam. Located in the Terekta district of West Kazakhstan region (Figure 46). Coordinates: N 50.652015º, E 52.081550º. Flat plain. Sown with rye grass with patches of solonetz under gray-polyn vegetation with feather grass. Vegetation: gray wormwood cop1, feather grass sol, rye grass sol. Closure 40%. Height 25-35 cm. Depth 60 cm, A+B = 25 cm. Boiling from 40 cm. No visible carbonates. No salts. Horizons A_1^K 0-4, AB 4-14, B_1^{CH} 14-25, BC^{CH} 25-40, C_1 40-bottom.

0-4 cm, grayish light brown, dry, loose, layered crust, medium loam

4-14 cm, brownish gray, dry, compacted, granular, heavy loam

14-25 cm, dirty dark brown, dry, very dense, columnar lumpy, clayey

25-40 cm, dark brown, dry, dense, slab-like lumpy, clayey

40- bottom, yellowish-brown, dry, dense, unstructured, clayey.



Figure 46 – Steppe clayey solonetz

Table 160 – Chemical and physicochemical properties of steppe solonchaks

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
44	0-4	2,44	0,154	0,16	31,19	5,94	0,29	0,98	38,4	7,41
	4-14	1,95	0,14	0,16	12,87	12,38	0,12	0,55	25,92	7,48
	15-25	1,29	0,098	0,32	7,92	14,85	2,29	0,15	25,21	7,88
	27-37	0,84	0,07	4,20	12,87	7,43	3,83	0,15	24,28	8,81
	50-60			0,16						8,99

Table 161 - Granulometric composition of steppe solonchaks

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
44	0-4	3,47	11,67	45,10	10,66	22,96	6,15	39,77
	4-14	2,41	35,90	20,56	6,99	22,62	11,52	41,13
	15-25	2,30	14,56	28,13	11,17	23,58	20,27	55,02
	27-37	3,95	21,66	23,97	11,16	22,73	16,53	50,42
	50-60	4,48	21,93	20,56	8,63	23,84	20,56	53,03

Table 162 – Composition of water-soluble salts in steppe solonchaks, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
44	0-4	0,042	0,017	0,000	0,001	0,010	0,004	0,001	0,003	0,006
			0,28	0,00	0,04	0,22	0,19	0,09	0,11	0,14
	4-14	0,049	0,01	0,000	0,003	0,022	0,002	0,002	0,008	0,002
			0,16	0,00	0,07	0,46	0,09	0,19	0,36	0,06
	15-25	0,068	0,044	0,000	0,005	0,000	0,002	0,002	0,013	0,001
			0,72	0,00	0,15	0,00	0,09	0,19	0,56	0,03
	27-37	0,120	0,054	0,005	0,01	0,020	0,002	0,001	0,032	0,001
			0,88	0,16	0,3	0,42	0,09	0,09	1,37	0,03

	50-60	0,227	0,059	0,005	0,03	0,066	0,002	0,002	0,066	0,001
			0,96	0,16	0,85	1,38	0,09	0,19	2,88	0,03

The top layer is grayish-brown, medium loamy. Below are dense clay horizons. Humus content is about 2.4% in the top layer, decreasing to 0.8%, pH 7.4-8.8. Na is low at the top (0.12-0.29), then increases to 2.3-3.8 (Table 160). The physical clay content is high (40-55%), increasing towards the bottom (Table 161). Salinity is moderate (Table 162).

Characteristics and forage value of the vegetation cover. Relief – plain, aspect of the landscape – greenish-grey, water regime – atmospheric. The projective cover of the soil surface by vegetation is 35–40%. The grass stand is wormwood–grass. During the study of the botanical composition of plants, it was revealed that wormwood occupies – 80%, bluegrass – 20% of the total area. The grass stand also includes limonium, izen, and knotgrass. The pasture biomass yield amounted to 7.5 c/ha.

Analysis of the data obtained when determining the chemical composition of plants growing on saline soils shows that the protein content in an air-dry state is 15.17%, fat – 5.44%, fiber – 33.71%, NFE – 35.82%, and ash – 6.93%. At the same time, on these types of pastures, the yield of feed units at natural plant moisture content is 0.57 per kilogram of feed, and the metabolic energy is 8.12 MJ.

Monitoring site No. 45. Soil: Lightly solonetzic chestnut, medium loamy. Located in Terekti District, West Kazakhstan Region (Figure 47). Coordinates: N 51.020283º, E 51.495817º. Flat plain. Field with wheatgrass and scattered trees of elm (karagach) and oleaster. Solonetz spots make up 20–25% of the area. Vegetation: grey wormwood – cop1, narrow-leaved wormwood – sol, feather grass (tyrsa) – sol, yarrow – sol, yellow alfalfa – sol, introduced wheatgrass – sol, bedstraw – sol. Canopy closure 40–50%. Height 25–35 cm. Depth 60 cm. A+B = 32. Effervescence from 32 cm. Carbonates – from 45 cm, sharply defined spots. Horizons: A_1 0–4, AB 4–15, B_1 ^{CH} 15–32, C_1 32–45, C_2^K 45–bottom.



Figure 47 – Chestnut slightly saline medium loamy soil

0-4 cm, brownish-gray, dry, layered, crust with roots, medium loam

4-15 cm, brown, dry, dense, lumpy, with vertical cracks

15-32 cm, dirty brown, dry, dense, lumpy-nutty, heavy loam

32-45 cm, light brown, dry, dense, lumpy, heavy loam

45-bottom, Yellow-brown, with sharply defined carbonate spots, dry, dense, clayey.

Exchangeable Na is low (0.2) throughout the profile, but magnesium content is high (Table 163). Physical clay increases from 35% to 45% down the profile (Table 164). The soil is not saline – the total salt content barely reaches 0.05% (Table 165). The soil can be classified as slightly saline magnesium soil.

Table 163 – Chemical and physicochemical properties of chestnut slightly saline soils

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
45	0-4	2,27	0,196	0,32	14,85	7,43	0,2	1,12	23,6	7,49
	4-14	1,58	0,126	0,23	13,86	7,43	0,2	0,51	22,00	7,48
	18-28	1,24	0,098	5,66	13,37	8,42	0,2	0,02	22,01	7,48

	33-43	0,94	0,056	6,02	17,82	5,45	0,2	0,02	23,49	8,54
	50-60			0,49						8,78

Table 164 - Granulometric composition of chestnut slightly saline soils

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
45	0-4	7,57	32,55	24,61	8,61	20,51	6,15	35,28
	4-14	5,57	29,51	25,48	11,92	18,08	9,45	39,45
	18-28	5,82	23,43	27,97	13,58	14,81	14,40	42,78
	33-43	2,02	19,84	32,90	6,99	21,39	16,86	45,24
	50-60	3,07	10,92	44,24	10,24	23,35	8,19	41,78

Table 165 – Composition of water-soluble salts in chestnut slightly saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
45	0-4	0,03	0,017	0,000	0,004	0,000	0,002	0,001	0,002	0,004
			0,28	0,00	0,11	0,00	0,09	0,09	0,09	0,11
	4-14	0,043	0,029	0,000	0,003	0,000	0,004	0,002	0,003	0,002
			0,48	0,00	0,07	0,00	0,19	0,19	0,13	0,06
	18-28	0,021	0,007	0,000	0,003	0,005	0,002	0,001	0,002	0,001
			0,12	0,00	0,07	0,11	0,09	0,09	0,09	0,02
	33-43	0,051	0,029	0,002	0,001	0,008	0,007	0,002	0,002	0,001
			0,48	0,08	0,04	0,16	0,37	0,19	0,09	0,02
	50-60	0,051	0,032	0,002	0,001	0,006	0,006	0,003	0,002	0,001
			0,52	0,08	0,04	0,12	0,28	0,28	0,09	0,02

Characteristics and forage value of the vegetation cover. Relief – plain, aspect of the landscape – grayish-green, water regime – atmospheric. The projective cover of the soil surface

by vegetation is 40–45%. Pasture type – wormwood. Analysis of the botanical composition of plants showed that wormwood accounts for 85%, couch grass – 10%, and feather grass – 5% of the total area. The grass stand also includes bluegrass, yarrow, brome, cinquefoil, toadflax, knotweed, wheatgrass, and kochia. The pasture biomass yield amounted to 8.0 c/ha.

A study of the chemical composition of plants growing on saline soils showed that the protein content in an air-dry state is 16.62%, fat – 6.00%, fiber – 31.44%, NFE – 33.79%, and ash – 9.33%. The yield of feed units at natural plant moisture content is 0.55 per kilogram of feed, and the metabolic energy is 7.82 MJ.

Monitoring site No. 46. Soil: Lightly solonetzic chestnut heavy loam. Located in Zelenovsky District, West Kazakhstan Region (Figure 48). Coordinates: N 51.218016º, E 51.272661º. Low flat plain. Vegetation: tall wormwood–grass – cop, mixed herbs–bluegrass–wormwood – sp, narrow-leaved wormwood – sol, bulbous bluegrass – sp, kochia – sol, annual saltwort. Depth 60 cm. A+B = 30. Effervescence from surface to 47 cm, none deeper. No carbonates. Horizons: A_1^{CH} 0–10, B_1C10–30, BC 30–47, B_1^{middle}47–bottom

0-10 cm, Dirty dark brown, dry, very dense, lumpy, heavy loam

10-30 cm, Dark brown with dark gray streaks,

30-47 cm, Similar to the previous one, but with a large amount of clay seepage

47-bottom, grayish-dark brown, fresh, dense, lumpy, clayey buried horizon.



Figure 48 – Chestnut slightly saline heavy loam

Table 166 – Chemical and physicochemical properties of chestnut slightly saline soils

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
46	0-10	1,88	0,112	0,52	18,81	3,96	0,2	1,18	24,15	8,42
	15-25	1,49	0,098	0,23	21,29	7,92	0,18	0,02	29,41	8,37
	33-43	2,17	0,112	0,29	15,35	8,91	0,12	0,02	24,40	7,81
	50-60			0,16						7,91

Table 167 - Granulometric composition of chestnut slightly saline soils

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
46	0-10	1,24	8,23	42,39	9,88	40,74	19,34	48,15
	15-25	0,52	7,41	39,22	8,26	47,07	28,90	52,85
	33-43	0,37	19,18	21,98	13,27	47,69	26,13	58,47
	50-60	0,69	16,74	23,65	12,03	49,38	28,22	58,92

Table 168 – Composition of water-soluble salts in chestnut slightly saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
46	0-10	0,061	0,029	0,000	0,001	0,013	0,007	0,002	0,002	0,006
			0,48	0,00	0,04	0,28	0,37	0,19	0,09	0,14
	15-25	0,044	0,024	0,000	0,001	0,007	0,007	0,001	0,002	0,001

			0,40	0,00	0,04	0,14	0,37	0,09	0,09	0,02
	33-43	0,059	0,024	0,000	0,001	0,017	0,009	0,001	0,005	0,001
			0,40	0,00	0,04	0,35	0,47	0,09	0,21	0,02
	50-60	0,075	0,029	0,000	0,004	0,021	0,011	0,002	0,006	0,001
			0,48	0,00	0,11	0,45	0,56	0,19	0,26	0,02

The soil is shallow (A+B = 30 cm), heavy loam, very dense. Humus content is about 1.9-2.2%. The soil is alkaline (pH up to 8.4). Despite the low exchangeable sodium content (1.18 mg-eq/100 g), a large amount of exchangeable magnesium (7.9-9.0 mg-eq/100 g) has been noted, which allows us to conclude that the soil is magnesium-saline (Table 166). The physical clay content is high (48–59%) and increases towards the bottom (Table 167). There is no salinity (Table 168).

Characteristics and forage value of the vegetation cover. Relief – flat plain, aspect of the landscape – gray, water regime – atmospheric. The projective cover of the soil surface by vegetation is 65%. Pasture type – wormwood–forb. The botanical composition of plants showed that wormwood accounts for 65%, bluegrass – 25%, and forbs – 10% of the total area. The grass stand includes couch grass, kochia, bassia, and annual saltwort. The pasture biomass yield amounted to 18.0 c/ha.

Determination of the chemical composition of plants growing on saline soils showed that the protein content in the air-dry state is 14.93%, fat – 6.61%, fiber – 34.21%, crude protein – 32.84%, and ash – 8.23%. The yield of feed units at natural plant moisture content is 0.55 per kilogram of feed, and the metabolic energy is 7.77 MJ.

Monitoring site No. 47. Soil: Steppe solonetz saline heavy loam. Located in Zelenovsky District, West Kazakhstan Region (Figure 49). Coordinates: N 51.116833º, E 50.557786º. Undulating plain. Complex vegetation, feather grass–grudnitsa, grudnitsa–feather grass with fescue: feather grass (*stipa pennata*) cop1, grudnitsa sol, fescue sol, bulbous bluegrass sol, izen sol. Canopy closure 70%. Height 25–35 cm. Depth 60–70 cm. A+B = 35. Effervescence from 25 cm. Carbonate spots from 25 cm to bottom. Horizons: A_1^D 0–4, B_1^{CH} 4–12, B_2^{CH} 12–25, B_3^{CH} 25–35, C_1^K 35–50, C_2^K 50–bottom.

0-4 cm, gray, dry, compacted, dusty and lumpy, medium loamy

4-12 cm, brownish-gray, dry, finely lumpy, with roots, heavy loamy

12-25 cm, brown, dry, very dense, lumpy, clayey

25-35 cm, slightly lighter, dry, dense, with carbonate spots, nutty, clayey

35-50 cm, brown with spots, dry, dense, lumpy, heavy loam

50- bottom, yellowish-brown, dry, compacted, unstructured, heavy loam

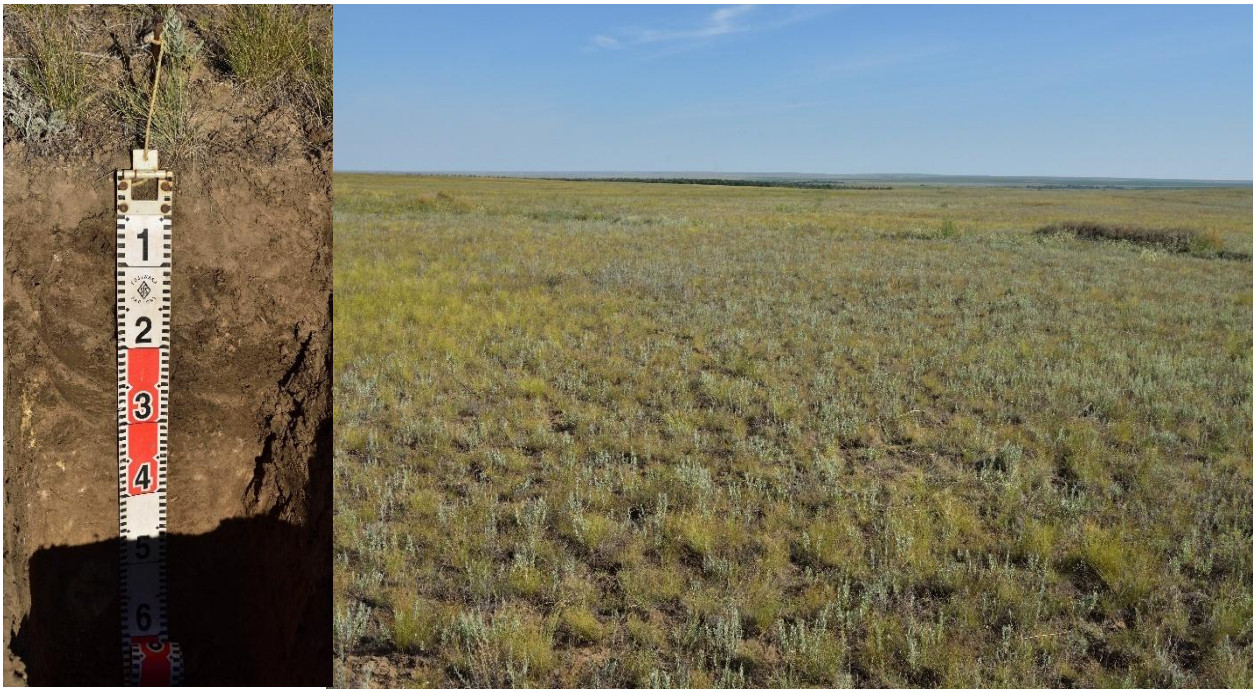


Figure 49 – Steppe saline heavy loam solonetz

Table 169 – Chemical and physicochemical properties of steppe salt marshes

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
47	0-4	1,59	0,168	0,16	11,88	9,41	0,01	0,02	21,32	7,07
	4-12	1,27	0,112	0,16	20,3	10,4	0,48	0,02	31,2	7,29
	13-23	1,2	0,112	0,23	15,35	12,38	3,94	0,02	31,69	7,77
	25-35	1,18	0,098	0,81	12,87	12,38	6,12	0,02	31,39	8,67
	37-47	0,86	0,098	2,49	23,76	7,92	5,23	0,02	36,93	8,77
	60-70			3,72						8,32

Table 170 – Granulometric composition of steppe salt marshes

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01

47	0-4	8,04	30,16	14,01	15,66	34,61	12,77	47,80
	4-12	11,42	29,42	15,61	11,50	34,51	15,20	43,55
	13-23	7,61	17,08	22,05	9,57	46,18	22,47	53,26
	25-35	5,24	10,58	19,69	7,96	59,06	31,00	64,50
	37-47	3,99	19,14	17,87	9,14	52,36	29,50	59,01
	60-70	2,65	22,74	17,00	7,05	53,06	2,07	57,62

Table 171 – Composition of water-soluble salts in steppe saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
47	0-4	0,042	0,005	0,000	0,001	0,023	0,002	0,001	0,009	0,001
			0,08	0,00	0,04	0,47	0,09	0,09	0,38	0,02
	4-12	0,044	0,007	0,000	0,003	0,021	0,002	0,001	0,01	0,001
			0,12	0,00	0,07	0,44	0,09	0,09	0,42	0,02
	13-23	0,090	0,017	0,002	0,004	0,041	0,002	0,001	0,024	0,001
			0,28	0,08	0,11	0,86	0,09	0,09	1,04	0,02
	25-35	0,165	0,063	0,005	0,034	0,015	0,002	0,001	0,048	0,001
			1,04	0,16	0,96	0,31	0,09	0,09	2,10	0,02
	37-47	0,323	0,051	0,002	0,059	0,107	0,004	0,003	0,097	0,001
			0,84	0,08	1,66	2,23	0,19	0,28	4,24	0,02
	60-70	0,783	0,027	0,000	0,089	0,422	0,065	0,018	0,16	0,001
			0,44	0,00	2,51	8,8	3,27	1,5	6,96	0,02

The entire profile is heavy loam, with carbonates appearing at 25 cm. The humus content is low (1.6%), pH 7.0-8.8. Na increases from 0.5 to 3.9-6.1 in horizons B2-B3 and remains high (5.2) (Table 169). Physical clay also increases from 44-53% to 65%, then decreases slightly (Table 170). Salinization is noted from 35 cm (0.3-0.8%) (Table 171), which allows the soil to be classified as saline. Classic saline differentiation.

Characteristics and forage value of the vegetation cover. Relief – gently undulating plain, aspect of the landscape – grayish-green, water regime – atmospheric. The projective cover of the soil surface by vegetation is 70%. Pasture type – fescue–feather grass–grudnitsa. The study of the botanical composition of plants revealed that fescue accounts for 45%, feather grass – 30%, and grudnitsa – 25% of the total

area. The grass stand includes wormwood, feather grass, izen, and bluegrass. The pasture biomass yield amounted to 11.5 c/ha.

Analysis of the data obtained when determining the chemical composition of plants growing on saline soils shows that the protein content in an air-dry state is 13.52%, fat – 6.93%, fiber – 29.62%, NFE – 33.53%, and ash – 12.92%. At the same time, on these types of pastures, the yield of feed units at natural plant moisture content is 0.55 per kilogram of feed, and the metabolic energy is 7.82 MJ.

Monitoring site No. 48. Soil: Strongly solonetzic chestnut clay. Located in Taskalinsky District, West Kazakhstan Region (Figure 50). Coordinates: N 50.126092º, E 50.161923º. Hilly undulating plain. Section on gentle eastern slope 2–3. Vegetation feather grass–wormwood: wormwood sp, feather grass sp, fescue sp, brome sol. Canopy closure 70 %. Height 25–30. Depth 60 cm. A+B = 40 cm. Effervescence – swelling from surface, vigorous from 5 cm. Carbonates – whitish horizon from 50 cm. Horizons A 0–5, B_1^{CH} 5–20, B_2 20–40, BC 40–bottom.

0-5 cm, Dark grayish brown, dry, loose, unusually lumpy and powdery, medium loam

5-20 cm, dirty dark brown, dry, dense, lumpy, clayey

20-40 cm, dark brown, dry, less dense, lumpy, clayey

40-bottom, brown with dark wedges, lumpy, clayey



Figure 50 – Chestnut strongly saline clay

The soil is low in humus, with 2.2% humus content. Violent bubbling occurs at a depth of 5 cm. The soil is heavy in terms of its mechanical composition. The reaction of the environment is alkaline (pH 8.3-8.8). Na is low at the top (0.2-0.12), increasing to 1.0-4.3 at the bottom (Table

172). The physical clay content is very high (56-67%), increasing towards the lower horizons (Table 173). Salinity is moderate (up to 0.14% salts) (Table 174). The soil is strongly saline.

Table 172 – Chemical and physicochemical properties of chestnut saline clay soil

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
48	0-5	2,24	0,168	0,55	25,25	4,95	0,2	0,51	30,91	8,38
	7-17	1,58	0,154	0,84	21,29	9,9	0,12	0,02	31,33	8,3
	25-35	1,5	0,168	1,94	16,83	9,9	0,97	0,02	27,72	8,53
	50-60	1,22	0,098	3,91	17,33	2,48	4,25	0,02	24,08	8,83

Table 173 - Granulometric composition of chestnut strongly saline clay soil

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
48	0-5	2,59	14,34	27,13	9,18	49,26	27,55	55,94
	7-17	2,32	9,81	27,20	11,72	51,46	33,47	60,67
	25-35	1,55	5,68	27,16	8,78	59,34	38,45	65,61
	50-60	2,24	8,79	22,14	8,35	60,99	39,68	66,83

Table 174 – Composition of water-soluble salts in chestnut strongly saline clay soil, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
48	0-5	0,049	0,027	0,000	0,004	0,004	0,007	0,001	0,002	0,003

			0,44	0,00	0,11	0,08	0,37	0,09	0,09	0,08
	7-17	0,058	0,022	0,000	0,003	0,017	0,009	0,001	0,005	0,001
			0,36	0,00	0,07	0,36	0,47	0,09	0,21	0,02
	25-35	0,095	0,041	0,002	0,003	0,025	0,004	0,002	0,02	0,001
			0,68	0,08	0,07	0,51	0,19	0,19	0,87	0,02
	50-60	0,142	0,071	0,007	0,003	0,028	0,004	0,001	0,035	0,001
			1,16	0,24	0,07	0,58	0,19	0,09	1,51	0,02

Characteristics and forage value of the vegetation cover. Relief – gently rolling plain, aspect of the landscape – grayish-green, water regime – atmospheric. The projective cover of the soil surface by vegetation is 35–40%.
The grass stand type is wormwood–grass. The study of the botanical composition of plants showed that wormwood occupies 60%, feather grass – 35%, and limonium – 5% of the total area. The grass stand includes fine grass (Stipa), bluegrass, yarrow, brome, grudnitsa, catchfly, knapweeds, couch grass, and yellow alfalfa. The pasture biomass yield amounted to 16.0 c/ha.

A study of the chemical composition of plants growing on saline soils showed that the protein content in an air-dry state is 16.83%, fat – 6.82%, fiber – 28.62%, NFE – 29.94%, and ash – 14.63%. The yield of feed units at natural plant moisture content is 0.54 per kilogram of feed, and the metabolic energy is 7.68 MJ.

Monitoring site No. 49.

Soil: Steppe solonetz saline. Located in Taskalin District, West Kazakhstan Region (Figure 51). Coordinates: N 51.108436º, E 50.462800º. Undulating plain. Vegetation fescue–wormwood with feather grass and grudnitsa: wormwood sp, fescue sp, feather grass sol, grudnitsa sol, bluegrass sol, onion un. Canopy closure 40–50%. Height 15–25 cm. Depth 60 cm, A+B = 60. Effervescence vigorous from 35 cm. Carbonates – whitish horizon from 35 cm. Horizons: A_1^D 0–4, AB 4–15, B_1^{CH} 15–35, C_1^K 35–bottom.

0-4 cm, Light gray, dry, heavily rooted, loose and dusty, medium loam

4-15 cm, Grayish light brown, dry, compacted, with roots, dusty and lumpy, medium loam

15-35 cm, bright brown, dry, very dense, nutty, with columnar divisions, clayey

35-bottom, whitish-yellow brown, fresh, lumpy, medium loamy.



Figure 51 – Steppe saline heavy loam

Table 175 – Chemical and physicochemical properties of steppe saline soils

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
49	0-4	3,05	0,21	0,16	16,34	4,46	0,2	0,53	21,53	6,68
	5-15	1,63	0,14	0,19	18,81	11,39	0,2	0,02	30,42	6,63
	20-30	1,05	0,112	0,26	15,35	10,4	2,6	0,02	28,37	7,94
	50-60	0,77	0,056	3,2	16,83	3,47	3,25	0,02	23,57	8,21

Table 176 - Granulometric composition of steppe saline soils

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
49	0-4	12,11	32,55	26,65	8,61	22,55	5,74	28,69
	5-15	16,27	33,05	20,03	6,95	26,16	8,99	30,66
	20-30	7,44	29,48	11,28	6,27	48,05	30,50	51,81
	50-60	10,97	31,88	12,84	8,28	38,51	7,87	44,31

Table 177 – Composition of water-soluble salts in steppe saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
49	0-4	0,031	0,015	0,000	0,003	0,004	0,002	0,001	0,002	0,005
			0,24	0,00	0,07	0,09	0,09	0,09	0,09	0,12
	5-15	0,022	0,007	0,000	0,003	0,006	0,002	0,001	0,002	0,001
			0,12	0,00	0,07	0,12	0,09	0,09	0,09	0,03
	20-30	0,106	0,037	0,000	0,01	0,026	0,002	0,001	0,028	0,001
			0,60	0,00	0,3	0,55	0,09	0,09	1,24	0,02
	50-60	0,878	0,024	0,000	0,347	0,198	0,065	0,014	0,226	0,003
			0,40	0,00	9,79	4,12	3,27	1,13	9,84	0,08

The top layer is gray, with a humus content of 3.0%. Below are dense horizons with a whitish carbonate horizon at 35 cm. Na is low at the top (0.2), with a sharp maximum (2.6-3.3) in the middle of the profile (Table 175). Physical clay increases from 29-31% to 52%, then decreases to 44% (Table 176). Salinity is moderate (up to 0.9%) from a depth of 50 cm, which allows the soil to be classified as saline (Table 177). Salinity is pronounced in the middle part of the profile.

Characteristics and forage value of the vegetation cover. Relief – undulating plain, aspect of the landscape – grayish-green, water regime – atmospheric. The projective cover of the soil surface by vegetation is 50%. Pasture type – wormwood–fescue–feather grass– saltwort**.** The determination of the botanical composition of plants revealed that wormwood occupies 60%, fescue – 25%, feather grass –

10%, saltwort – 5% of the total area. The grass stand includes fine grass, limonium, catchfly, cinquefoil, and betony. The pasture biomass yield amounted to 13.1 c/ha.

Determination of the chemical composition of plants growing on saline soils showed that the protein content in the air-dry state is 15.22%, fat – 6.44%, fiber – 30.31%, NFE – 31.41%, and ash – 13.84%. The yield of feed units at natural plant moisture content is 0.55 per kilogram of feed, and the metabolic energy is 7.78 MJ.

Monitoring plot No. 50. Soil: Chestnut weakly solonetzic medium loam. Located in Zelenov district, West Kazakhstan region (Figure 52). Coordinates: N 51.054148º, E 51.222784º. Flat surface. Vegetation dominated by wormwood, trampled near the settlement, pasture trails. Cover density 35-40%. Height 20-25 cm. Depth 60 cm, A+B = 30 cm. Swelling from 17 cm. Carbonates – spots from 17 cm. Horizons A_1^K 0-5, AB 5-17, B_1^{CH} 17-30, BC 30-43, C_1^K 40-bottom.



Figure 52 – Chestnut slightly saline medium loam

0-5 cm, brownish-gray, lumpy with roots, medium loam

5-17 cm, dark brown, dry, compacted, coarse-grained and lumpy, medium loam

17-30 cm, brown, very dense, dry, lumpy, medium loam

30-43 cm, light brown, dry, dense, lumpy, medium loam

43-bottom, whitish light brown, dry, dense, lumpy, medium loam

Table 178 – Chemical and physicochemical properties of chestnut slightly saline soils

№ cut	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed bases, mg-eq/100 g					pH of water.
					Ca	Mg	Na	K	Amount	
50	0-5	2,42	0,196	0,26	15,35	6,44	0,2	1,2	23,19	7,85
	6-16	1,16	0,196	0,49	14,85	5,94	0,2	0,02	21,01	8,48
	18-28	1,02	0,126	0,68	14,36	5,45	0,2	0,02	20,03	8,5
	32-42	0,99	0,14	1,46	19,8	6,44	0,12	0,02	26,38	8,63
	50-60			6,82						9,2

Table 179 - Granulometric composition of chestnut slightly saline soils

№ cut	Depth, cm	Fraction content in % on dry soil						
		fraction size in mm						
		Sand		Dust			Silt	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
50	0-5	2,26	26,72	37,77	7,80	27,92	9,85	33,25
	6-16	0,70	26,52	30,43	5,76	39,06	20,56	42,35
	18-28	0,27	27,82	30,82	8,63	34,93	15,62	41,09
	32-42	0,41	37,63	26,26	9,85	28,31	11,90	35,70
	50-60	0,22	34,92	26,51	11,42	29,37	14,28	38,34

Table 180 – Composition of water-soluble salts in chestnut slightly saline soils, %/mg-eq

№ cut	Depth, cm	Sum of salts, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			General in HCO_3^-	From normal carbonates in CO_3^{2-}						
50	0-5	0,057	0,024	0,000	0,004	0,010	0,006	0,001	0,002	0,01
			0,40	0,00	0,11	0,21	0,28	0,09	0,09	0,25
	6-16	0,039	0,024	0,000	0,004	0,000	0,006	0,001	0,002	0,002
			0,40	0,00	0,11	0,00	0,28	0,09	0,09	0,04
	18-28	0,051	0,029	0,000	0,003	0,005	0,009	0,001	0,002	0,001
			0,48	0,00	0,07	0,11	0,47	0,09	0,07	0,03

	32-42	0,069	0,032	0,001	0,003	0,016	0,006	0,002	0,01	0,001
			0,52	0,04	0,07	0,34	0,28	0,19	0,44	0,02
	50-60	0,107	0,051	0,007	0,003	0,023	0,004	0,001	0,025	0,001
			0,84	0,24	0,07	0,47	0,19	0,09	1,08	0,02

The soil is shallow (A+B = 30 cm), medium loamy, and very dense. Humus content is about 2.4%. The soil is alkaline (pH up to 9.2). Despite the low exchangeable sodium content, a large amount of exchangeable magnesium (5.4-6.2 mg-eq/100 g) was noted, which allows for the diagnosis of magnesium salinity (Table 178). In terms of mechanical composition, the soil is medium loamy with an increase in physical clay content in the middle part of the profile (Table 179). There is no salinity (Table 180). Salinity is weak.

Characteristics and forage value of the vegetation cover. Relief – undulating plain, landscape aspect – grayish-green, water regime – atmospheric. The projective vegetation cover of the soil surface is 35–40%. Pasture type – wormwood-dominated. When determining the botanical composition of the vegetation, it was found that wormwood occupies 100% of the total area. In the grass stand, single specimens of bluegrass, horsemint, alyssum, schismus, and stellaria were found. The yield of pasture biomass amounted to 12.0 c/ha.

Determination of the chemical composition of plants growing on saline soils showed that the protein content in the air-dry state is 16.12%, fat – 6.231%, fiber – 29.44%, NFE – 31.56%, and ash – 13.52%. The yield of feed units at natural plant moisture content is 0.55 per kilogram of feed, and the metabolic energy is 7.82 MJ.

Establishment of a database of solonetz lands in pastures using GIS technologies across geographical or climatic zones

Soil salinization and solonetzicity are among the most pressing issues facing the agricultural sector and the environment of the Republic of Kazakhstan. Under arid and semi-arid climatic conditions, limited water resources and high evaporation rates promote salt accumulation in the soil profile, leading to reduced land productivity and deterioration of the structural and physical properties of soils.

Establishing a database of solonetz lands in pastures using GIS technologies is an important task that will support land resource management in Kazakhstan.

The developed database stores geospatial data and data in the form of tables and files that can be queried and accessed through various web services hosted on different servers. The database ensures data integrity and simultaneous availability to multiple web services, for example for visualization and downloading.

At the “Database” (DB) level (Figure 53), multiple thematic spatial databases can be connected and managed to make them available to the logical layer for visualization and service processing.

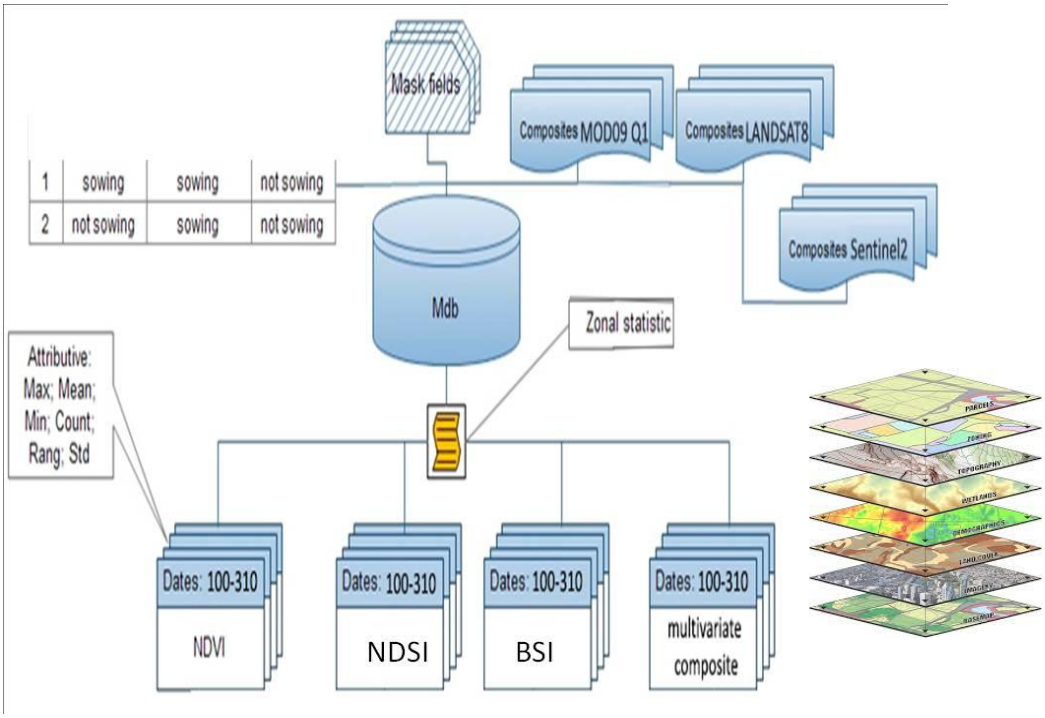


Figure 53 – Structure of the satellite information database for solonetz lands in pastures

This enables support for spatial functions and indexes that improve the performance of spatial data retrieval and processing. Different datasets do not necessarily have to be stored in a single central database, as the system is modular and the layer logic can work with different data sources. The data layer is managed using PostgreSQL with the PostGIS spatial extension, as this is the most mature solution. This database management system supports importing and exporting data in all major spatial formats, such as Shapefile, GeoTiff, GeoJSON, Well-Known Text (WKT), etc. PostGIS includes support for GiST-based R-Tree spatial indexes and functions for GIS feature analysis and processing.

Data and preparation requirements. Database management systems (DBMSs) are required to manage large volumes of data. A spatial database provides spatial types (geometry types such as points, lines and polygons), spatial functions and the ability to create spatial indexes to improve the performance of spatial queries and functions. A DBMS offers many advantages for managing and working with large amounts of data, including multi-user support (concurrency), data consistency and integrity, persistent storage and querying capabilities through a programming interface.

The following stages were implemented to meet the basic requirements for loading and preparing spatial data:

– defining the spatial data inventory and developing the geodatabase structure (reviewing reference directories, classifiers and rules for spatial data identification codes);

– optimization, spatial and attribute indexing;

– a unified map projection;

– consistent map legends, scales and gradations;

– a uniform level of generalization.

All requirements for representing the geodatabase structure have been met, except those that would compromise geodatabase integrity. Feature classes repeated with identical attribute information but referring to different dates are physically included in a feature class dataset, although they may be omitted from the description.

The main database includes the datasets listed in Table 181 and is updated using satellite imagery.

Table 181 - Composition of the published project layers

Feature class dataset	Spatial data class	
	Name in the geodatabase	Type
Monitoring of solonetz lands	salinity_monitoring(date_span)	Polygon
Pasture monitoring	biomass_monitoring(date_span)	Polygon
Hydraulic structures	hydro_structures_lines	Lines
	hydro_structures_points	Points
Agricultural facilities	agricultural_areas	Polygon

The “Monitoring of solonetz lands” feature class dataset contains several layers and is updated regularly, with only the acquisition date and satellite pass changing. Satellite monitoring data are presented in Table 182.

Table 182 - List of published remote sensing data

Types of parametric interpretation of remote sensing data	Names of output raster products	Alias
NDVI (Normalized Difference Vegetation Index)	salinity_ndvi	LC150030_salinity_ndvi

NDSI	salinity_ndsi	LC170080_salinity_ndsi

The geodatabase is supplemented with data as satellite imagery and ground survey data become available.

The choice of spatial resolution for map production is determined by the specific monitoring tasks. In our project, these are regional-scale maps.

The choice of time intervals is also determined by the specific task. The July–August interval was used to identify salinization and solonetz soils.

Materials and methods. Recently, particular attention has been paid to monitoring land resource degradation using satellite data. Landsat (30 m, since 1972), Sentinel-2 (10–20 m, since 2015) and MODIS (250–500 m, since 2000) data series have been widely used to assess vegetation dynamics, water availability and signs of salinization. Recent studies show that NDVI can reliably identify reductions in biological productivity in saline areas [27], while NDSI determines the degree of surface salinization and the presence of salt crusts [28]. However, an integrated approach that accounts for the clustering of soil types and agroclimatic factors is needed: combining vegetation, moisture and soil texture indices (NDVI, NDSI, EVI) can provide a more detailed picture of soil salinization and solonetzicity.

The Normalized Difference Vegetation Index (NDVI) is one of the most widely used satellite indices for assessing vegetation condition and indirectly diagnosing soil and hydrological conditions [29]. For Landsat 8 OLI data, NDVI is calculated by combining the near-infrared and red bands using the following formula:

NDVI=NIR−RedNIR+RedNDVI = \frac{NIR - Red}{NIR + Red}NDVI=NIR+RedNIR−Red

Where: NIR – near-infrared band (Band 5, 0.85–0.88 μm),

Red – red band (Band 4, 0.64–0.67 μm).

NDVI values range from –1 to +1. Under normal conditions, healthy vegetation typically has values of 0.3–0.8, degraded or sparse plant communities have values of 0.1–0.3, and negative or near-zero values indicate bare soil, solonchak patches or water surfaces.

When monitoring solonetz lands, low NDVI values indicate suppressed vegetation development caused by sodium toxicity, salinization and soil profile compaction [30]. Patchy NDVI distribution patterns are characteristic: areas with NDVI < 0.2 correlate with the occurrence of solonetz and solonchak soils, whereas more productive areas (NDVI>0.3)

correspond to meadow-steppe associations on non-saline soils. NDVI dynamics in time series, for example over 10-20 years of Landsat observations, make it possible to identify trends in pasture degradation and the expansion of solonetz complexes, particularly under climate change and anthropogenic pressure (irrigation, grazing).

Thus, NDVI serves as an important indicator for mapping, monitoring and assessing the resilience of agricultural landscapes, enabling objective identification of areas with a high degree of salinization and a potential decline in biological productivity [31]. Its use in combination with additional moisture and salinity indices (EVI, NDSI) increases diagnostic reliability.

In our project, areas with sharply reduced NDVI relative to the background may indicate salt-related degradation (Figure 54).

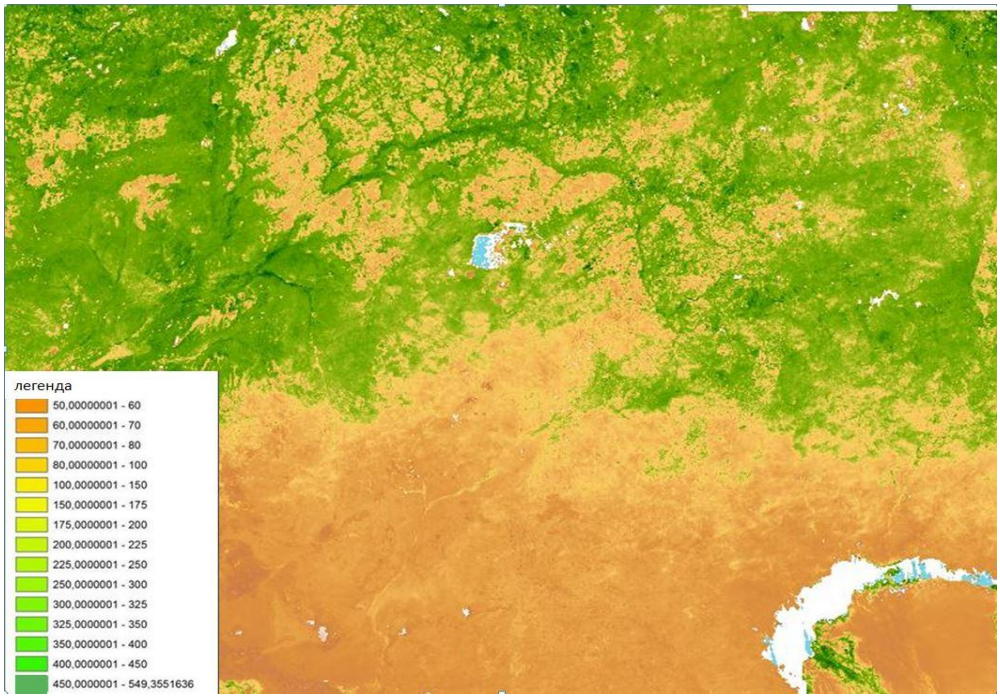


Figure 54 – NDVI vegetation index for a portion of Karaganda region, derived from Landsat 8 satellite data for the period from 01.07 to 30.09 2023.

The Enhanced Vegetation Index (EVI) was developed as an improved indicator of vegetation condition compared with NDVI, particularly for regions with dense vegetation cover or strong soil background and atmospheric effects [32]. For Landsat 8 OLI data, EVI is calculated using the following formula:

$$EVI=GNIR−RedNIR+C1·Red−C2·Blue+LEVI = G \cdot \frac{NIR - Red}{NIR + C_1 \cdot Red - C_2 \cdot Blue + L}EVI=GNIR+C1Red−C2Blue+LNIR−Red$$

where:

NIR – near-infrared band (Band 5, 0.85–0.88 μm),

Red – red band (Band 4, 0.64–0.67 μm),

Blue – blue band (Band 2, 0.45–0.51 μm),

G=2.5G = 2.5G=2.5 — gain factor,

C1=6,C2=7.5C_1 = 6, C_2 = 7.5C1=6,C2=7.5 - coefficients for suppressing atmospheric effects,

L=1L = 1L=1 — soil background adjustment factor.

EVI has an advantage over NDVI because it reduces saturation in dense vegetation and corrects for the effects of aerosols and soil reflectance [33].

In the context of Kazakhstan's solonetz lands, where degraded soils, solonchak patches and sparse vegetation frequently occur together, EVI makes it possible to:

- identify areas of suppressed plant growth more accurately at low biomass levels;

- distinguish areas with sparse herbaceous vegetation (EVI ~0.1–0.2) from areas with completely bare or saline surfaces (EVI < 0.1);

- reduce false salinization signals caused by high background soil reflectance.

Monitoring EVI time series derived from Landsat data makes it possible to assess the dynamics of pasture and irrigated land degradation, record the expansion of solonetz–solonchak complexes and analyse spatial and temporal changes in ecosystem productivity [34]. Using EVI together with NDVI and salinity indices (NDSI, SI) improves interpretation reliability and provides more robust results under conditions of climatic variability and contrasts in soils and vegetation.

Areas with lower EVI values than the background may indicate salt-related degradation (Figure 55).

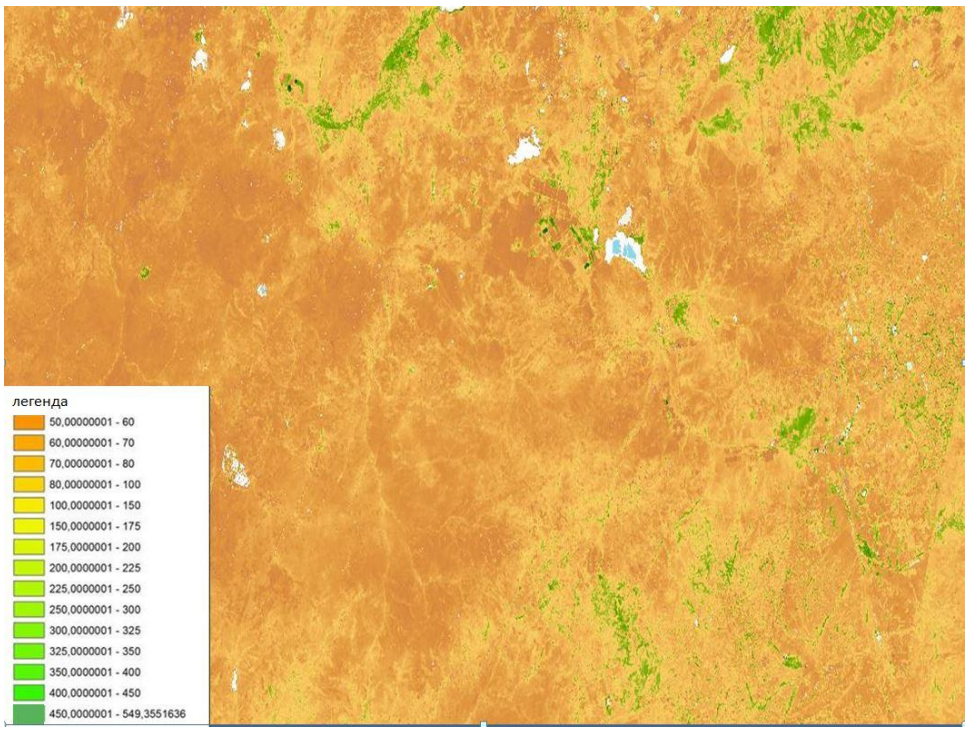


Figure 55 – EVI vegetation index for a portion of Karaganda region, derived from Landsat 8 satellite data for the period from 01.07 to 30.09 2023.

The Normalized Difference Salinity Index (NDSI) is one of the specialized spectral indices used for remote diagnosis of saline soils. Unlike the standard snow cover index (Snow Index), in soil science NDSI refers to an index intended to identify salt crusts and saline areas [35]. For Landsat 8 OLI data, NDSI is calculated using the following formula:

$$NDSI=SWIR−GreenSWIR+GreenNDSI = \frac{SWIR - Green}{SWIR + Green}NDSI=SWIR+GreenSWIR−Green$$

where:

SWIR – shortwave infrared band (Band 6 or 7: 1.57–1.65 μm or 2.11–2.29 μm),

Green – green band (Band 3, 0.53–0.59 μm). [36].

The physical basis of the index is that saline soils have high reflectance in the near- and shortwave-infrared ranges and lower reflectance in the green region of the spectrum.

In Kazakhstan's solonetz–solonchak complexes, elevated NDSI values (>0.2) indicate the presence of surface salt crusts and degraded soil areas. Low values (<0.1) are characteristic of areas with vegetation cover or non-saline soils. The spatial mosaic of NDSI values correlates well with the patchy pattern of solonetz soils and allows both active and potentially vulnerable zones to be identified.

Monitoring NDSI in Landsat time series makes it possible to assess secondary salinization processes on irrigated land, the dynamics of pasture degradation and the effectiveness of land reclamation measures. Comparing NDSI with NDVI and NDWI provides

an integrated picture of the combined effects of vegetation cover, moisture availability and salt stress.

Thus, NDSI is a reliable indicator for mapping and assessing the degree of soil salinity, particularly under steppe and semi-desert conditions and in adjacent regions of Kazakhstan [37] (Figure 56).

The work described results in a comprehensive geographic information system for solonetz lands. This GIS database makes it possible to:

- Assess the overall distribution and condition of solonetz pastures within the region.

- Develop recommendations for their sustainable use, for example by identifying particularly degraded areas for reclamation or restricted grazing.

- Promptly monitor pasture changes using new satellite imagery and remote sensing data.

Maps of solonetz lands were produced using GIS technologies based on satellite and ground data (Figures 57-61):

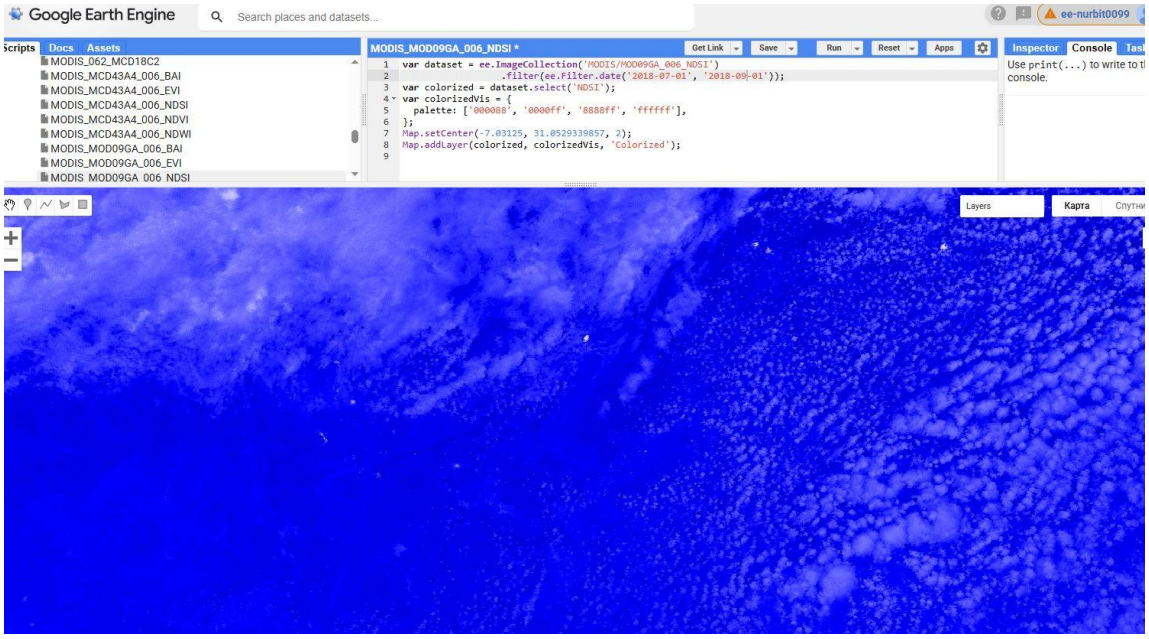


Figure 56 – NDSI vegetation index for a portion of Karaganda region, derived from Landsat satellite data for the period from 01.07 to 30.09 2023



Figure 57 – Map of solonetz lands in Akmola region, derived from Landsat satellite data.



Figure 58 – Map of solonetz lands in Aktobe region, derived from Landsat satellite data.



Figure 59 – Map of solonetz lands in West Kazakhstan region, derived from Landsat satellite data.

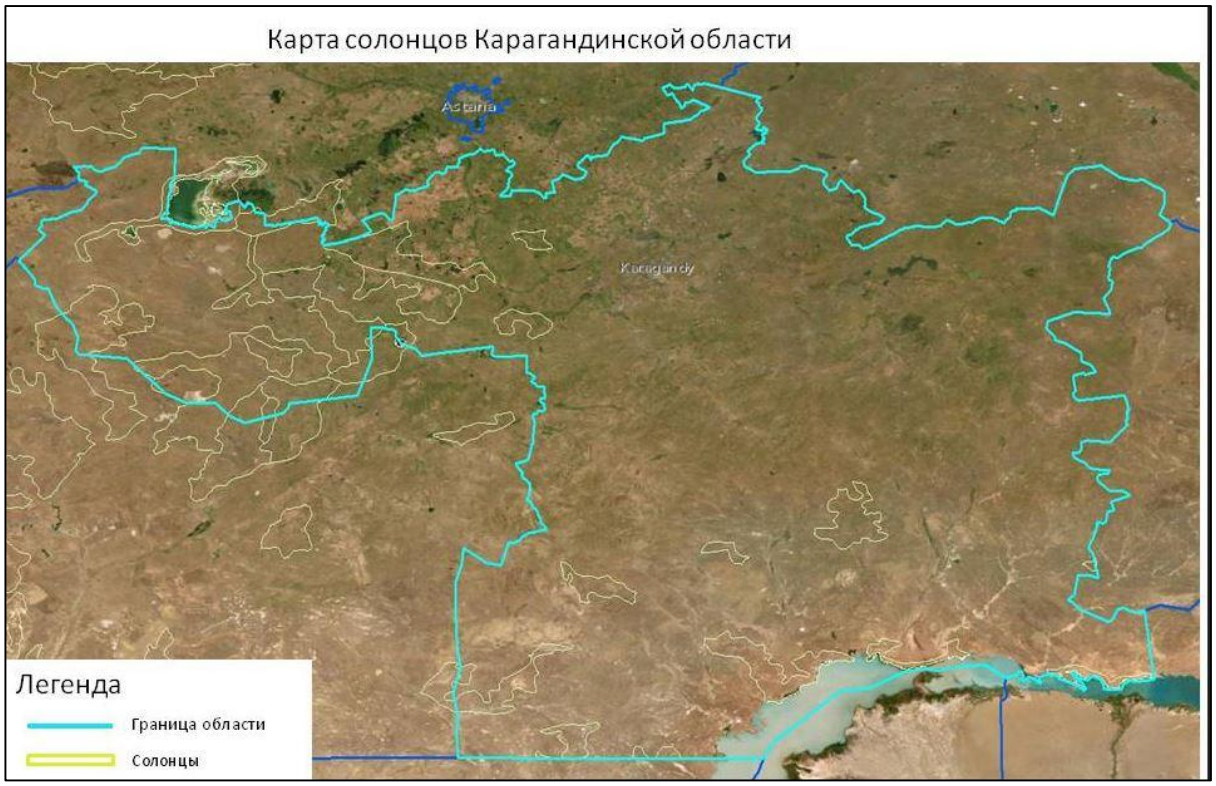


Figure 60 – Map of solonetz lands in Karaganda region, derived from Landsat satellite data.



Figure 61 – Map of solonetz lands in Ulytau region, derived from Landsat satellite data.

Analysis of satellite and ground data resulted in the establishment of a geoinformation database of Kazakhstan's solonetz lands, covering key pasture areas in arid and semi-arid zones. The use of NDVI, EVI and NDSI made it possible to identify degraded areas characterized by low vegetation productivity and a high degree of salinity.

Main conclusions:

Solonetz lands are widespread throughout Kazakhstan and occupy substantial pasture areas; NDVI and NDSI dynamics indicate the expansion of solonetz patches as a result of climatic factors (rising temperatures, declining precipitation) and anthropogenic pressure (grazing, irrigation); Satellite monitoring has proved effective for mapping solonetz complexes, especially when integrated with field data; The database enables timely updating of information and its application in agricultural planning, sustainable pasture use and land reclamation.

Total areas of solonetz lands by region (according to the report and the maps produced): Akmola region — approximately 1,25 million ha; Aktobe region — approximately 2,1 million ha; West Kazakhstan region — approximately 1,8 million ha; Karaganda region — approximately 2,4 million ha; Ulytau region — approximately 1,3 million ha.

The total for the regions considered is 8,85 million ha of solonetz lands, corresponding to approximately 15–17% of their total pasture area.

PART III

Research on the development of a database of solonetzic soils on pastures using GIS technologies across the geographical and climatic zones of Kazakhstan was conducted in 2026 by the NJSC «Kazakh National Agrarian Research University». The studies were carried out along survey routes covering five administrative regions of the Republic of Kazakhstan: Abai Region (Figure 1), Kostanay Region (Figure 9), North Kazakhstan Region (Figure 17), East Kazakhstan Region (Figure 32). Field studies were conducted at monitoring sites selected based on soil and geographical maps, as well as satellite imagery.

At these monitoring sites, a comprehensive description of the landscapes, vegetation, and morphological properties of the soils was carried out. Soil samples were collected for the assessment of their physicochemical properties. In parallel, photographs of the landscapes and soil profiles were taken. Upon completion of the fieldwork, the soil pits were backfilled to prevent damage to agricultural machinery and to avoid potential hazards to livestock.

At the same monitoring sites, a forage and botanical survey was conducted, which included the determination of vegetation projective cover and species composition. Plant samples were collected from 1 m × 1 m plots, and the aboveground biomass was weighed to determine vegetation yield.

Abai Region

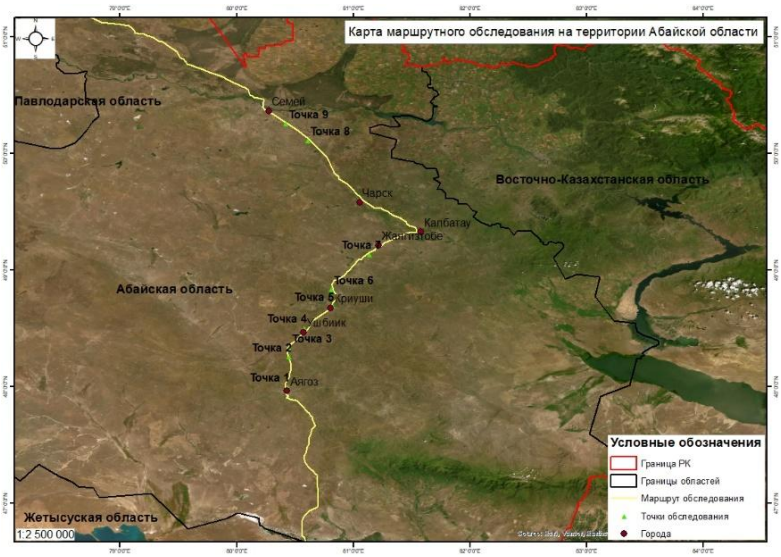


Figure 1 – Route map of the field survey for the ground assessment of solonetzic soils on pastures in Abai Region

Study Site No. 1. Ayaguz, Abai Region, located 200 m east of the highway and 1,500 m from the city of Ayaguz. The terrain is a slightly undulating plain (Figure 2). The landscape

aspect is brownish-green. Soil type: shallow solonetz. Dry steppe zone.

Morphological properties of the shallow solonetz. Coordinates: N 47°59′39.9″; E 080°25′18.1″; H = 675 m. The soil profile was established on a flat surface under a wormwood–kokpek community with the participation of feather grass (wormwood, kokpek, feather grass, bluegrass, wild barley, stinkweed, and izen). The projective vegetation cover was 45–50%. Vegetation height ranged from 0–6 cm to 53–130 cm. The soil profile depth was 130 cm. The combined thickness of the A+B horizons was 29 cm. The following horizons were identified: A, 0–6 cm; B_1, 7–18 cm; B_2, 19–29 cm; BC, 30–52 cm; C, 53–130 cm. Soil samples were collected from the following depths: 0–6 cm; 7–18 cm; 19–29 cm; 30–52 cm; and 53–130 cm.



Profile structure of the shallow solonetz

A 0–6 cm: light gray, dry, dusty–crumbly, light loam. The soil surface is gravelly. Vigorous effervescence with HCl occurs from the soil surface. Roots are present. The horizon is loose, with an abrupt transition based on density.

B_1 7–18 cm: dark brown, dry, dense, columnar–prismatic structure, heavy loam. Roots are present. Effervescence with HCl is observed. The transition is clear based on color and density.

B_2 19–29 cm: brown, dry, compacted, crumbly, heavy loam. Few roots are present. Effervescence with HCl is observed. The transition is abrupt based on color; the horizon is structureless.

BC 30–52 cm: brown with a whitish hue, carbonate layer, moist, compacted, loamy. Numerous carbonate mottles are present. Effervescence with HCl is observed. The transition is clear based on color.

C 53–130 cm: brownish-reddish in color, moist, structureless, clayey. No effervescence with HCl is observed. Gypsum accumulations (gypsum crystals) are present, with occasional black manganese mottles.



Figure 2 – General view of the landscape and its surface

The chemical composition data for the shallow solonetz at Study Site No. 1 in Abai Region indicate that the humus content in the upper horizons ranges from 1.22 to 1.28% (Table 1). The CO_2 content of carbonates varies from 0.49 to 2.94%. The highest carbonate content is observed in the upper horizons, while the lowest values are recorded in the lower horizons. The total nitrogen content ranges from 0.112 to 0.126%, whereas its hydrolysable form varies from 22.4 to 28.0 mg/kg. The contents of available phosphorus and potassium are 6.0–12.0 and 150–340 mg/kg, respectively. The pH values range from 7.64 to 8.59, with the maximum value recorded in the solonetzic horizon, indicating an alkaline soil reaction.

Table 1 – Chemical Composition of the Shallow Solonetz in Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
1	0-6	1,22	0,126	12	340	22,4	8,22	2,45
	8-18	1,28	0,112	6	150	28,0	8,59	2,94
	20-29						7,81	2,42
	40-50						7,64	0,49
	100-110						7,96	0,33

In the aqueous extract of the shallow solonetz soils at Study Site No. 1, bicarbonate ions predominate in the solonetzic horizon, with a concentration of 1.04 meq per 100 g of soil. In addition, in the lower horizons, chlorides and sulfates are the dominant anions, with concentrations ranging from 6.29 to 13.64 meq/100 g and from 10.95 to 26.60 meq/100 g, respectively. Among the cations, sodium is present in the highest concentration, reaching a maximum of 19.36–26.16 mg/100 g in the lower horizons. These conditions characterize the bicarbonate–chloride–sulfate type of salinity of the shallow solonetz soils.

Throughout the soil profile, the maximum accumulation of Na^+, Mg^{2+}, and other ions is observed within the 20–110 cm layer. This indicates the downward accumulation and migration of soluble salts below the solonetzic horizon and demonstrates the pronounced development of the solonetzic process in the subhumus horizon (Table 2).

The composition of exchangeable cations in the shallow solonetz soils at Study Site No. 1 in the Abai Region is characterized by the predominance of Ca^{2+}. Its content throughout the soil profile ranged from 16.15 to 22.86 meq per 100 g of soil (Table 3). At the same time, the contents of Mg^{2+} and Na^+ increased from 3.48 to 14.41 meq and from 1.59 to 14.22 meq,

respectively, while the content of K^+ reached 0.07 meq per 100 g of soil with increasing depth down the soil profile. A sharp increase in exchangeable Na^+ content to 3.83 meq per 100 g of soil in the solonetzic B1 horizon indicates an increase in the degree of sodium saturation of the soil exchange complex and a pronounced development of the solonetzic process.

Table 2 – Ionic composition of the aqueous extract of shallow solonetz soil in the Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K+
			Total HCO_3^-	From normal carbonates as CO_3						
1	0-6		0,76	0,08	0,07	0,20	0,10	0,10	0,82	0,02
		0,081	0,046	0,002	0,002	0,010	0,002	0,001	0,019	0,001
	8-18		1,04	0,16	0,94	1,18	0,10	0,10	2,96	0,02
		0,225	0,063	0,005	0,033	0,057	0,002	0,001	0,068	0,001
	20-29		0,36	0,00	6,29	26,60	11,21	2,67	19,36	0,02
		2,224	0,022	0,000	0,223	1,277	0,224	0,032	0,445	0,001
	40-50		0,36	0,00	13,29	25,37	8,57	4,28	26,16	0,02
		2,537	0,022	0,000	0,471	1,218	0,171	0,052	0,602	0,001
	100-110		0,44	0,08	13,64	10,95	0,76	0,95	23,29	0,02
		1,599	0,027	0,002	0,484	0,525	0,015	0,012	0,536	0,001

Table 3 – Composition of Exchangeable Cations in Shallow Solonetz Soil of the Abai Region

Section	Sampling depth, cm	Exchangeable bases, meq/100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
1	0-6	21,85	3,48	1,59	0,07
	8-18	16,15	9,44	3,83	0,07
	20-29	22,86	8,95	9,24	0,07
	40-50	22,37	9,44	7,44	0,07
	100-110	25,65	14,41	14,22	0,07

Table 4 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
1	0-6	3,94	8,974	14,824	14,991	6,246	26,234	28,732	61,212
	8-18	4,00	11,771	16,563	9,167	5,417	28,750	28,333	62,500
	20-29	3,90	14,110	27,617	3,330	7,076	22,477	25,390	54,943
	40-50	4,62	29,985	6,270	5,452	5,452	27,679	25,163	58,293
	100-110	5,32	15,463	10,604	12,252	9,717	16,477	35,488	61,681

The particle-size distribution data for the solonetz of the study site No. 1 in Abai Region

indicate a light-clay texture. The content of physical clay within the soil profile ranges from 54.943 to 62.500% (Table 4). Silt predominates in the particle-size composition. A particularly sharp increase in the content of fine particles is observed at a depth of 100–110 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Characteristics and Feed Value of the Vegetation Cover

The study of the biological characteristics of the vegetation revealed that the projective vegetation cover of the solonetzic soils accounted for 45–50% of the total area. The pasture type was identified as a wormwood–kokpek pasture with the participation of feather grass. In the botanical composition, wormwood accounted for 60%, kokpek for 30%, and feather grass for 10% of the area. The vegetation community also included Koeleria spp., Eremopyrum spp., Lepidium spp., and izen (Kochia prostrata).

The pasture biomass yield was 5.5 c/ha. The coordinates of the study site were N 47°09′39.9″, E 080°25′18.1″. Analysis of the chemical composition of the plants showed that, on an air-dry basis, the protein content was 15.10%, fat 8.92%, fiber 32.90%, nitrogen-free extractive substances (NFE) 31.65%, and ash 8.22%.

The yield of feed units at the natural moisture content of the plants was 0.59 feed units per kilogram of feed, while the metabolizable energy content was 8.17 MJ.

Study Site No. 2 is located near Zharma settlement, Zharma District, Abai Region, 2,000 m west of Zharma settlement and 2,000 m east of the highway. The terrain is a gently sloping piedmont plain (Figure 3). The landscape aspect is grayish-yellowish. The soil type is shallow solonetz. The site is located within the dry-steppe zone.

 Soil Profile Structure of Shallow Solonetz Soil	A (0–7 cm): brown, dry, dusty-cloddy, loamy, loose; no effervescence with HCl; roots present; gravelly surface; abrupt transition in density. B1 (8–18 cm): brownish, dry, dense, columnar-prismatic structure, heavy loam; no effervescence with HCl; few roots; gradual transition. B2 (19–36 cm): brown, dry, dense, cloddy, heavy loam; no effervescence with HCl; single roots; clear transition in color. BC (37–61 cm): pale brownish, dry, compacted, clayey; roots absent; effervesces with HCl; gradual transition; structureless carbonate spots. C (62–120 cm): dark brown, pale with a rusty hue, moist, compacted, clayey; carbonate spots; structureless; vigorous effervescence with HCl.

Morphological Properties of Shallow Solonetz Soil. Coordinates: N 48°786′340″, E

080°861′024″, H = 693 m. The soil profile was established on a flat surface under a wormwood–fescue–sedge vegetation community, consisting mainly of wormwood, fescue, and sedge, with occasional feather grass, occasional izen, and bluegrass. The projective vegetation cover was 65%. The soil profile depth was 120 cm. The combined thickness of the A + B horizons was 36 cm. The identified horizons were: A, 0–7 cm; B_1, 8–18 cm; B_2, 19–36 cm; BC, 37–61 cm; and C, 62–130 cm. Soil samples were collected from the following depths: 0–7 cm, 8–18 cm, 19–36 cm, 37–61 cm, and 62–120 cm.



Figure 3 – General View of the Landscape and Its Surface

The chemical composition data for the shallow solonetz soils at Study Site No. 2 in the Abai Region show that the humus content in the upper horizons ranges from 2.49 to 1.95% (Table 5). The CO_2 content of carbonates varies from 0.23 to 8.05%. The maximum value was recorded in the deepest horizon (8.05%), whereas the minimum values were observed in the upper horizons. The total nitrogen content ranges from 0.112 to 0.154%, while its hydrolyzable form varies from 22.4 to 33.6 mg/kg. The contents of available phosphorus and potassium range from 14.0 to 34.0 mg/kg and from 400 to 500 mg/kg, respectively. The pH values range from 8.08 to 8.62, with the highest values recorded in the lower horizons, indicating an alkaline soil reaction.

Table 5 – Chemical Composition of Shallow Solonetz Soil in the Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
2	0-7	2,49	0,154	34	500	33,6	8,12	0,23

	8-18	1,95	0,112	14	400	22,4	8,08	0,33
	25-35						8,61	0,23
	45-55						8,81	1,18
	90-100						8,62	8,05

In the aqueous extract of the shallow solonetz soils at Study Site No. 2, chlorides and sulfates predominated among the anions, with concentrations of 0.14–0.73 meq/100 g and 0.78–4.36 meq/100 g, respectively. Traces of soda were detected in the lower horizons, reaching 0.08 meq/100 g of soil. Among the cations, sodium was present in the highest concentration, with maximum values recorded in the lower horizons (0.29–0.19 mg/100 g). These conditions characterize a weak chloride–sulfate type of salinity in the deeper layers of the shallow solonetz soils. Throughout the soil profile, the maximum accumulation of Na^+, Mg^{2+}, and other ions was observed within the 45–100 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon (Table 6).

Table 6 – Ionic Composition of the Aqueous Extract of Shallow Solonetz Soil in the Abai Region,

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
2	0-7		0,28	0,00	0,07	0,08	0,19	0,10	0,04	0,11
		0,034	0,017	0,000	0,002	0,004	0,004	0,001	0,001	0,004
	8-18		0,24	0,00	0,07	0,04	0,10	0,19	0,04	0,03
		0,025	0,015	0,000	0,002	0,002	0,002	0,002	0,001	0,001
	25-35		0,20	0,00	0,03	0,35	0,10	0,19	0,29	0,02
		0,042	0,012	0,000	0,001	0,017	0,002	0,002	0,007	0,001
	45-55		0,64	0,08	0,14	0,78	0,10	0,29	1,16	0,02
		0,114	0,039	0,002	0,005	0,038	0,002	0,003	0,027	0,001
	90-100		0,76	0,08	0,73	4,36	0,10	0,19	5,56	0,02
		0,414	0,046	0,002	0,026	0,209	0,002	0,002	0,128	0,001

The composition of exchangeable cations in the shallow solonetz soils at Study Site No. 2 in the Abai Region is characterized by the predominance of Ca^{2+}. Its content throughout the soil profile ranged from 6.65 to 11.88 meq/100 g of soil (Table 7). Mg^{2+} ranked second, with its content increasing down the profile from 0.99 to 9.44 meq/100 g. The content of Na^+ also increased with depth, from 0.25 to 1.33 meq/100 g. In contrast, the content of K^+ decreased with depth, from 0.83 to 0.07 meq/100 g of soil. Despite the relatively low content of exchangeable Na^+, reaching 0.25 meq/100 g, particularly in the B1 solonetzic horizon, its presence indicates an increase in the sodium saturation of the soil exchange complex and the development of the solonetzic process.

Table 7 – Composition of Exchangeable Cations in the Solonetz Soil of Abai Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
2	0-7	10,45	0,99	0,25	0,83
	8-18	11,88	4,47	0,25	0,32
	25-35	6,65	4,97	0,05	0,07
	45-55	8,55	5,47	1,05	0,07
	90-100	9,50	9,44	1,33	0,07

The particle-size distribution data for the solonetz of the study site No. 2 in Abai Region indicate a medium-to-light loamy texture. The content of physical clay within the soil profile ranges from 32.081 to 21.960% (Table 8). The particle-size composition is dominated by sand and silt fractions. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 8 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
2	0-7	1,50	27,330	18,660	21,929	11,371	15,431	5,279	32,081
	8-18	1,64	37,658	22,489	17,893	2,033	16,673	3,253	21,960
	25-35	1,52	43,400	23,700	8,936	1,219	15,028	7,717	23,964
	45-55	2,12	49,918	12,485	4,904	3,678	15,938	13,077	32,693
	90-100	2,94	25,613	8,448	10,715	0,412	23,903	30,909	55,224

Characterization and Feed Value of the Vegetation Cover

The projective vegetation cover of the solonetz soil surface accounts for only 45% of the total area. The pasture type is wormwood–fescue–sedge. The botanical composition of the vegetation consists of 65% wormwood, 25% fescue, and 10% sedge. In addition, isolated specimens of feather grass, bluegrass, cinquefoil, izen, and meadow grass occur in the vegetation cover. The pasture yield is 7.0 c/ha. The coordinates are N 48°47′10.8″, E 080°51′34.3″. The content of nutrients in the air-dry plant material is 14.40% crude protein, 5.71% fat, 35.63% fiber, 30.33% nitrogen-free extractive substances (NFE), and 10.81% ash. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of feed, while the metabolizable energy content was 7.35 MJ.

Research Site No. 3 - Zhangiz-Tobe settlement, Zharma District, Abai Region, located 3,500 m southeast of Zhangiz-Tobe settlement and 300 m southeast of the Zhangiz-Tobe–

Kalbatau highway. The relief is a plain (Figure 4). The landscape aspect is greenish-gray. The soil type is medium solonetz. The site is located in the dry steppe zone.

Morphological properties of the shallow solonetz. Coordinates: N 48°20′37.64″, E 081°24′01.89″, H = 458 m. The soil profile was established on a flat surface under wormwood vegetation consisting of wormwood, alyssum, and fescue, with isolated specimens of feather grass, wall-rocket, and fenugreek. The projective vegetation cover was 45%. Vegetation height ranged from 0–11 cm to 57–110 cm. The profile depth was 110 cm. The total thickness of the A+B horizons was 32 cm. The identified horizons were: A - 0–11 cm; B_1 - 12–21 cm; B_2 - 22–32 cm; BC - 33–56 cm; C - 57–110 cm. Soil samples were collected from the following depths: 0–11 cm; 12–21 cm; 22–32 cm; 33–56 cm; and 57–110 cm.



Profile structure of a medium solonetz

A 0–11 cm — light brown, dry, dusty-cloddy, with a layered and loose structure in the upper part; loamy; roots present; no reaction to HCl; clear transition based on density.
B_1 11–21 cm — brownish, dry, columnar-prismatic, heavy loam; roots present; dense; no reaction to HCl; gradual transition.
B_2 22–32 cm — brown, dry, dense, cloddy, heavy loam; no reaction to HCl; carbonate spots appear toward the lower part; gravel fragments present; few roots; abrupt transition by color.
BC 33–56 cm — pale brown, dry, dense, structureless, clayey; vigorous reaction to HCl; the amount of gravel increases toward the lower part; gradual transition.
C 57–110 cm — darker than the overlying horizon, moist, dense, clayey; vigorous reaction to HCl; abundant gravel; structureless.



Figure 4 – General view of the landscape and its surface

The chemical composition data for the medium solonetz at Research Site No. 3 in Abai

Region show that the humus content in the upper horizons ranges from 2.34 to 2.04% (Table 9). The CO_2 content of carbonates ranges from 0.36 to 11.4%. The maximum value was recorded in the 40–50 cm layer (11.4%), while the minimum value was observed in the upper layer. The total nitrogen content ranges from 0.168 to 0.140%, while its hydrolysable form varies from 22.4 to 19.6 mg/kg. The contents of available phosphorus and potassium are 12.0 and 140–410 mg/kg, respectively. The soil pH ranges from 8.06 to 9.15, with the highest values recorded in the lower horizons, indicating an alkaline soil reaction.

Table 9 – Chemical Composition of the Medium Solonetz of Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
3	0-10	2,34	0,168	12	410	22,4	8,06	0,36
	10-20	2,04	0,140	12	140	19,6	8,15	2,16
	20-30						8,44	5,56
	40-50						8,68	11,4
	80-90						9,15	1,64

The aqueous extract of the medium solonetz at Research Site No. 3 in Abai Region contains traces of carbonate ions in the lower horizons (0.04–0.08 mg-eq/100 g of soil). In addition, among the anions in the lower horizons, sulfates predominate, with concentrations of 0.54–0.55 mg-eq/100 g, respectively. Among the cations, magnesium predominates, accompanied by sodium, with maximum concentrations in the lower horizons (0.76 and 0.74 mg/100 g of soil, respectively). These conditions indicate a pronounced sulfate type of salinity, with traces of soda in the lower horizon of the shallow solonetz. Across the profile, the maximum accumulation of Na^+, Mg^{2+}, and other soluble salts is observed at a depth of 80–90 cm, indicating the downward accumulation and migration of soluble salts below the solonetzic horizon and the persistence of a residual solonetzic process in the subhumus horizon (Table 10).

Table 10 – Ionic Composition of the Aqueous Extract of the Medium Solonetz of Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl',	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
3	0-10		0,32	0,00	0,07	0,33	0,19	0,48	0,04	0,02
		0,049	0,020	0,000	0,002	0,016	0,004	0,006	0,001	0,001
	10-20		0,40	0,00	0,17	0,07	0,19	0,38	0,05	0,02
		0,044	0,024	0,000	0,006	0,003	0,004	0,005	0,001	0,001
	20-30		0,44	0,00	0,14	0,16	0,19	0,48	0,05	0,02

		0,051	0,027	0,000	0,005	0,008	0,004	0,006	0,001	0,001
	40-50		0,52	0,04	0,07	0,54	0,19	0,76	0,16	0,02
		0,078	0,032	0,001	0,002	0,026	0,004	0,009	0,004	0,001
	80-90		0,76	0,08	0,10	0,55	0,19	0,48	0,74	0,02
		0,104	0,046	0,002	0,004	0,027	0,004	0,006	0,017	0,001

The composition of exchangeable cations in the medium solonetz at Research Site No. 3 in Abai Region is characterized by a predominance of Ca^{2+}. Its content within the soil profile decreases with depth, from 19.95 to 8.08 mg-eq/100 g of soil (Table 11). Mg^{2+} ranks second, with a content ranging from 6.46 to 8.95 mg-eq/100 g, followed by Na^{+}, ranging from 0.02 to 0.21 mg-eq/100 g, and K^{+}, ranging from 0.23 to 0.07 mg-eq/100 g of soil. Despite the residual content of sodium, including in the solonetzic B_1 horizon, its presence indicates an increase in the saturation of the soil exchange complex with sodium and the pronounced development of the solonetzic process.

Table 11 – Composition of Exchangeable Cations of the Medium Solonetz of Abai Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
3	0-10	19,95	6,46	0,21	0,23
	10-20	18,05	7,95	0,16	0,07
	20-30	18,05	8,95	0,14	0,07
	40-50	10,45	7,95	0,02	0,07
	80-90	8,08	8,45	0,19	0,07

The particle-size distribution data for the medium solonetz of the study site No. 3 in Abai Region indicate a heavy-loam to light-clay texture. The content of physical clay within the soil profile ranges from 65.105 to 23.998% (Table 12). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 80–90 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 12 – Particle-Size Distribution of the Medium Solonetz Soils

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
3	0-10	3,46	20,261	11,374	10,773	7,458	21,131	29,004	57,593
	10-20	3,54	18,723	10,367	5,806	17,831	26,125	21,149	65,105
	20-30	3,46	14,129	12,534	11,187	9,530	24,031	28,589	62,150

40-50	1,92	27,019	15,885	9,380	11,419	24,878	11,419	47,716
80-90	1,66	57,535	11,552	6,915	5,288	11,796	6,915	23,998

Characterization and Feed Value of the Vegetation Cover

The study of the biological characteristics of the vegetation showed that the projective vegetation cover of the solonetz soil surface was 45%. The pasture type is wormwood-dominated. The botanical composition of the vegetation consists of 90% wormwood, 7% alyssum, and 3% fescue. In addition, isolated specimens of feather grass, wall-rocket, and fenugreek were observed. The yield of pasture biomass was 8.5 c/ha. The coordinates are N 49°12′22.7″, E 081°14′41.3″. The nutrient content in the air-dry plant material was 16.50% crude protein, 7.32% fat, 33.93% fiber, 31.05% nitrogen-free extractive substances (NFE), and 8.11% ash. The feed unit yield at natural moisture content was 0.57 feed units per kilogram of feed, while the metabolizable energy content was 8.14 MJ.

Research Site No. 4 - the city of Charsk, Charsk District, Abai Region, located 3,000 m north of the city of Shar and 200 m west of the Almaty–Semey highway. The relief is a slightly undulating plain. The landscape aspect is greenish-gray. The soil type is shallow solonetz. The site is located in the dry steppe zone (Figure 5).

Morphological properties of the shallow solonetz. Coordinates: N 49°06′05.869″, E 081°07′03.478″, H = 334 m. The soil profile was established on a flat surface under wormwood–fescue–feather grass vegetation consisting of wormwood, fescue, feather grass, bluegrass, and alyssum. The projective vegetation cover was 55–60%. Vegetation height ranged from 0–8 cm to 45–100 cm. The profile depth was 110 cm. The total thickness of the A+B horizons was 36 cm. The identified horizons were: A - 0–8 cm; B_1 - 9–20 cm; B_2 - 21–36 cm; BC - 37–44 cm; C - 45–100 cm. Soil samples were collected from the following depths: 0–8 cm; 9–20 cm; 21–36 cm; 37–44 cm; and 45–100 cm.



A, 0–8 cm — light gray, dry, loamy, loose, dusty-cloddy, with abundant roots; reacts to HCl; abrupt transition based on density; gravelly surface.
B_1, 9–20 cm — dark brown, dry, very dense, loamy, columnar-prismatic; roots present; reacts to HCl; clear transition based on density.
B_2, 20–36 cm — brown, dry, dense, cloddy, loamy; vigorous reaction to HCl; fine gravel is observed throughout the profile; distinct transition in color and structure.
BC, 37–44 cm — brown with a whitish hue, dry, structureless, compacted, loamy; vigorous reaction to HCl; distinct transition.
C, 45–100 cm — grayish with a yellowish hue, dry,

Profile structure of a shallow solonetz	structureless; vigorous reaction to HCl; light loam; abundant coarse sand and gravel.

The chemical composition data for the shallow solonetz at Research Site No. 4 in Abai Region show that the humus content in the upper horizons ranges from 2.29 to 1.68% (Table 13). The CO_2 content of carbonates ranges from 1.37 to 6.51%. The maximum values were recorded in the lower horizons, while the minimum values were observed in the upper horizons. The total nitrogen content ranges from 0.168 to 0.154%, while its hydrolysable form varies from 22.4 to 25.2 mg/kg.



Figure 5 – General view of the landscape and its surface

The available forms of phosphorus and potassium range from 22.0 to 10.0 mg/kg and 500 to 150 mg/kg, respectively. The soil pH ranges from 8.41 to 8.75, with the maximum values increasing with depth, indicating an alkaline soil reaction throughout the entire profile.

Table 13 – Chemical Composition of the Shallow Solonetz of Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
4	0-6	2,29	0,168	22	500	22,4	8,41	1,37
	7-17	1,68	0,154	10	150	25,2	8,64	2,62
	19-29						8,69	4,58
	40-50						8,87	6,51
	80-90						8,75	4,09

The aqueous extract of the shallow solonetz at Research Site No. 4 in Abai Region is characterized by the predominance of carbonate ions in the solonetzic and subsolonetzic

horizons (0.04 and 0.08 mg-eq/100 g of soil, respectively). In addition, sulfates predominate among the anions in the lower horizons, with concentrations of 0.55–0.96 mg-eq/100 g of soil, respectively. Among the cations, magnesium predominates, with maximum concentrations recorded in the lower horizons (0.76 and 0.95 mg/100 g of soil, respectively). These conditions characterize a residual sulfate type of salinity in the studied solonetz soils. Across the soil profile, the maximum accumulation of Mg^{2+} and other soluble salts is observed within the 40–90 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of a residual relict solonetzic process in the subhumus horizon (Table 14).

Table 14 – Ionic Composition of the Aqueous Extract of the Shallow Solonetz of Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
4	0-6		0,36	0,00	0,03	0,30	0,19	0,38	0,04	0,09
		0,051	0,022	0,000	0,001	0,015	0,004	0,005	0,001	0,004
	7-17		0,48	0,04	0,03	0,30	0,19	0,57	0,04	0,02
		0,057	0,029	0,001	0,001	0,014	0,004	0,007	0,001	0,001
	19-29		0,64	0,08	0,03	0,25	0,19	0,67	0,05	0,02
		0,066	0,039	0,002	0,001	0,012	0,004	0,008	0,001	0,001
	40-50		0,72	0,08	0,00	0,55	0,10	0,76	0,39	0,02
		0,091	0,044	0,002	0,000	0,026	0,002	0,009	0,009	0,001
	80-90		0,44	0,04	0,07	0,96	0,19	0,95	0,31	0,02
		0,098	0,027	0,001	0,002	0,046	0,004	0,012	0,007	0,001

The composition of exchangeable cations in the shallow solonetzes at study point No. 4 in Abai Region is characterized by the predominance of Ca^{2+} over Mg^{2+} in the upper horizons. Its content within the soil profile decreases with depth, from 13.78 to 3.80 mg-eq per 100 g of soil (Table 15). At the same time, the content of Mg^{2+} shows the opposite pattern, increasing with depth from 5.96 to 14.41 mg-eq per 100 g of soil. Within the profile, Na^+ exhibits a relatively uniform distribution, ranging from 0.25 to 0.14 mg-eq per 100 g of soil, while K^+ ranges from 0.53 to 0.07 mg-eq per 100 g of soil. The so-called residual solonetzes, despite their reduced Na^+ content, particularly in the solonetzic B_1 horizon, indicate an increase in the degree of sodium saturation of the exchange complex and a more pronounced development of the solonetzic process.

Table 15 – Composition of Exchangeable Cations in the Shallow Solonetz of Abai Region

Section	Sampling	Exchangeable bases, mg-eq./100 g of soil

	depth, cm	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
4	0-6	13,78	5,96	0,25	0,53
	7-17	10,93	7,95	0,23	0,07
	19-29	8,08	9,94	0,14	0,07
	40-50	8,08	12,43	0,45	0,07
	80-90	3,80	14,41	0,20	0,07

The particle-size distribution data for the solonetz of the study site No. 4 in Abai Region indicate a light- to medium-loamy texture. The content of physical clay within the soil profile ranges from 38.240 to 12.776% (Table 16). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in its content is observed at a depth of 80–90 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 16 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
4	0-6	2,54	18,900	23,640	29,551	4,104	10,671	13,134	27,909
	7-17	2,72	19,757	20,621	21,382	12,336	13,158	12,747	38,240
	19-29	2,58	21,146	15,623	25,867	12,728	18,887	5,748	37,364
	40-50	2,60	30,144	21,396	15,195	8,624	18,070	6,571	33,265
	80-90	2,94	56,254	21,080	9,891	9,891	0,412	2,473	12,776

Characteristics and Feed Value of the Vegetation Cover

The study of the soil cover showed that the projective plant cover of the soil surface accounted for 55–60% of the total area. The pasture type was identified as wormwood–Stipa feather grass–fescue. The botanical composition consisted of wormwood (65%), fescue (20%), and feather grass (15%); bluegrass and alyssum were also present in the vegetation. The yield of pasture biomass was 7.0 c/ha. The geographical coordinates were N 49°36′35.9″, E 081°04′41.2″. In the air-dry state, the protein content was 14.92%, fat – 6.23%, fiber – 34.51%, nitrogen-free extractives (NFE) – 32.79%, and ash – 8.82%. The yield of feed units at natural moisture content was 0.55 feed units per kilogram of feed, while the exchange energy content was 7.75 MJ.

Study Point No. 5 – Uzynzhol settlement, Abai Region, located 2,000 m south of Uzynzhol settlement and 1,500 m west of the Almaty–Semey highway. The relief is a plain. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The site is located in the

dry-steppe zone (Figure 6).

Morphological properties of the shallow solonetz. Coordinates: N 49°973′473″, E 080°750′224″. H = 263 m. The soil profile was established on a flat surface under a wormwood–wormwood–izzen–ephemeral plant community (wormwood, izen, alyssum, ephemeral plants, with single fescue and single feather grass plants). The projective plant cover was 45%. Plant height ranged from 0–10 to 61–120 cm. The depth of the soil profile was 120 cm. The combined thickness of the A+B horizons was 39 cm. The horizons were as follows: A, 0–10 cm; B_1, 11–24 cm; B_2, 25–39 cm; BC, 40–60 cm; C, 61–120 cm. Soil samples were collected from the following depths: 0–10 cm; 11–24 cm; 25–39 cm; 40–60 cm; and 61–120 cm.

The chemical composition data for the shallow solonetz at Study Point No. 5 in Abai Region show that the humus content in the upper horizons ranges from 0.61 to 0.84% (Table 17).

 Profile Structure of the Shallow Solonetz	A 0–10 cm – light gray, dry, dusty-cloddy, loamy, loose; roots present; vigorous effervescence with HCl; abrupt transition due to density. B_1 11–24 cm – dark gray, dry, columnar, loamy, dense; roots present; vigorous effervescence with HCl; gradual transition. B_2 25–39 cm – darker than the preceding horizon, dry, cloddy, dense, heavy loam; few roots; vigorous effervescence with HCl; clear transition by color. BC 40–60 cm – dark gray, dry, structureless, dense, clayey; effervesces with HCl; carbonate horizon. C 61–120 cm – darker than the preceding horizon, dry, compacted; gravel and sand occur; structureless, heavy loam; effervesces with HCl.



Figure 6 – General View of the Landscape and Its Surface

Table 17 – Chemical Composition of the Shallow Solonetz in Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
5	0-10	0,61	0,098	8	380	25,2	8,81	3,73
	12-22	0,84	0,098	6	170	22,4	8,64	4,58
	25-35						8,58	4,25
	45-55						8,24	4,32
	80-90						8,23	9,10

The CO_2 content of carbonates ranges from 3.73 to 9.10%. The maximum value was recorded in the parent material (9.10%), while the minimum value was observed in the humus horizon (3.73%). The total nitrogen content is 0.098%, while its hydrolysable form ranges from 25.2 to 22.4 mg/kg. The available forms of phosphorus and potassium are 6.0–8.0 and 380–170 mg/kg, respectively. The pH value ranges from 8.23 to 8.81, with the maximum values observed in the solonetzic and supra-solonetzic horizons, indicating an alkaline reaction throughout the soil profile.

In the water extract of the shallow solonetz at Study Point No. 5 in Abai Region, chlorides and sulfates predominate among the anions in the lower horizons, with concentrations of 0.73–1.40 mg-eq and 1.68–3.37 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the lower horizons (1.24 and 3.76 mg-eq per 100 g of soil). These conditions characterize the salinity of the shallow solonetzes as weak chloride–sulfate salinity. Throughout the soil profile, the maximum accumulation of soluble salts (Na^+, Cl^-, SO_4^{2-}, etc.) is observed within the 45–90 cm layer, indicating the downward accumulation and migration of soluble salts below the solonetzic horizon and the pronounced development of the residual solonetzic process in the subhumus horizon (Table 18).

Table 18 – Ionic Composition of the Water Extract of the Shallow Solonetz in Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
5	0-10		0,36	0,00	0,00	0,21	0,10	0,29	0,04	0,16
		0,044	0,022	0,000	0,000	0,010	0,002	0,003	0,001	0,006
	12-22		0,40	0,00	0,03	0,38	0,19	0,57	0,04	0,02
		0,056	0,024	0,000	0,001	0,018	0,004	0,007	0,001	0,001
	25-35		0,44	0,00	0,00	0,45	0,19	0,38	0,31	0,02

		0,065	0,027	0,000	0,000	0,022	0,004	0,005	0,007	0,001
	45-55		0,36	0,00	0,73	1,68	0,86	0,67	1,24	0,02
		0,183	0,022	0,000	0,026	0,081	0,017	0,008	0,028	0,001
	80-90		0,44	0,04	1,40	3,37	0,57	0,86	3,76	0,02
		0,347	0,027	0,001	0,050	0,162	0,011	0,010	0,087	0,001

The composition of exchangeable cations in the shallow solonetz at Study Point No. 5 in Abai Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 6.65 to 9.50 mg-eq per 100 g of soil (Table 19). At the same time, the content of Mg^{2+} increases sharply in the 12–22, 45–55, and 80–90 cm layers, reaching 5.47, 6.46, and 12.92 mg-eq per 100 g of soil, respectively. The content of exchangeable Na^{+} is residual in nature and amounts to 0.21 mg-eq per 100 g of soil in the solonetzic horizon. Nevertheless, the main cause of the solonetzic character of the B_1 horizon is the saturation of the exchange complex with sodium.

Table 19 – Composition of Exchangeable Cations in the Shallow Solonetz of Abai Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
5	0-10	6,65	3,98	0,25	0,33
	12-22	8,08	5,47	0,21	0,07
	25-35	9,50	3,98	0,05	0,07
	45-55	9,50	6,46	0,94	0,07
	80-90	9,03	12,92	0,24	0,07

The particle-size distribution data for the solonetz of the study site No. 5 in Abai Region indicate a sandy-loam to heavy-loam texture. The content of physical clay within the soil profile ranges from 19.009 to 56.274% (Table 20). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 25–35 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 20 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
5	0-10	1,10	29,080	38,564	13,347	3,236	11,729	4,044	19,009
	12-22	1,38	15,940	38,633	15,818	2,839	11,762	15,007	29,609
	25-35	1,38	18,860	44,230	7,706	12,168	1,217	15,818	29,203

45-55	1,48	27,284	36,175	11,774	8,526	4,466	11,774	24,767
80-90	2,62	7,907	18,156	17,663	10,680	13,555	32,039	56,274

Characteristics and Feed Value of the Vegetation Cover

The results of field studies showed that the projective plant cover of the soil surface accounted for 45% of the total area. The pasture type was identified as wormwood–izen–ephemeral. The botanical composition consisted of wormwood (60%), izen (30%), and ephemeral plants (10%). Alyssum was also present, along with single fescue, single feather grass, and ephemeral plants (e.g., ebelek). The yield of pasture biomass was 7.0 c/ha. The geographical coordinates were N 49°58′41.5″, E 080°44′99.3″. The chemical analysis of the plants showed that, in the air-dry state, the protein content was 15.71%, fat – 6.92%, fiber – 39.61%, nitrogen-free extractives (NFE) – 24.85%, and ash – 10.00%. The yield of feed units at natural moisture content was 0.50 feed units per kilogram of feed, while the exchange energy content was 7.32 MJ.

Study Point No. 6 – Semey city, Abai Region, located 3,000 m from Semey in the direction of Pavlodar and 200 m east of the Semey–Pavlodar highway. The relief is a plain. The landscape aspect is grayish-green. The soil type is a shallow saline solonetz. The site is located in the dry-steppe zone (Figure 7).

Morphological properties of the shallow solonetz. Coordinates: N 50°689′608″, E 079°775′617″. H = 224 m. The soil profile was established on a flat surface under a wormwood–camphorosma–grass–ephemeral plant community (wormwood, camphorosma, fescue, single feather grass plants, alkali grass, bluegrass, and single izen plants). The projective plant cover was 60%. Plant height ranged from 0–12 to 63–105 cm. The depth of the soil profile was 105 cm. The combined thickness of the A+B horizons was 44 cm. The horizons were as follows: A, 0–12 cm; B_1, 13–23 cm; B_2, 24–44 cm; BC, 45–62 cm; C, 63–105 cm. Soil samples were collected from the following depths: 0–12 cm; 13–23 cm; 24–44 cm; 45–62 cm; and 63–105 cm.

 Profile Structure of the Shallow Solonetz	A 0–12 cm – light gray, dry, dusty, loamy, loose; many roots; weak effervescence with HCl; abrupt transition by color and density. B_1 13–23 cm – dark brown, dry, columnar, heavy loam, dense; roots present; effervesces with HCl; clear transition by density. B_2 24–44 cm – dark brown, moist, cloddy, slightly compacted, loamy; effervesces with HCl; single roots; abrupt transition by color. BC 45–62 cm – gleyed, moist, structureless, slightly compacted, clayey; vigorous effervescence with HCl; gradual transition. C 63–105 cm – gleyed with a whitish tint due to the accumulation of carbonate mottles; moist, structureless, clayey, slightly compacted; vigorous effervescence with HCl.

The chemical composition data for the shallow solonetz at Study Point No. 6 in Abai Region show that the humus content in the upper horizons is 0.30% (Table 21). The CO_2 content of carbonates ranges from 0.75 to 6.02%. The maximum values were recorded in the lower horizons, while the minimum values were observed in the upper horizons. The total nitrogen content ranges from 0.056 to 0.042%, while its hydrolysable form ranges from 14.0 to 19.6 mg/kg. The available forms of phosphorus and potassium are 12.0–14.0 and 190–290 mg/kg, respectively. The pH value ranges from 9.65 to 10.33, with the maximum values observed in the lower horizons, indicating a very strongly alkaline reaction of the soil.



Figure 7 – General View of the Landscape and Its Surface

Table 21 – Chemical Composition of the Shallow Saline Solonetz in Abai Region

Section	Depth, cm	Types of analysis

		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
6	0-10	0,30	0,056	12	190	14,0	9,65	0,75
	13-23	0,30	0,042	14	290	19,6	9,94	1,47
	30-40						10,33	1,66
	50-60						10,22	9,98
	80-90						10,14	6,02

In the water extract of the shallow solonetz at Study Point No. 6 in Abai Region, bicarbonate and carbonate ions predominate in the solonetzic and subsolonetzic horizons, with concentrations of 3.08–4.72 and 0.64–1.84 mg-eq per 100 g of soil, respectively. In addition, sulfates predominate among the anions in the lower horizons, with concentrations of 2.56–3.08 mg-eq per 100 g of soil. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the middle and lower horizons (4.97–7.15 mg-eq per 100 g of soil). These conditions characterize the salinity of the shallow solonetz as sulfate–soda type salinity. Throughout the soil profile, the maximum accumulation of soluble salts (Na^+, CO_3^{2-}, HCO_3^-, SO_4^{2-}, etc.) is observed within the 13–90 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the soda-type solonetzic process throughout almost the entire soil profile (Table 22).

The composition of exchangeable cations in the shallow saline solonetz at Study Point No. 6 in Abai Region is characterized by the predominance of Na^+. Its content in the solonetzic and subsolonetzic horizons ranges from 4.05 to 2.18 mg-eq per 100 g of soil (Table 23). At the same time, the content of Mg^{2+} increases in the lower horizons, reaching 4.47 and 1.99 mg-eq per 100 g of soil.

Table 22 – Ionic Composition of the Water Extract of the Shallow Saline Solonetz in Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
6	0-10		0,44	0,08	0,03	0,37	0,10	0,10	0,63	0,03
		0,064	0,027	0,002	0,001	0,018	0,002	0,001	0,014	0,001
	13-23		3,72	1,44	0,07	1,49	0,10	0,10	4,97	0,12
		0,423	0,227	0,043	0,002	0,071	0,002	0,001	0,114	0,005
	30-40		4,12	1,36	0,14	3,08	0,10	0,29	6,78	0,17
		0,572	0,251	0,041	0,005	0,148	0,002	0,003	0,156	0,007
	50-60		4,72	1,84	0,17	2,56	0,10	0,19	7,15	0,02
		0,586	0,288	0,055	0,006	0,123	0,002	0,002	0,164	0,001

	80-90		3,08	0,64	0,10	2,67	0,10	0,19	5,51	0,05
		0,453	0,188	0,019	0,004	0,128	0,002	0,002	0,127	0,002

A considerable amount of Ca^{2+} was detected in the upper horizons (2.85 and 2.38 mg-eq per 100 g of soil). The elevated Na^{+} content in the B_1 solonetzic horizon indicates an increase in the sodium saturation of the exchange complex and a more pronounced development of the solonetzic process.

Table 23 – Composition of Exchangeable Cations of the Shallow Saline Solonetz in Abai Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
6	0-10	2,85	0,99	0,20	0,12
	13-23	2,38	0,50	4,05	0,08
	80-40	0,48	1,49	2,18	0,06
	50-60	0,48	4,47	3,63	0,14
	80-90	2,38	1,99	1,75	0,14

The particle-size distribution data for the saline solonetz of the study site No. 6 in Abai Region indicate a sandy to light-loamy texture. The content of physical clay within the soil profile ranges from 10.026 to 56.412% (Table 24). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 80–90 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 24 – Particle-Size Distribution of the Saline Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
6	0-10	0,26	41,067	40,485	8,422	5,214	1,604	3,208	10,026
	13-23	1,28	27,127	42,484	6,078	8,509	1,216	14,587	24,311
	80-40	0,88	34,181	42,413	6,053	6,457	5,650	5,246	17,353
	50-60	1,44	14,184	9,923	19,481	6,088	20,698	29,627	56,412
	80-90	1,04	15,097	56,205	14,147	2,829	2,021	9,701	14,551

Characteristics and Feed Value of the Vegetation Cover

The data obtained from the study of the biological characteristics of the vegetation showed that the projective plant cover of the soil surface accounted for 60% of the total area. The pasture type was identified as wormwood–camphorosma–grass–ephemeral. The botanical

composition of the vegetation consisted of wormwood (40%), camphorosma (30%), alkali grass (15%), fescue (7%), feather grass (3%), and bluegrass (5%) of the total area. In addition, reed-like wormwood and single izen plants were observed. The yield of pasture biomass was 9.5 c/ha. The geographical coordinates were N 50°41′18.0″, E 079°46′53.7″. The chemical analysis of the plants showed that, in the air-dry state, the protein content was 16.10%, fat – 5.00%, fiber – 36.50%, nitrogen-free extractives (NFE) – 29.65%, and ash – 9.73%. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of feed, while the exchange energy content was 7.46 MJ.

Study Point No. 7 – Beskaragai District, Abai Region, located 6,800 m south of Beskaragai settlement and 6,400 m west of the Semey–Pavlodar highway. The relief is a gently undulating plain. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The site is located in the dry-steppe zone (Figure 8).

Morphological characteristics of the shallow solonetz. Coordinates: N 50°869′117″, E 079°483′883″. H = 231 m. The soil profile was established on a flat surface under a wormwood–sedge plant community with the participation of camphorosma (wormwood, sedge, camphorosma). The projective plant cover was 65%. Plant height ranged from 0–11 to 68–120 cm. The depth of the soil profile was 120 cm. The combined thickness of the A+B horizons was 41 cm. The horizons were as follows: A, 0–11 cm; B_1, 12–26 cm; B_2, 27–41 cm; BC, 42–67 cm; C, 68–120 cm. Soil samples were collected from the following depths: 0–11 cm; 12–26 cm; 27–41 cm; 42–67 cm; and 68–120 cm.



Profile Structure of the Shallow Solonetz

A 0–11 cm – dark brown, dry, loose, densely penetrated by roots; light loam, dusty-cloddy; does not effervesce with HCl; abrupt transition by density.
B_1 12–26 cm – dark gray, dry, very dense, cloddy, heavy loam; roots present; does not effervesce with HCl; gradual transition.
B_2 27–41 cm – brown, fresh, dense, loamy, cloddy; few roots; does not effervesce with HCl; gradual transition.
BC 42–67 cm – lighter than the preceding horizon, fresh, compacted, structureless, loamy; does not effervesce with HCl; sparse roots; gradual transition.
C 68–120 cm – light brown with a yellowish tint, fresh, light loam, slightly compacted, structureless; does not effervesce with HCl.



Figure 8 – General View of the Surface and Its Vegetation

The chemical composition data for the shallow solonetz at Study Point No. 7 in Abai Region show that the humus content in the upper horizons ranges from 0.81 to 0.89% (Table 25). The CO_2 content of carbonates ranges from 0.26 to 0.33%. The maximum values were recorded in the middle horizons, while the minimum value was observed in the upper horizon. The total nitrogen content ranges from 0.070 to 0.084%, while its hydrolysable form ranges from 19.6 to 14.0 mg/kg. The available forms of phosphorus and potassium are 40.0–44.0 and 210–220 mg/kg, respectively. The pH value ranges from 6.87 to 7.53, with maximum values observed in the upper and lower horizons, indicating a slightly alkaline reaction of the soil.

Table 25 – Chemical Composition of the Shallow Solonetz in Abai Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
7	0-11	0,81	0,070	40	210	19,6	7,53	0,26
	15-25	0,89	0,084	44	220	14,0	7,12	0,33
	30-40						7,14	0,33
	50-60						6,87	0,29
	90-100						7,53	0,26

In the water extract of the shallow solonetz at Study Point No. 7 in Abai Region, the ions exhibit a residual pattern of accumulation. Throughout the soil profile, noticeable accumulation of soluble salts (Na^+, Cl^-, SO_4^{2-}, etc.) is observed in the solonetzic horizon, indicating the

accumulation of soluble salts in the middle horizons and the pronounced development of the residual solonetzic process. In the solonetzic horizon, the concentrations of chlorides and sulfates are 0.14 and 0.22 mg-eq per 100 g of soil, respectively. These conditions characterize the salinity of the shallow solonetzes as residual-type salinity (Table 26).

Table 26 – Ionic Composition of the Water Extract of the Shallow Solonetz in Abai Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
7	0-11		0,20	0,00	0,10	0,06	0,10	0,19	0,02	0,05
		0,026	0,012	0,000	0,004	0,003	0,002	0,002	0,001	0,002
	15-25		0,08	0,00	0,14	0,21	0,10	0,29	0,02	0,02
		0,027	0,005	0,000	0,005	0,010	0,002	0,003	0,001	0,001
	30-40		0,04	0,00	0,07	0,22	0,10	0,19	0,02	0,02
		0,021	0,002	0,000	0,002	0,011	0,002	0,002	0,001	0,001
	50-60		0,08	0,00	0,14	0,03	0,10	0,10	0,02	0,03
		0,016	0,005	0,000	0,005	0,001	0,002	0,001	0,001	0,001
	90-100		0,04	0,00	0,07	0,13	0,10	0,10	0,02	0,02
		0,016	0,002	0,000	0,002	0,006	0,002	0,001	0,001	0,001

The composition of exchangeable cations in the shallow solonetz at Study Point No. 7 in Abai Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 4.75 to 7.13 mg-eq per 100 g of soil (Table 27). At the same time, the content of Mg^{2+} is 3.48 and 5.47 mg-eq per 100 g of soil in the 0–11 and 50–60 cm layers, respectively, while Na^+ has a residual character and amounts to 0.13 mg-eq per 100 g of soil. Nevertheless, exchangeable Na^+ remains the main cause of the solonetzic process in the studied soils.

Table 27 – Composition of Exchangeable Cations in the Shallow Solonetz in Abai Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
7	0-11	4,75	3,48	0,13	0,37
	15-25	7,13	1,49	0,13	0,30
	30-40	7,13	0,99	0,13	0,30
	50-60	7,13	5,47	0,13	0,22
	90-100	4,75	0,99	0,13	0,14

The particle-size distribution data for the solonetz of the study site No. 7 in Abai Region indicate a sandy-loam texture. The content of physical clay within the soil profile ranges from 10.861 to 14.519% (Table 28). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm,

which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 28 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
7	0-11	0,56	37,550	49,175	2,414	3,620	0,805	6,436	10,861
	15-25	0,76	28,980	52,479	4,434	2,418	0,403	11,286	14,107
	30-40	0,82	31,176	45,029	9,276	4,033	0,807	9,679	14,519
	50-60	0,84	40,500	35,296	10,085	4,841	0,807	8,471	14,119
	90-100	0,50	44,764	37,950	5,226	2,010	5,226	4,824	12,060

Characteristics and Feed Value of the Vegetation Cover

Analysis of the data obtained during field studies showed that the projective plant cover of the soil surface accounted for 65% of the total area. The pasture type was identified as wormwood–sedge. The botanical composition consisted of wormwood (80%), sedge (15%), and camphorosma (5%). The yield of pasture biomass was 8.5 c/ha. The geographical coordinates were N 50°52′14.9″, E 079°29′27.3″. The chemical analysis of the plants showed that, in the air-dry state, the protein content was 14.10%, fat – 7.63%, fiber – 38.44%, nitrogen-free extractives (NFE) – 27.30%, and ash – 10.00%. The yield of feed units at natural moisture content was 0.52 feed units per kilogram of feed, while the exchange energy content was 7.37 MJ.

Kostanay Region

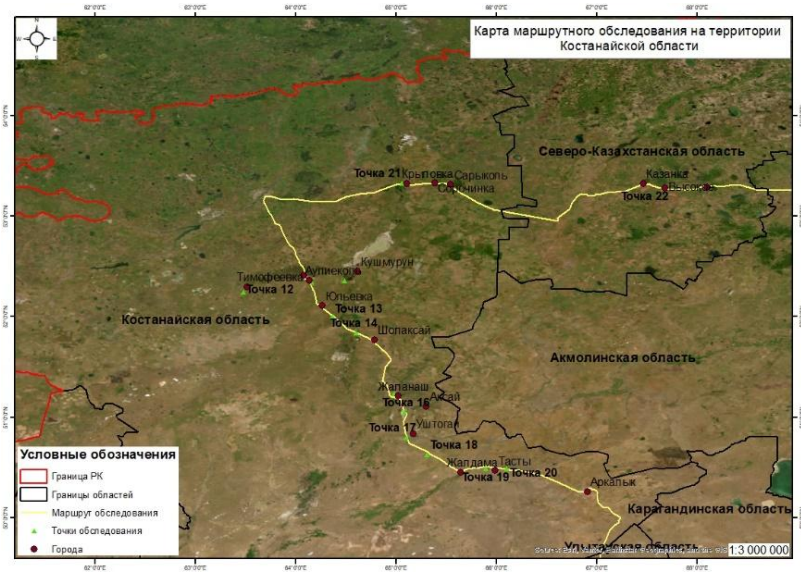


Figure 9 – Route Map for Ground-Based Survey of Solonetzic Soils on Pastures in Kostanay Region

Study Point No. 8. The soil profile was established in Kostanay Region, 3 km east of the Akmola–Kostanay highway from Aidarly settlement, and 200 m southward (19 June 2026). Coordinates: N 52°194′513″, E 065°297′767″. Elevation above sea level: 264 m. The terrain is flat (Figure 10). The plant community (land-use type) is classified as wormwood–mixed-grass. The plant species include wormwood, couch grass, plantain, bedstraw, cinquefoil, feather grass, fescue, and spurge. The landscape aspect is grayish-green. The soil type is a medium meadow solonetz. The soil profile consists of the following horizons: A, 0–15 cm; B_1, 16–30 cm; B_2, 31–47 cm; BC, 48–68 cm; C, 69–120 cm. Soil samples were collected from the following depths: 0–10 cm; 20–30 cm; 35–45 cm; 50–60 cm; and 90–100 cm.



Figure 10 – General View of the Surface and Its Vegetation Morphological Characteristics of the Medium Meadow Solonetz.

 Profile Structure of the Medium Meadow Solonetz	A 0–15 cm – grayish-brown, fresh, loose, with abundant plant roots; loamy, cloddy-granular; effervesces with HCl; clear transition by density. B_1 16–30 cm – brown, fresh, dense, cloddy-prismatic, roots present; effervesces with HCl; heavy loam; gradual transition. B_2 31–47 cm – dark gray, fresh, dense, cloddy, heavy loam; roots present; effervesces with HCl; gradual transition. BC 48–68 cm – lighter than the preceding horizon, fresh, compacted, structureless, clayey; vigorous effervescence with HCl; single plant roots. C 69–120 cm – light brown, fresh, compacted, structureless, clayey; vigorous effervescence with HCl.

The chemical composition data for the medium meadow solonetz at Study Point No. 8 in Kostanay Region show that the humus content in the upper horizons ranges from 3.02 to 2.34% (Table 29). The CO_2 content of carbonates ranges from 1.96 to 4.74%. The maximum value was recorded in the parent material (4.74%), while the minimum value was observed in the upper horizon. The total nitrogen content ranges from 0.252 to 0.182%, while its hydrolysable form ranges from 39.2 to 33.6 mg/kg. The available forms of phosphorus and potassium are 52.0–12.0 and 770–270 mg/kg, respectively. The pH value ranges from 8.03 to 8.94, with the maximum values observed in the lower horizons, indicating an alkaline reaction of the soil as a whole.

Table 29 – Chemical Composition of the Medium Meadow Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
8	0-10	3,02	0,252	52	770	39,2	8,03	1,96
	20-30	2,34	0,182	12	270	33,6	8,16	2,22
	35-45						8,39	2,71
	50-60						8,64	3,83
	90-100						8,94	4,74

In the water extract of the medium meadow solonetz at Study Point No. 8 in Kostanay Region, soda is present in the lower horizons (50–60 and 90–100 cm). The concentrations of bicarbonate and carbonate ions in these layers are 0.84–1.16 and 0.08–0.16 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the lower horizons (1.11–1.37 mg-eq per 100 g of soil). Therefore,

these conditions characterize the salinity of the studied solonetzes as soda-type salinity. In addition, a gradual increase in sulfate ions is observed in the lower horizons, reaching 0.79 mg-eq per 100 g of soil. Throughout the soil profile, the maximum accumulation of salts (0.102–0.154%) is observed in the second half-meter layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the soda process in the middle and lower parts of the soil profile (Table 30).

Table 30 – Ionic Composition of the Medium Meadow Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
8	0-10		0,44	0,00	0,14	0,16	0,29	0,38	0,02	0,04
		0,052	0,027	0,000	0,005	0,007	0,006	0,005	0,001	0,002
	20-30		0,52	0,00	0,14	0,19	0,19	0,38	0,26	0,02
		0,061	0,032	0,000	0,005	0,009	0,004	0,005	0,006	0,001
	35-45		0,64	0,00	0,10	0,39	0,10	0,29	0,73	0,02
		0,085	0,039	0,000	0,004	0,019	0,002	0,003	0,017	0,001
	50-60		0,84	0,08	0,17	0,31	0,10	0,10	1,11	0,02
		0,102	0,051	0,002	0,006	0,015	0,002	0,001	0,026	0,001
	90-100		1,16	0,16	0,10	0,79	0,10	0,57	1,37	0,02
		0,154	0,071	0,005	0,004	0,038	0,002	0,007	0,031	0,001

The composition of exchangeable cations in the medium solonetz at Study Point No. 8 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile decreases from 23.28 to 11.88 mg-eq per 100 g of soil (Table 31). At the same time, the content of Mg^{2+} increases sharply in the solonetzic horizon, reaching 10.44 mg-eq per 100 g of soil, which may indicate possible magnesium solonetzicity. The content of exchangeable Na^+ is residual in nature and amounts to 0.04 mg-eq per 100 g of soil in the 20–30 cm layer. The highest content of exchangeable K^+ is observed in the humus horizon, amounting to 0.56 mg-eq per 100 g of soil.

Table 31 – Composition of Exchangeable Cations of the Medium Meadow Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
8	0-10	23,28	5,96	0,13	0,56
	20-30	22,33	10,44	0,04	0,14
	35-45	19,00	7,46	0,17	0,14
	50-60	15,20	13,92	0,37	0,14
	90-100	11,88	8,95	2,01	0,14

The particle-size distribution data for the medium solonetz of the study site No. 8 in

Kostanay Region indicate a light-clay texture. The content of physical clay within the soil profile ranges from 63.723 to 69.223% (Table 32). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 32 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
8	0-10	3,96	0,646	11,474	24,157	24,573	3,332	35,818	63,723
	20-30	3,96	0,333	5,123	30,820	9,996	24,990	28,738	63,723
	35-45	4,06	0,667	10,110	24,599	10,423	14,176	40,025	64,624
	50-60	3,50	0,477	10,819	19,482	12,850	18,238	38,135	69,223
	90-100	1,32	0,385	11,654	22,294	17,430	8,107	40,130	65,667

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this solonetzic site accounted for 75% of the total area. The pasture type was identified as wormwood–mixed-grass. The botanical composition consisted of wormwood (65%), couch grass (20%), plantain (5%), bedstraw (5%), and cinquefoil (5%) of the total area. In addition, feather grass, fescue, and spurge were also widespread. The yield of pasture biomass was 11.3 c/ha. The geographical coordinates were N 52°11′674″, E 065°17′867″. The chemical composition of the forage showed that, in the air-dry state, the protein content was 14.41%, fat – 6.42%, fiber – 36.52%, nitrogen-free extractives (NFE) – 27.48%, and ash – 11.83%. The yield of feed units at natural moisture content was 0.50 feed units per kilogram of feed, while the exchange energy content was 7.17 MJ.

Study Point No. 9. The soil study was conducted on 19 June 2026. The soil profile was established 500 m east of Zhuzbai settlement and 700 m northwest of the river. Profile coordinates: N 52°334′424″, E 064°561′630″. The surface elevation is 114 m. The terrain is gently undulating (Figure 11). The plant community (land-use type) is classified as wormwood–grass. The plant species include wormwood, alkali grass, bluegrass, Martyuk grass, and kokpek. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The soil profile consists of the following horizons: A, 0–11 cm; B_1, 12–21 cm; B_2, 22–36 cm; BC, 37–68 cm; C, 69–120 cm. Soil samples were collected from the following depths: 0–10 cm; 10–20 cm; 25–35 cm; 50–60 cm; and 110–120 cm.

Morphological Characteristics of the Shallow Solonetz

 Profile Structure of the Shallow Solonetz	A 0–11 cm – dark gray, dry, cloddy-granular, loamy, loose, penetrated by roots; effervesces with HCl toward the bottom; clear transition. B_1 12–21 cm – dark brown, dry, dense, columnar-nutty, heavy loam; effervesces with HCl; roots present toward the bottom; accumulation of salts; abrupt transition. B_2 22–36 cm – brown, moist, slightly compacted, light clay, cloddy; single roots; effervesces with HCl; gradual transition. BC 37–68 cm – darker than the preceding horizon, moist, compacted, clayey, structureless; vigorous effervescence with HCl; clear transition by color. C 69–120 cm – brown with gypsum rosettes, moist, slightly compacted, structureless, clayey; vigorous effervescence with HCl.



Figure 11 – General View of the Surface and Its Vegetation

The chemical composition data for the shallow solonetz at Study Point No. 9 in Kostanay Region show that the humus content in the upper horizons ranges from 1.48 to 1.09% (Table 33). The CO_2 content of carbonates ranges from 0.19 to 4.09%. The maximum value was recorded in the parent material (4.09%), while the minimum value was observed in the upper horizon (0.19%). The total nitrogen content is 0.126%, while its hydrolysable form ranges from 47.6 to 42.0 mg/kg. The available phosphorus content is 32.0 mg/kg, while the available potassium content ranges from 380 to 510 mg/kg. The pH value ranges from 7.78 to 8.35, with the maximum values observed in the lower horizons, indicating an alkaline reaction of the soil beginning from the solonetzic horizon.

Table 33 – Chemical Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
9	0-10	1,48	0,126	32	380	47,6	7,78	0,19
	10-20	1,09	0,126	32	510	42,0	8,27	0,55
	25-35						8,35	3,11
	50-60						8,19	1,86
	110-120						8,30	4,09

In the water extract of the shallow solonetz at Study Point No. 9 in Kostanay Region, alternating predominance of chloride and sulfate ions is observed throughout the soil profile. The concentration of chloride ions first increases sharply and then gradually from the soil surface downward, ranging from 2.97 to 18.36 mg-eq per 100 g of soil. A somewhat different distribution pattern is observed for sulfate ions. Their concentration initially increases gradually from 3.82 to 9.57 mg-eq per 100 g of soil, followed by a sharp increase to a maximum of 26.16 mg-eq per 100 g of soil in the middle part of the profile. These conditions characterize the salinity of the shallow solonetzes as very strongly expressed chloride–sulfate type salinity. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the middle and lower horizons (6.48–27.00 mg-eq per 100 g of soil). Throughout the profile, maximum accumulation of toxic ions (Na^+, Cl^-, SO_4^{2-}, etc.) is observed practically throughout the entire soil profile, indicating the accumulation of soluble salts and the pronounced development of the solonetzic process (Table 34).

Table 34 – Ionic Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
9	0-10		0,32	0,00	2,97	3,82	0,10	0,48	6,48	0,06
		0,468	0,020	0,000	0,105	0,183	0,002	0,006	0,149	0,003
	10-20		0,76	0,16	15,91	9,57	0,86	1,24	24,09	0,05
		1,659	0,046	0,005	0,564	0,460	0,017	0,015	0,554	0,002
	25-35		0,36	0,00	16,09	26,16	13,33	3,33	25,91	0,04
		2,753	0,022	0,000	0,570	1,256	0,267	0,040	0,596	0,002
	50-60		0,32	0,00	16,96	23,54	10,00	3,80	27,00	0,02
		2,619	0,020	0,000	0,601	1,130	0,200	0,046	0,621	0,001
	110-120		0,44	0,04	18,36	9,51	0,95	1,43	25,91	0,02
		1,768	0,027	0,001	0,651	0,457	0,019	0,017	0,596	0,001

The composition of exchangeable cations in the shallow solonetz at Study Point No. 9 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile

ranges from 5.23 to 27.55 mg-eq per 100 g of soil (Table 35). At the same time, the contents of Mg^{2+} and Na^{+} in the solonetzic horizon are high, amounting to 9.94 and 9.46 mg-eq per 100 g of soil, respectively. The increase in the proportion of exchangeable Na^{+} relative to the cation exchange capacity (CEC), particularly in the B_1 solonetzic horizon, indicates an increase in the sodium saturation of the exchange complex and a more pronounced development of the solonetzic process.

Table 35 – Composition of Exchangeable Cations in the Shallow Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
9	0-10	5,23	4,47	0,19	0,29
	10-20	10,45	9,94	9,46	0,32
	25-35	17,40	8,95	7,35	0,09
	50-60	27,55	7,95	8,76	0,04
	110-120	7,13	12,43	21,05	0,14

The particle-size distribution data for the solonetz of the study site No. 9 in Kostanay Region indicate a medium- to heavy-loamy texture. The content of physical clay within the soil profile ranges from 9.422 to 54.031% (Table 36). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 110–120 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 36 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
9	0-10	4,12	8,114	59,762	11,264	7,509	6,258	7,092	20,859
	10-20	6,72	2,916	30,617	12,436	0,429	9,863	43,739	54,031
	25-35	6,60	9,443	33,169	47,966	2,570	2,141	4,711	9,422
	50-60	3,18	5,391	44,206	10,328	2,066	9,915	28,093	40,074
	110-120	3,82	20,732	15,221	13,724	8,734	10,813	30,776	50,322

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site accounted for 70% of the total area. The pasture type was identified as wormwood–grass. The botanical composition consisted of wormwood (60%), alkali grass (20%), kokpek (10%), bluegrass (5%), and martyuk grass (5%) of the total area. The yield of pasture biomass was 12.8 c/ha. The geographical coordinates were

N 52°20′06.4″, E 064°33′70.0″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 15.00%, fat – 6.92%, fiber – 37.00%, nitrogen-free extractives (NFE) – 29.63%, and ash – 8.51%. The yield of feed units at natural moisture content was 0.53 feed units per kilogram of feed, while the exchange energy content was 7.59 MJ.

Study Point No. 10. The study site is located in Auliekol District of Kostanay Region. The soil profile was established on 20 June 2025, 400 m south of Akkuduk settlement and 2.5 km west of the Auliekol–Torgai highway. Profile coordinates: N 52°222′908″; E 064°174′586″. Elevation above sea level: 207 m. The terrain is flat (Figure 12). The plant community (land-use type) is classified as wormwood-dominated. The plant species include wormwood, martyuk grass, bluegrass, cinquefoil, fescue, and single plants of crested wheatgrass. The landscape aspect is greenish-gray. The soil type is a medium solonetz. The soil profile consists of the following horizons: A, 0–15 cm; B_1, 16–32 cm; B_2, 33–48 cm; BC, 49–74 cm; C, 75–110 cm. Soil samples were collected from the following depths: 0–10 cm; 20–30 cm; 35–45 cm; 50–60 cm; and 85–95 cm.

Morphological Characteristics of the Medium Solonetz.

 Profile Structure of the Medium Solonetz	A 0–15 cm – dark brown, dry, cloddy-dusty, loamy, loose, with abundant roots; does not effervesce with HCl; abrupt transition by density. B_1 16–32 cm – dark brown, dry, prismatic-cloddy, loamy, dense, roots present; does not effervesce with HCl; gradual transition. B_2 33–48 cm – dark brown, fresh, cloddy, loamy, dense, single roots; does not effervesce with HCl; gradual transition. BC 49–74 cm – brown, fresh, dense, structureless, loamy; does not effervesce with HCl; gradual transition. C 75–110 cm – brown with a yellowish tint, fresh, dense, loamy, with carbonate spots; vigorous effervescence with HCl.

The chemical composition data for the medium solonetz at Study Point No. 10 in Kostanay Region show that the humus content in the upper horizons ranges from 1.20 to 1.57% (Table 37). The CO_2 content of carbonates ranges from 0.33 to 0.46%. The maximum value was recorded in the parent material (0.46%), while the minimum value was observed in the upper horizons (0.33%).



Figure 12 – General View of the Surface and Its Vegetation

The total nitrogen content ranges from 0.084 to 0.098%, while its hydrolysable form ranges from 14.0 to 22.4 mg/kg. The available forms of phosphorus and potassium are 44.0–20.0 and 310–470 mg/kg, respectively. The pH value ranges from 7.12 to 7.97, with the maximum values observed in the lower horizons, indicating a slightly alkaline reaction of the soil.

Table 37 – Chemical Composition of the Medium Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
10	0-10	1,20	0,084	44	310	14,0	7,12	0,33
	20-30	1,57	0,098	20	470	22,4	7,55	0,33
	35-45						7,69	0,33
	50-60						7,97	0,39
	85-95						7,75	0,46

In the water extract of the medium solonetz at Study Point No. 10 in Kostanay Region, residual salinity is observed. Throughout the soil profile, the maximum accumulation of salts is recorded in the parent material (0.155%), indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the residual solonetzic process. In the anion composition of this layer, the concentrations of chloride and sulfate ions increase noticeably, reaching 0.35 and 1.76 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the lower horizons (0.32–0.52 mg-eq per 100 g of soil). These conditions characterize the salinity of the studied solonetzes as deep, weak sulfate-type salinity (Table 38).

Table 38 – Ionic Composition of the Medium Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
10	0-10		0,12	0,00	0,10	0,08	0,10	0,10	0,02	0,09
		0,022	0,007	0,000	0,004	0,004	0,002	0,001	0,001	0,003
	20-30		0,12	0,00	0,10	0,10	0,10	0,10	0,02	0,11
		0,024	0,007	0,000	0,004	0,005	0,002	0,001	0,001	0,004
	35-45		0,20	0,00	0,14	0,07	0,19	0,10	0,06	0,06
		0,029	0,012	0,000	0,005	0,003	0,004	0,001	0,001	0,003
	50-60		0,20	0,00	0,21	0,32	0,10	0,29	0,32	0,03
		0,049	0,012	0,000	0,007	0,015	0,002	0,003	0,007	0,001
	85-95		0,24	0,00	0,35	1,76	1,14	0,67	0,52	0,02
		0,155	0,015	0,000	0,012	0,084	0,023	0,008	0,012	0,001

The composition of exchangeable cations in the medium solonetz at Study Point No. 10 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 4.28 to 9.03 mg-eq per 100 g of soil (Table 39). At the same time, the content of Mg^{2+} ranges from 1.49 to 4.47 mg-eq, Na^+ from 0.04 to 0.27 mg-eq, and K^+ from 0.14 to 0.49 mg-eq per 100 g of soil. Despite the residual nature of exchangeable Na^+, particularly in the B_1 solonetzic horizon, it remains the main factor responsible for the solonetzic process.

Table 39 – Composition of Exchangeable Cations of the Medium Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
10	0-10	4,28	2,49	0,13	0,26
	20-30	7,60	2,98	0,11	0,49
	35-45	7,13	4,47	0,04	0,36
	50-60	8,55	3,98	0,11	0,14
	85-95	9,03	1,49	0,27	0,14

The particle-size distribution data for the medium solonetz of the study site No. 10 in Kostanay Region indicate a light-loamy to sandy-loam texture. The content of physical clay within the soil profile ranges from 26.978 to 16.606% (Table 40). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 85–95 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 40 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
10	0-10	0,66	18,603	48,379	6,040	1,611	5,637	19,730	26,978
	20-30	1,24	26,002	50,506	6,885	1,620	2,835	12,151	16,606
	35-45	1,28	34,279	40,194	4,052	1,621	6,078	13,776	21,475
	50-60	1,50	30,904	43,919	2,030	1,218	6,904	15,025	23,147
	85-95	1,20	40,870	39,291	1,215	4,453	1,215	12,955	18,623

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site accounted for 70% of the total area. The pasture type was identified as wormwood-dominated. The botanical composition consisted of wormwood (90%), martyuk grass (5%), and bluegrass (5%). In addition, cinquefoil, fescue, and single plants of crested wheatgrass were also observed. The yield of pasture biomass was 15.0 c/ha. The geographical coordinates were N 52°13′37.3″, E 064°10′47.6″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 16.90%, fat – 6.82%, fiber – 36.41%, nitrogen-free extractives (NFE) – 22.94%, and ash – 13.62%. The yield of feed units at natural moisture content was 0.49 feed units per kilogram of feed, while the exchange energy content was 7.30 MJ.

Study Point No. 11. The soil profile was established on 20 June 2026 in Kostanay Region. The profile is located 400 m east of Yulyevka settlement and 200 m south of the road leading toward Yulyevka. Profile coordinates: N 52°108′604″; E 064°259′007″. The terrain is a gently undulating plain (Figure 13). The elevation is 162 m. The plant community (land-use type) is classified as wormwood-dominated. The plant species include wormwood, martyuk grass, sedge, ebelek, bird's knotweed, and saltwort. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The soil profile consists of the following horizons: A, 0–10 cm; B_1, 11–23 cm; B_2, 24–35 cm; BC, 36–67 cm; C, 68–120 cm. Soil samples were collected from the following depths: 0–10 cm; 10–20 cm; 20–30 cm; 50–60 cm; and 90–100 cm.

The chemical composition data for the shallow solonetz at Study Point No. 11 in Kostanay Region show that the humus content in the upper horizons ranges from 0.49 to 0.63% (Table 41). The CO_2 content of carbonates ranges from 0.33 to 0.42%. The maximum value was recorded in the middle horizon (0.42%), while the minimum value was observed in the upper horizon.

Morphological Characteristics of the Shallow Solonetz

 Profile Structure of the Shallow Solonetz	A 0–10 cm – gray, dry, granular-dusty, with abundant roots; light loam, loose; does not effervesce with HCl; noticeable transition by color. B_1 11–23 cm – brown, dry, dense, cloddy, loamy, with roots; does not effervesce with HCl; gradual transition; small salt spots are observed. B_2 24–35 cm – darker than the preceding horizon, dry, cloddy, loamy, dense, with roots; individual salt specks; does not effervesce with HCl; gradual transition. BC 36–67 cm – dark brown, dry, structureless, loamy, compacted, with single roots; salt specks are present; does not effervesce with HCl; gradual transition. C 68–120 cm – brown with a yellowish tint, fresh, structureless, loamy, compacted; does not effervesce with HCl.



Figure 13 – General View of the Surface and Its Vegetation

The total nitrogen content ranges from 0.084 to 0.098%, while its hydrolysable form is 14.0 mg/kg. The available forms of phosphorus and potassium are 60.0–78.0 and 430–470 mg/kg, respectively. The pH value ranges from 6.26 to 7.54, with the maximum value recorded in the middle horizon, indicating a neutral to slightly alkaline reaction of the soil.

The composition of the water extract of the shallow solonetz at Study Point No. 11 in Kostanay Region is characterized by residual salinity, since the total content of water-soluble

salts throughout the soil profile does not exceed 0.1% (Table 42).

Table 41 – Chemical Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
11	0-10	0,49	0,084	60	430	14	7,27	0,39
	10-20	0,63	0,098	78	470	14	7,48	0,33
	20-30						7,51	0,42
	50-60						6,26	0,36
	90-100						7,49	0,39

Among the anions, chloride ions predominate, with concentrations of 0.17–0.24 mg-eq per 100 g of soil, respectively. Among the cations, potassium is present in the highest concentration, with maximum values recorded in the middle and lower horizons (0.32–0.30 mg-eq per 100 g of soil). Thus, the accumulation of salts throughout the profile of the shallow solonetz is characterized as residual.

Table 42 – Ionic Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
11	0-10		0,12	0,00	0,14	0,15	0,10	0,10	0,02	0,19
		0,031	0,007	0,000	0,005	0,007	0,002	0,001	0,001	0,008
	10-20		0,12	0,00	0,07	0,20	0,10	0,10	0,02	0,17
		0,030	0,007	0,000	0,002	0,009	0,002	0,001	0,001	0,007
	20-30		0,16	0,00	0,17	0,30	0,10	0,19	0,02	0,32
		0,048	0,010	0,000	0,006	0,014	0,002	0,002	0,001	0,013
	50-60		0,08	0,00	0,24	0,18	0,10	0,10	0,02	0,29
		0,037	0,005	0,000	0,009	0,009	0,002	0,001	0,001	0,011
	90-100		0,16	0,00	0,14	0,22	0,10	0,10	0,02	0,30
		0,040	0,010	0,000	0,005	0,010	0,002	0,001	0,001	0,012

Table 43 – Composition of Exchangeable Cations of the Shallow Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
11	0-10	3,80	0,00	0,27	0,25
	10-20	4,28	0,00	0,13	0,31
	20-30	6,65	0,00	0,13	0,62
	50-60	5,70	0,00	0,13	0,38
	90-100	5,23	2,49	0,13	0,78

The composition of exchangeable cations in the shallow solonetz at Study Point No. 11 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 3.80 to 6.65 mg-eq per 100 g of soil (Table 43). At the same time, Mg^{2+} is absent from the exchange complex down to the parent material, while Na^{+} has a residual character and amounts to 0.13 mg-eq per 100 g of soil in the solonetzic and subsolonetzic horizons. Although the sodium saturation of the exchange complex is relatively low, it indicates the presence of a pronounced solonetzic process.

The particle-size distribution data for the solonetz of the study site No. 11 in Kostanay Region indicate a sandy texture. The content of physical clay within the soil profile ranges from 6.431 to 15.292% (Table 44). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 44 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
11	0-10	0,42	58,646	29,705	4,820	2,008	3,615	1,205	6,829
	10-20	0,48	45,358	47,809	0,402	1,206	4,019	1,206	6,431
	20-30	0,72	29,573	57,937	2,820	1,209	5,238	3,223	9,670
	50-60	0,60	38,612	45,694	0,402	8,048	4,427	2,817	15,292
	90-100	2,40	53,053	32,602	2,049	1,230	6,148	4,918	12,295

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site did not exceed 75% of the total area. The pasture type was identified as wormwood-dominated. The botanical composition consisted of wormwood (95%), martyuk grass (3%), and sedge (2%). Single specimens of ebelek, bird's knotweed, and saltwort were also observed. The yield of pasture biomass was 14.0 c/ha. The geographical coordinates were N 52°06′51.5″, E 064°15′54.2″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 16.42%, fat – 7.23%, fiber – 34.81%, nitrogen-free extractives (NFE) – 28.50%, and ash – 10.41%. The yield of feed units at natural moisture content was 0.54 feed units per kilogram of feed, while the exchange energy

content was 7.79 MJ.

Study Point No. 12. The study was conducted on 20 June 2026 between Yulyeva and Shomeksaya settlements in Kostanay Region. The soil profile was established 300 m south of the Auliekol–Torgai highway. Profile coordinates: N 52°050′146″; E 064°314′076″. Elevation above sea level: 174 m. The terrain is flat (Figure 14). The plant community (land-use type) is classified as wormwood-dominated. The plant species include wormwood, crested wheatgrass, Climacoptera, yarrow, Platyplodnik, and horse sorrel. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The soil profile consists of the following horizons: A, 0–9 cm; B_1, 10–24 cm; B_2, 25–37 cm; BC, 38–53 cm; C, 54–100 cm. Soil samples were collected from the following depths: 0–9 cm; 12–22 cm; 25–35 cm; 40–50 cm; and 80–90 cm.

Morphological Characteristics of the Shallow Solonetz.

 Profile Structure of the Shallow Solonetz	A 0–9 cm – light gray, dry, cloddy-granular, loamy, loose, with roots; does not effervesce with HCl; abrupt transition by color and density. B_1 10–24 cm – dark brown, dry, columnar, heavy loam, very dense, with roots; does not effervesce with HCl; clear transition. B_2 25–37 cm – brown, dry, dense, clayey, cloddy, with fine roots; does not effervesce with HCl; gradual transition. BC 38–53 cm – lighter than the preceding horizon, dry, dense, clayey, structureless, with fine roots; does not effervesce with HCl; gradual transition. C 54–100 cm – light brown, fresh, structureless, compacted, clayey; slightly effervesces with HCl.



Figure 14 – General View of the Surface and Its Vegetation

The chemical composition data for the shallow solonetz at Study Point No. 12 in Kostanay Region show that the humus content in the upper horizons ranges from 2.36 to 1.78% (Table 45). The CO_2 content of carbonates ranges from 0.29 to 0.98%. The maximum value was recorded in the parent material (0.98%), while the minimum value was observed in the upper horizon. The total nitrogen content ranges from 0.154 to 0.126%, while its hydrolysable form ranges from 28.0 to 19.6 mg/kg. The available forms of phosphorus and potassium are 24.0–10.0 and 900–470 mg/kg, respectively. The pH value ranges from 6.91 to 8.05, with the maximum values recorded in the lower horizons, indicating an alkaline reaction of the soil in this part of the profile.

Table 45 – Chemical Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
12	0-9	2,36	0,154	24	900	28,0	6,91	0,33
	12-22	1,78	0,126	10	470	19,6	6,91	0,42
	25-35						7,62	0,29
	40-50						7,96	0,33
	80-90						8,05	0,98

In the water extract of the shallow solonetz at Study Point No. 12 in Kostanay Region, a gradual increase in salt content, reaching 0.699%, is observed down the soil profile. The maximum salt content is recorded in the parent material. In the lower horizons, chlorides and sulfates predominate among the anions, with concentrations of 1.64–4.02 and 3.27–6.32 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the lower horizons (4.03–7.69 mg-eq per 100 g of soil). These conditions characterize the salinity of the shallow solonetzes as a deep chloride-sulfate type. The maximum accumulation of soluble ions (Na^+ and others) is observed within the 40–90 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the solonetzic process (Table 46).

The composition of exchangeable cations in the shallow solonetz at Study Point No. 12 in Kostanay Region is characterized by the predominance of Mg^{2+}. Its content increases with depth from 15.90 to 24.35 mg-eq per 100 g of soil (Table 47). At the same time, the content of Ca^{2+} is relatively high (10.93 mg-eq per 100 g of soil) in the solonetzic and suprasolonetzic horizons. The content of exchangeable Na^+ increases with depth, reaching 1.28 mg-eq per 100 g of soil.

The increased proportion of exchangeable Na^+ in the B_1 solonetzic horizon, particularly in the subsolonetzic horizons, indicates an increase in sodium saturation of the exchange complex and a pronounced solonetzic process.

Table 46 – Ionic Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
12	0-9		0,20	0,00	0,14	0,76	0,10	0,48	0,44	0,09
		0,075	0,012	0,000	0,005	0,037	0,002	0,006	0,010	0,003
	12-22		0,16	0,00	0,24	0,65	0,10	0,38	0,55	0,02
		0,069	0,010	0,000	0,009	0,031	0,002	0,005	0,013	0,001
	25-35		0,20	0,00	0,42	0,94	0,10	0,48	0,97	0,02
		0,103	0,012	0,000	0,015	0,045	0,002	0,006	0,022	0,001
	40-50		0,28	0,00	1,64	3,27	0,19	0,95	4,03	0,02
		0,341	0,017	0,000	0,058	0,157	0,004	0,012	0,093	0,001
	80-90		0,52	0,04	4,02	6,32	0,67	2,48	7,69	0,02
		0,699	0,032	0,001	0,143	0,303	0,013	0,030	0,177	0,001

Table 47 – Composition of Exchangeable Cations of the Shallow Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
12	0-9	10,93	15,90	0,06	0,86
	12-22	10,93	17,40	0,45	0,35
	25-35	7,60	21,87	0,88	0,12
	40-50	5,23	23,36	1,28	0,14
	80-90	5,23	24,35	0,31	0,12

The particle-size distribution data for the solonetz of the study site No. 12 in Kostanay Region indicate a light-clay to heavy-loam texture. The content of physical clay within the soil profile ranges from 73.023 to 50.791% (Table 48).

Table 48 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
12	0-9	3,68	3,696	18,646	11,628	4,983	30,316	30,731	66,030
	12-22	3,92	2,394	18,505	28,310	7,077	12,490	31,224	50,791
	25-35	4,14	2,420	17,463	7,094	5,007	37,555	30,461	73,023
	40-50	4,22	2,213	16,350	14,199	6,264	32,992	27,981	67,237

	80-90	4,22	2,067	18,584	7,935	5,847	36,333	29,234	71,414

At the same time, the particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 80–90 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site accounted for 75% of the total area. The pasture type was identified as wormwood–crested wheatgrass. The botanical composition consisted of wormwood (70%), crested wheatgrass (20%), Climacoptera (6%), and yarrow (4%). Single specimens of Platyplodnik, horse sorrel, feather grass, and saltwort were also observed. The yield of pasture biomass was 20.5 c/ha. The geographical coordinates were N 52°03′00.6″, E 064°18′84.6″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 15.93%, fat – 6.31%, fiber – 34.51%, nitrogen-free extractives (NFE) – 30.60%, and ash – 9.91%. The yield of feed units at natural moisture content was 0.54 feed units per kilogram of feed, while the exchange energy content was 7.70 MJ.

Study Point No. 13. Field studies were conducted on 20 June 2026 in Kostomar (Semenovka) settlement, Kostanay District, Kostanay Region. The soil profile was established 800 m west of Kostomar settlement and 600 m east of the Auliekol–Kostanay highway. Profile coordinates: N 52°822′525″; E 063°883′803″. Elevation above sea level: 210 m. The terrain is a plain (Figure 15). The plant community (land-use type) is classified as wormwood–ephemeral. The plant species include wormwood, alyssum, martyuk grass, and single specimens of ebelek, crested wheatgrass, and feather grass. The landscape aspect is gray. The soil type is a shallow solonetz. The soil profile consists of the following horizons: A, 0–8 cm; B_1, 9–22 cm; B_2, 23–36 cm; BC, 37–52 cm; C, 53–120 cm. Soil samples were collected from the following depths: 0–8 cm; 10–20 cm; 25–35 cm; 40–50 cm; and 80–90 cm.



Figure 15 – General View of the Surface and Its Vegetation Morphological Characteristics of the Shallow Solonetz.

 Profile Structure of the Shallow Solonetz	A 0–8 cm – dark gray, dry, cloddy-dusty, loamy, loose, with abundant roots; strongly effervesces with HCl; abrupt transition by color and density. B_1 9–22 cm – dark brown, dry, very dense, columnar, penetrated by roots, heavy loam; strongly effervesces with HCl; clear transition. B_2 23–36 cm – brown, with accumulations of carbonate white-eye spots, fresh, dense, clayey, cloddy; effervesces with HCl; single fine roots; gradual transition. BC 37–52 cm – dark brown, with carbonate accumulations, fresh, clayey, structureless, compacted; gradual transition. C 53–120 cm – brown, moist, structureless, clayey, slightly compacted; effervesces with HCl; carbonate spots are observed.

The chemical composition data for the shallow solonetz at Study Point No. 13 in Kostanay Region show that the humus content in the upper horizons ranges from 2.43 to 1.95% (Table 49). The CO_2 content of carbonates ranges from 1.31 to 2.45%. The maximum value was recorded in the parent material (2.45%), while the minimum value was observed in the middle horizons (1.31%). The total nitrogen content ranges from 0.182 to 0.140%, while its hydrolysable form ranges from 47.6 to 64.4 mg/kg. The available forms of phosphorus and potassium are 14.0–12.0 and 920–660 mg/kg, respectively. The pH value ranges from 7.49 to 8.21, with the maximum values recorded in the upper horizons, indicating an alkaline reaction of the soil.

Table 49 – Chemical Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
13	0-8	2,43	0,182	14	920	47,6	8,21	1,41
	10-20	1,95	0,140	12	660	64,4	8,13	1,67
	25-35						7,57	1,31
	40-50						7,49	1,31
	80-90						7,56	2,45

In the water extract of the shallow solonetz at Study Point No. 13 in Kostanay Region, chloride and sulfate ions predominate in the subsolonetzic horizons. Their concentrations increase with depth down the soil profile, from 0.35 to 3.50 mg-eq and from 0.98 to 30.56 mg-eq per 100 g of soil, respectively. Among the cations, sodium and magnesium are present in the highest concentrations, with maximum values recorded in the middle and lower horizons (6.97–7.51 and 7.62–8.09 mg-eq per 100 g of soil, respectively). These conditions characterize the salinity of the shallow solonetzes as a chloride-sulfate type of strong salinity. The maximum accumulation of soluble ions (Na^+ and others) is observed within the 25–90 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the solonetzic process throughout the soil profile (Table 50).

Table 50 – Ionic Composition of the Shallow Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
13	0-8		0,56	0,00	0,07	0,64	0,19	0,38	0,57	0,13
		0,094	0,034	0,000	0,002	0,031	0,004	0,005	0,013	0,005
	10-20		0,60	0,00	0,35	0,98	0,19	0,57	1,08	0,09
		0,135	0,037	0,000	0,012	0,047	0,004	0,007	0,025	0,003
	25-35		0,32	0,00	3,15	25,64	13,80	7,62	6,97	0,72
		1,919	0,020	0,000	0,112	1,231	0,276	0,093	0,160	0,028
	40-50		0,36	0,00	3,50	24,30	13,33	7,14	6,78	0,90
		1,857	0,022	0,000	0,124	1,166	0,267	0,087	0,156	0,035
	80-90		0,24	0,00	2,97	30,56	16,18	8,09	7,51	1,98
		2,259	0,015	0,000	0,105	1,467	0,324	0,098	0,173	0,077

The composition of exchangeable cations in the shallow solonetz at Study Point No. 13 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 18.05 to 39.90 mg-eq per 100 g of soil (Table 51). The content of Mg^{2+} ranges from 5.47 to 12.43 mg-eq, Na^+ from 0.03 to 3.53 mg-eq, and K^+ from 0.71 to 1.40 mg-eq per 100 g of

soil. The residual character of exchangeable Na^+ in the upper horizons, particularly in the B_1 solonetzic horizon, indicates a relict solonetzic process.

Table 51 – Composition of Exchangeable Cations of the Shallow Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
13	0-8	19,48	6,46	0,06	1,29
	10-20	18,05	9,94	0,04	0,84
	25-35	39,90	5,47	0,03	1,40
	40-50	29,32	11,43	2,89	0,71
	80-90	29,45	12,43	3,53	0,66

The particle-size distribution data for the solonetz of the study site No. 13 in Kostanay Region indicate a light-clay texture. The content of physical clay within the soil profile ranges from 61.411 to 53.605% (Table 52). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 80–90 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 52 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
13	0-8	3,54	6,386	30,997	2,073	4,976	32,760	22,807	60,543
	10-20	3,62	11,351	24,735	2,905	7,470	31,127	22,411	61,009
	25-35	3,74	6,462	27,883	12,051	6,649	22,439	24,517	53,605
	40-50	3,70	7,290	24,590	8,307	6,646	29,076	24,091	59,813
	80-90	3,60	7,137	12,780	18,672	5,394	30,290	25,726	61,411

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface accounted for 75% of the total area. The pasture type was identified as wormwood–ephemeral. The botanical composition consisted of wormwood (70%), alyssum (20%), and martyuk grass (10%). The yield of pasture biomass was 17.0 c/ha. The geographical coordinates were N 52°49′35.2″, E 063°53′02.5″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 16.43%, fat – 6.00%, fiber – 31.00%, nitrogen-free extractives (NFE) – 33.27%, and ash – 10.32%. The yield of feed units at natural moisture content was 0.56 feed units per kilogram of feed, while the

exchange energy content was 7.95 MJ.

Study Point No. 14. The soil profile was established on 21 June 2026, 5 km northwest of Karaoba settlement and 400 m south of the Kostanay–Sarykol highway, in Aktobe District, Kostanay Region. Profile coordinates: N 53°316′224″; E 065°035′295″. Elevation above sea level: 103 m. The terrain is a plain (Figure 16). The plant community (land-use type) is classified as crupina–fescue–feather grass–wormwood with participation of meadowsweet. The plant species include crupina, fescue, feather grass, meadowsweet, speedwell, yellow alfalfa, yarrow, izen, and wormwood. The landscape aspect is grayish-green. The soil type is a medium solonetz. The soil profile consists of the following horizons: A, 0–16 cm; B_1, 17–31 cm; B_2, 32–46 cm; BC, 47–68 cm; C, 69–120 cm. Soil samples were collected from the following depths: 0–10 cm; 20–30 cm; 30–40 cm; 50–60 cm; and 90–100 cm.

Morphological Characteristics of the Medium Solonetz.

 Profile Structure of the Medium Solonetz	A 0–16 cm – dark gray, dry, loamy, loose, cloddy-granular-dusty, does not effervesce with HCl, with abundant plant roots; abrupt transition by density. B_1 17–31 cm – dark brown, dry, heavy loam, columnar, very dense, with fine roots; does not effervesce with HCl; clear transition. B_2 32–46 cm – dark brown, with evidence of tongue-like penetration of the humus horizon, fresh, clayey, compacted, cloddy; effervescence with HCl increases toward the lower part of the profile; single fine roots; clear transition by color. BC 47–68 cm – light brown, fresh, clayey, structureless, with carbonate spots, compacted, strongly effervesces with HCl; gradual transition. C 69–120 cm – lighter than the preceding horizon, fresh, slightly compacted, with carbonate and gypsum spots, structureless, clayey, strongly effervesces with HCl.



Figure 16 – General View of the Surface and Its Vegetation

The chemical composition data for the medium solonetz at Study Point No. 14 in Kostanay Region show that the humus content in the upper horizons ranges from 2.99 to 1.86% (Table 53). The CO_2 content of carbonates ranges from 0.33 to 4.25%. The maximum value was recorded in the parent material (4.22%), while the minimum value was observed in the upper humus horizon (0.33%). The total nitrogen content ranges from 0.154 to 0.140%, while its hydrolysable form is 25.2 mg/kg. The available forms of phosphorus and potassium are 14.0–12.0 and 220–450 mg/kg, respectively. The pH value ranges from 7.07 to 8.52, with the maximum value recorded in the subsolonetzic horizon, indicating an alkaline reaction of the soil.

Table 53 – Chemical Composition of the Medium Solonetz in Kostanay Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
14	0-10	2,99	0,154	14	220	25,2	7,07	0,33
	20-30	1,86	0,140	12	450	25,2	8,04	0,36
	30-40						8,52	0,98
	50-60						8,33	4,25
	90-100						8,34	4,22

In the water extract of the medium solonetz at Study Point No. 14 in Kostanay Region, chloride and sulfate ions predominate in the solonetzic and subsolonetzic horizons. Their concentrations increase with depth down the soil profile, from 1.78 to 3.85 mg-eq and from 3.31 to 19.53 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with maximum values recorded in the middle and lower horizons (4.61–

10.78 mg-eq per 100 g of soil). These conditions characterize the salinity of the medium solonetzes as a chloride-sulfate type of strong salinity. The maximum accumulation of soluble ions (Na^+ and others) is observed within the 30–100 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon and the pronounced development of the solonetzic process throughout the soil profile (Table 54).

Table 54 – Ionic Composition of the Medium Solonetz in Kostanay Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
14	0-10		0,08	0,00	0,07	0,25	0,10	0,10	0,19	0,02
		0,028	0,005	0,000	0,002	0,012	0,002	0,001	0,004	0,001
	20-30		0,40	0,00	1,78	3,31	0,19	0,67	4,61	0,03
		0,366	0,024	0,000	0,063	0,159	0,004	0,008	0,106	0,001
	30-40		0,76	0,08	2,62	6,11	0,19	0,86	8,42	0,02
		0,641	0,046	0,002	0,093	0,293	0,004	0,010	0,194	0,001
	50-60		0,32	0,00	3,85	19,53	7,14	5,71	10,78	0,06
		1,556	0,020	0,000	0,136	0,937	0,143	0,069	0,248	0,003
	90-100		0,32	0,00	3,85	14,23	4,28	4,76	9,32	0,02
		1,198	0,020	0,000	0,136	0,683	0,086	0,058	0,214	0,001

The composition of exchangeable cations in the medium solonetz at Study Point No. 14 in Kostanay Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 6.18 to 23.75 mg-eq per 100 g of soil (Table 55). At the same time, the content of Mg^{2+} is high in the solonetzic and subsolonetzic horizons (11.43–14.41 mg-eq per 100 g of soil), indicating the magnesian nature of the studied soils. Exchangeable sodium has a residual character and amounts to 0.06 and 0.92 mg-eq per 100 g of soil in the solonetzic and subsolonetzic horizons, respectively.

Table 55 – Composition of Exchangeable Cations of the Medium Solonetz in Kostanay Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
14	0-10	10,45	2,49	0,08	0,27
	20-30	6,65	11,43	0,06	0,30
	30-40	6,18	14,41	0,92	0,37
	50-60	11,93	11,93	0,16	0,23
	90-100	23,75	9,44	1,01	0,07

The particle-size distribution data for the medium solonetz of the study site No. 14 in Kostanay Region indicate a sandy-loam to medium-loamy texture. The content of physical clay

within the soil profile ranges from 15.422 to 43.281% (Table 56). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 56 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25- 0,05	0,05- 0,01	0,01- 0,005	0,005- 0,001	<0,001	< 0,01
14	0-10	1,44	34,436	33,097	17,045	1,218	12,581	1,623	15,422
	20-30	2,96	28,627	17,786	10,717	0,412	26,381	16,076	42,869
	30-40	2,96	19,868	30,256	6,595	4,534	23,908	14,839	43,281
	50-60	2,78	27,916	32,174	1,646	4,114	22,218	11,932	38,264
	90-100	2,02	33,088	30,578	2,858	2,041	17,555	13,880	33,476

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site accounted for 85% of the total area. The pasture type was identified as crupina–fescue–feather grass with participation of meadowsweet. The botanical composition consisted of crupina (40%), fescue (30%), feather grass (20%), and wormwood (10%). Other plant species occurring in the vegetation included bedstraw, speedwell, yellow alfalfa, yarrow, izen, and wormwood. The yield of pasture biomass was 17.5 c/ha. The geographical coordinates were N 53°18′97.2″, E 065°02′11.5″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 14.41%, fat – 6.40%, fiber – 30.51%, nitrogen-free extractives (NFE) – 33.83%, and ash – 11.81%. The yield of feed units at natural moisture content was 0.55 feed units per kilogram of feed, while the exchange energy content was 7.71 MJ.

North Kazakhstan Region

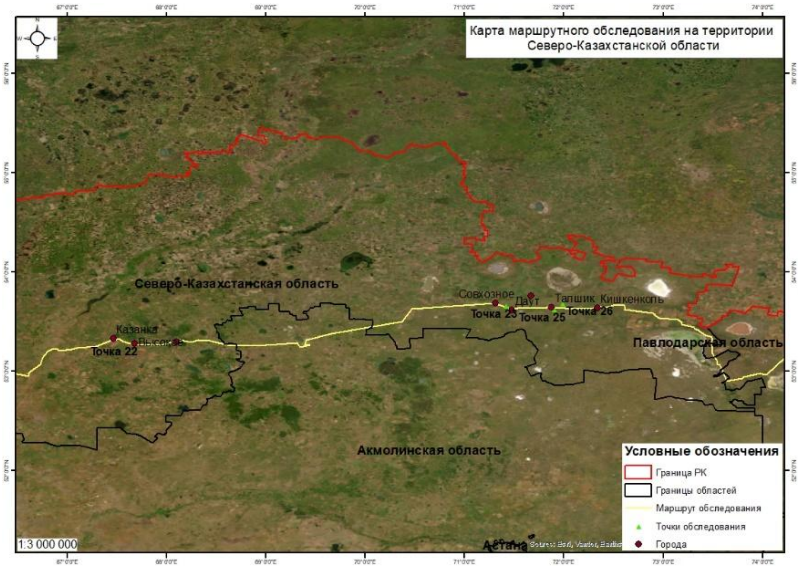


Figure 17 – Route Map for Ground-Based Survey of Solonetzic Lands on Pastures in North Kazakhstan Region

Study Point No. 15. The soil profile was established on 22 June 2026, 1.0 km southwest of Toksan-bi settlement and 200 m south of the Sarykol–Ruzaevka highway, in the Gabit Musrepov District of North Kazakhstan Region. Profile coordinates: N 52°950′278″; E 066°602′816″. Elevation above sea level: 192 m. The terrain is a plain (Figure 18). The plant community (land-use type) is classified as wormwood–fescue. The plant species include wormwood, fescue, crested wheatgrass, yarrow, Leymus (volosnets), and feather grass. The landscape aspect is greenish-gray. The soil type is a shallow solonetz. The soil profile consists of the following horizons: A, 0–8 cm; B_1, 9–24 cm; B_2, 25–38 cm; BC, 39–62 cm; C, 63–120 cm. Soil samples were collected from the following depths: 0–8 cm; 10–20 cm; 25–35 cm; 50–60 cm; and 90–100 cm.

Morphological Characteristics of the Shallow Solonetz.

 Profile Structure of the Shallow Solonetz	A 0–8 cm – light gray, dry, cloddy-dusty, loamy, loose, with abundant plant roots; effervesces with HCl; abrupt transition by density. B_1 9–24 cm – dark brown, dry, cloddy-columnar, very dense, heavy loam, with fine roots; effervesces with HCl; clear transition. B_2 25–38 cm – brown, dry, cloddy, dense, clayey, with fine roots; effervesces with HCl; carbonate spots are observed; tongue-like penetration of humus from the upper horizon is noted; gradual transition. BC 39–62 cm – dark brown, fresh, clayey, dense, structureless, with single fine roots and carbonate spots; effervesces with HCl. C 63–120 cm – light brown, fresh, clayey, compacted, structureless; effervesces with HCl.



Figure 18 – General View of the Surface and Its Vegetation

The chemical composition data for the shallow solonetz at Study Point No. 15 in North Kazakhstan Region show that the humus content in the upper horizons ranges from 4.17 to 3.49% (Table 57). The CO_2 content of carbonates ranges from 2.29 to 5.92%. The maximum value was recorded above the parent material (5.92%), while the minimum value was observed in the upper humus horizon (2.29%). The total nitrogen content ranges from 0.280 to 0.238%, while its hydrolysable form ranges from 44.8 to 39.2 mg/kg. The available forms of phosphorus and potassium are 17.0–8.0 and 920–380 mg/kg, respectively. The pH value ranges from 8.16 to 8.69, with the maximum value recorded above the parent material, indicating an alkaline reaction throughout the soil profile.

Table 57 – Chemical Composition of the Shallow Solonetz in North Kazakhstan Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
15	0-8	4,17	0,280	17	920	44,8	8,19	2,29
	10-20	3,49	0,238	8	380	39,2	8,18	2,45
	25-35						8,48	4,91
	50-60						8,69	5,92
	90-100						8,16	4,84

In the water extract of the shallow solonetz at Study Point No. 15 in North Kazakhstan Region, chloride and sulfate ions predominate in the saline parent material, where the total salt content is 0.515%. Their toxic concentrations are 3.22 and 4.17 mg-eq per 100 g of soil, respectively. Among the cations, sodium is present in the highest concentration, with the maximum value recorded in the lower C horizon (6.42 mg-eq per 100 g of soil). These conditions characterize the salinity of the shallow solonetzes as a deep chloride-sulfate type of medium salinity. Thus, the maximum accumulation of soluble ions (Na^+ and others) is observed in the 90–100 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon (Table 58).

Table 58 – Ionic Composition of the Shallow Solonetz in North Kazakhstan Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
15	0-8		0,48	0,00	0,07	0,45	0,38	0,48	0,02	0,12
		0,072	0,029	0,000	0,002	0,022	0,008	0,006	0,001	0,005
	10-20		0,44	0,00	0,10	0,45	0,38	0,57	0,02	0,02
		0,068	0,027	0,000	0,004	0,022	0,008	0,007	0,001	0,001
	25-35		0,60	0,08	0,03	0,57	0,19	0,48	0,52	0,02
		0,087	0,037	0,002	0,001	0,027	0,004	0,006	0,012	0,001
	50-60		0,84	0,08	0,31	0,45	0,19	0,10	1,30	0,02
		0,120	0,051	0,002	0,011	0,022	0,004	0,001	0,030	0,001
	90-100		0,48	0,00	3,22	4,17	0,67	0,76	6,42	0,02
		0,515	0,029	0,000	0,114	0,200	0,013	0,009	0,148	0,001

The composition of exchangeable cations in the shallow solonetz at Study Point No. 15 in North Kazakhstan Region is characterized by the predominance of Ca^{2+}. Its content within the soil profile ranges from 12.83 to 24.70 mg-eq per 100 g of soil (Table 59). The content of Mg^{2+} ranges from 4.97 to 10.93 mg-eq, Na^+ from 0.17 to 3.89 mg-eq, and K^+ from 0.07 to 0.74 mg-eq per 100 g of soil. The residual character of exchangeable Na^+, particularly in the B_1 solonetzic horizon, indicates a relict expression of the solonetzic process.

Table 59 – Composition of Exchangeable Cations of the Shallow Solonetz in North Kazakhstan Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
15	0-8	23,28	6,96	0,17	0,74
	10-20	24,70	4,97	0,17	0,15
	25-35	19,00	9,94	0,60	0,07
	50-60	12,83	8,95	2,57	0,07
	90-100	14,73	10,93	3,89	0,07

The particle-size distribution data for the solonetz of the study site No. 15 in North Kazakhstan Region indicate a light-clay texture. The content of physical clay within the soil profile ranges from 64.583 to 72.780% (Table 60). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 60 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
15	0-8	4,26	2,173	14,686	17,965	10,863	16,712	37,602	65,177
	10-20	4,26	1,421	11,260	20,054	12,116	17,965	37,184	67,266
	25-35	3,82	0,915	8,838	17,467	14,140	34,934	23,706	72,780
	50-60	3,70	0,498	8,120	21,599	9,969	39,045	20,768	69,782
	90-100	4,00	0,250	10,167	25,000	5,000	37,083	22,500	64,583

Characteristics and Feed Value of the Vegetation Cover

The projective plant cover of the soil surface at this site accounted for 65% of the total area. The pasture type was identified as wormwood–fescue. The botanical composition consisted of wormwood (60%), fescue (10%), crested wheatgrass (9%), yarrow (10%), Leymus (4%), and feather grass (7%). In addition, plantain and wheatgrass were observed as single specimens. The yield of pasture biomass was 13.4 c/ha. The geographical coordinates were N 52°57′01.6″, E 066°36′16.2″. The chemical analysis of the forage showed that, in the air-dry state, the protein content was 15.50%, fat – 5.91%, fiber – 38.30%, nitrogen-free extractives (NFE) – 26.32%, and ash – 11.09%. The yield of feed units at natural moisture content was 0.49 feed units per kilogram of feed, while the exchange energy content was 7.22 MJ.

Study Point No. 16. The soil profile was established on 23 June 2026 in the Aiyrtau

District of North Kazakhstan Region, 300 m southeast of Kamensky Brod settlement and 3 km southeast of the Ruzaevka–Saumakol highway. Profile coordinates: N 52°092′972″; E 067°683′165″. Elevation above sea level: 266 m. The terrain is a slightly undulating plain (Figure 19). The plant community (land-use type) is classified as halophytic goosefoot–Azhrek. The plant species include goosefoot, Azhrek, wormwood, fescue, single specimens of feather grass, and alkali grass. The landscape aspect is grayish-green. The soil type is a medium solonetz. The soil profile consists of the following horizons: A, 0–13 cm; B_1, 14–27 cm; B_2, 28–40 cm; BC, 41–64 cm; C, 65–120 cm. Soil samples were collected from the following depths: 0–10 cm; 15–25 cm; 25–35 cm; 45–55 cm; and 90–100 cm.

Morphological characteristics of a medium solonetz

 Profile structure of a medium solonetz	A - 0–13 cm, dark gray, dry, cloddy-granular, loose, loamy, with abundant roots, slightly effervescent with HCl, abrupt transition due to density. B1 - 14–27 cm, dark brown, dry, columnar, dense, heavy loam, with roots, non-effervescent with HCl, gradual transition. B2 - 28–40 cm, dark brown, moist, compacted, cloddy, clayey, with few roots, effervescent with HCl, distinct transition. BC - 41–64 cm, brown with carbonate mottles, moist, structureless, compacted, clayey, strongly effervescent with HCl, distinct transition by color. C - 65–120 cm, light brown, moist, structureless, slightly compacted, clayey, strongly effervescent with HCl.



Figure 19 – General view of the soil surface and its vegetation

The chemical composition data of the medium solonetz at research site No. 16 in the North Kazakhstan Region show that the humus content in the upper horizons ranges from 5.45 to 3.08% (Table 61). The CO_2 content of carbonates varies from 0.42 to 5.24%. The maximum value was recorded above the parent material (5.24%), while the minimum value was observed in the upper humus horizon (0.42%). The total nitrogen content ranges from 0.336 to 0.196%, while its hydrolysable form varies from 61.6 to 47.6 mg/kg. The contents of available phosphorus and potassium range from 26.0 to 8.0 mg/kg and from 2000 to 780 mg/kg, respectively. The pH values range from 7.85 to 8.30, with the maximum values observed in the middle horizons, indicating a generally slightly to moderately alkaline soil reaction.

Table 61 – Chemical Composition of a Medium Solonetz in the North Kazakhstan Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
16	0-10	5,45	0,336	26	2000	61,6	7,85	0,42
	15-25	3,08	0,196	8	780	47,6	8,22	4,09
	25-35						8,30	4,65
	45-55						7,89	5,24
	90-100						7,85	5,01

In the composition of the water extract of the medium solonetz at study point No. 16 in the North Kazakhstan Region, chloride and sulfate ions predominate alternately at depths of 45–55 and 90–100 cm, with a total salt content of 0.512 and 0.939%, respectively. Their toxic concentrations range from 4.97–9.44 and 3.12–5.73 mg-eq per 100 g of soil, respectively. In the saline lower horizons, sodium and magnesium are the predominant cations, with maximum concentrations of 4.79–9.14 and 1.34–3.15 mg-eq per 100 g of soil, respectively. These conditions characterize a deep sulfate–chloride type of medium to strong salinity in the solonetz profile. Thus, the maximum accumulation of soluble salts (Na^+, Cl^-, SO_4^{2-}, etc.) along the profile is observed in the 45–100 cm layer, indicating the downward accumulation and migration of soluble salts below the solonetzic horizon (Table 62).

Table 62 – Ionic composition of the medium solonetz in the North Kazakhstan Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						

16	0-10		0,56	0,00	0,03	0,71	0,10	0,38	0,48	0,35
		0,101	0,034	0,000	0,001	0,034	0,002	0,005	0,011	0,014
	15-25		0,48	0,08	0,07	0,50	0,29	0,48	0,19	0,10
		0,075	0,029	0,002	0,002	0,024	0,006	0,006	0,004	0,004
	25-35		0,44	0,00	0,31	0,86	0,38	0,57	0,64	0,02
		0,110	0,027	0,000	0,011	0,041	0,008	0,007	0,015	0,001
	45-55		0,24	0,00	4,97	3,12	2,19	1,34	4,79	0,02
		0,512	0,015	0,000	0,176	0,150	0,044	0,016	0,110	0,001
	90-100		0,28	0,00	9,44	5,73	3,14	3,15	9,14	0,02
		0,939	0,017	0,000	0,335	0,275	0,063	0,038	0,210	0,001

The composition of exchangeable cations in the medium solonetz at study point No. 16 in the North Kazakhstan Region is characterized by a predominance of Ca^{2+}. Its content within the soil profile ranged from 14.25 to 25.65 mg-eq per 100 g of soil (Table 63). At the same time, the content of Mg^{2+} increased down the profile from 1.99 to 17.89 mg-eq per 100 g of soil. Exchangeable Na^{+} occurred in residual amounts in the solonetzic horizon (0.11 mg-eq per 100 g of soil), while a sharp increase in its content was observed in the deepest horizons (2.19 and 1.38 mg-eq per 100 g of soil).

Table 63 – Composition of Exchangeable Cations in the Medium Solonetz of the North Kazakhstan Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
16	0-10	25,65	1,99	0,51	2,65
	15-25	19,95	7,46	0,11	0,59
	25-35	20,90	5,47	0,42	0,07
	45-55	16,63	10,44	2,19	0,07
	90-100	14,25	17,89	1,38	0,07

The particle-size distribution data for the medium solonetz of the study site No. 16 in North Kazakhstan Region indicate a light-clay texture. The content of physical clay within the soil profile ranges from 69.352 to 58.958% (Table 64). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 64 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil			
			Particle-size fractions, mm			
			Sand	Silt	Clay	Physical clay

			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
16	0-10	4,14	3,547	7,574	23,367	14,187	28,375	22,950	65,512
	15-25	3,56	2,219	18,976	16,176	7,881	31,522	23,227	62,630
	25-35	3,66	1,619	13,681	25,742	4,567	29,894	24,497	58,958
	45-55	3,92	1,228	6,765	26,644	6,661	37,469	21,232	65,362
	90-100	3,68	1,121	7,517	22,010	12,458	36,545	20,349	69,352

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover of the soil is 60% of the total area. The pasture type is a goosefoot–azhrek pasture. The botanical composition of the vegetation consists of goosefoot (60%), azhrek (35%), and feather grass (5%) of the area. Wormwood, fescue, and alkali grass occur as isolated specimens. The yield of pasture herbage is 15.5 c/ha. The chemical composition of the forage showed that, in the air-dry state, the content of crude protein was 13.22%, fat – 4.41%, fiber – 36.00%, nitrogen-free extractive substances (NFE) – 35.26%, and ash – 7.92%. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of forage, while the metabolizable energy content was 7.30 MJ.

Study Point No. 17. The soil profile was established in the Taiynshinsky District of the North Kazakhstan Region, 4 km west of the village of Akkuduk and 300 m north of the Chkalovo–Akkuduk highway (23 June 2026). The coordinates of the soil profile are N 53° 651′ 484″; E 070° 769′ 105″. The elevation is 128 m above sea level. The terrain is a slightly undulating plain (Figure 20). The plant community (land-use type) is wormwood–grass. The plant species include wormwood, couch grass, alkali grass, yarrow, Bassia, and forget-me-not. The soil type is crusted solonetz. The soil profile consists of the following horizons: A 0–4 cm, B_1 5–18 cm, B_2 19–30 cm, BC 31–78 cm, and C 79–120 cm. Soil samples were collected from the following depths: 0–4 cm, 7–17 cm, 20–30 cm, 50–60 cm, and 90–100 cm.

Morphological Characteristics of the Crusted Solonetz.

	A 0–4 cm, gray, dry, slightly compacted, crumbly-powdery, loamy, with many roots; does not effervesce with HCl; abrupt transition in color and density. B_1 5–18 cm, dark brown, dry, very dense, columnar, heavy loam, with roots; salt streaks are observed toward the lower part of the horizon; does not effervesce with HCl; distinct transition. B_2 19–30 cm, dark brown, moist, clayey, slightly compacted, crumbly, with salt streaks and roots; strongly effervesces with HCl; distinct transition. BC 31–78 cm, brown, moist, clayey, structureless, slightly compacted; effervesces with HCl; gradual transition. C 79–120 cm, darker than the overlying horizon, moist, structureless, slightly compacted, clayey;

Profile Structure of the Crusted Solonetz	strongly effervesces with HCl.



Figure 20 – General View of the Surface and Its Vegetation

The chemical composition data for the crusted solonetz at study point No. 17 in the North Kazakhstan Region show that the humus content in the upper horizons ranges from 3.07 to 2.57% (Table 65). The CO_2 content of carbonates varies from 0.33 to 3.27%. The maximum value is observed above the parent material (3.27%), whereas the minimum value is recorded in the upper humus horizon (0.33%). The content of total nitrogen ranges from 0.196 to 0.168%, while its hydrolyzable form varies from 33.6 to 64.4 mg/kg. The contents of available phosphorus and potassium are 34.0–12.0 and 380–170 mg/kg, respectively. The pH values range from 7.37 to 8.12, with the maximum values observed in the middle and lower horizons, indicating a slightly to moderately alkaline soil reaction overall.

Table 65 – Chemical Composition of the Crusted Solonetz in the North Kazakhstan Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
17	0-4	3,07	0,196	34	380	33,6	7,37	0,33
	7-17	2,57	0,168	12	170	64,4	7,67	0,49
	20-30						8,13	2,62
	50-60						8,07	3,27
	90-100						8,12	2,62

In the composition of the water extract of the crusted solonetz at study point No. 17 in the North Kazakhstan Region, chloride and sulfate ions predominate starting from the solonetzic horizon. Their toxic concentrations, against a background of high total salt content (1.123–

2.364%), range from 1.96 to 6.99 and from 14.19 to 29.33 mg-eq per 100 g of soil, respectively. Among the cations, sodium is predominant, with its maximum concentration recorded in the lower C horizon (18.29 mg-eq per 100 g of soil). These conditions characterize a chloride–sulfate type of very strong salinity in the crusted solonetz. Thus, the maximum accumulation of ions (Na^+, Cl^-, SO_4^{2-}, etc.) is observed practically throughout the entire soil profile, indicating the accumulation of soluble salts downward, below the humus horizon (Table 66).

Table 66 – Ionic Composition of the Crusted Solonetz in the North Kazakhstan Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
17	0-4		0,32	0,00	0,07	0,84	0,10	0,10	1,01	0,03
		0,090	0,020	0,000	0,002	0,040	0,002	0,001	0,023	0,001
	7-17		0,32	0,00	1,96	14,19	3,52	1,43	11,50	0,02
		1,123	0,020	0,000	0,069	0,681	0,070	0,017	0,265	0,001
	20-30		0,28	0,00	5,94	29,33	12,85	4,76	17,92	0,02
		2,364	0,017	0,000	0,211	1,408	0,257	0,058	0,412	0,001
	50-60		0,24	0,00	6,29	27,23	11,42	4,76	17,56	0,02
		2,236	0,015	0,000	0,223	1,307	0,228	0,058	0,404	0,001
	90-100		0,28	0,00	6,99	18,18	2,38	4,76	18,29	0,02
		1,664	0,017	0,000	0,248	0,872	0,048	0,058	0,421	0,001

The composition of exchangeable cations in the crusted solonetz at study point No. 17 in the North Kazakhstan Region is characterized by a predominance of Ca^{2+}. Its content within the soil profile ranged from 7.46 to 19.48 mg-eq per 100 g of soil (Table 67). At the same time, the content of Mg^{2+} is also relatively high, reaching 9.94 mg-eq per 100 g of soil in the solonetzic and subsolonetzic horizons. The exchange complex of these horizons is characterized by a high degree of sodium saturation (3.12 and 4.56 mg-eq per 100 g of soil). The increase in exchangeable Na^+ in the solonetzic B_1 horizon indicates the development of the solonetzic process.

Table 67 – Composition of Exchangeable Cations of the Crusted Solonetz in the North Kazakhstan Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
17	0-4	13,78	3,98	1,67	0,14
	7-17	7,46	9,94	3,12	0,15
	20-30	18,39	9,94	4,56	0,14
	50-60	14,91	6,46	1,08	0,12
	90-100	19,48	11,93	1,33	0,14

The particle-size distribution data for the crusty solonetz of the study site No. 17 in North Kazakhstan Region indicate a light- to heavy-loamy texture. The content of physical clay within the soil profile ranges from 21.996 to 47.001% (Table 68). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 68 – Particle-Size Distribution of the Crusty Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
17	0-4	1,80	25,662	26,680	25,662	1,629	13,442	6,925	21,996
	7-17	3,16	20,302	23,523	9,500	4,544	33,870	8,261	46,675
	20-30	8,42	15,156	30,684	39,747	5,241	7,862	1,310	24,414
	50-60	4,20	24,864	28,789	10,438	4,175	18,372	13,361	35,908
	90-100	2,98	18,924	23,768	10,307	7,009	20,202	19,790	47,001

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover does not exceed 80% of the total area. The pasture type is wormwood–grass. The botanical composition consists of wormwood (60%) and grasses (40%) of the area. Couch grass, alkali grass, yarrow, forget-me-not, and Bassia occur as isolated specimens. The yield of pasture herbage is 12.4 c/ha. The coordinates are N 53° 39′ 09.6″, E 070° 46′ 15.1″. The chemical composition of the forage shows that, in the air-dry state, the protein content is 14.72%, fat – 6.53%, fiber – 39.19%, nitrogen-free extractive substances (NFE) – 25.81%, and ash – 10.41%. The yield of feed units at natural moisture content was 0.49 feed units per kilogram of forage, while the metabolizable energy content was 7.18 MJ.

Study Point No. 18. The soil profile was established in the Akzhar District of the North Kazakhstan Region, 400 m east of the village of Akzharkyna and 2 km south of the road from Akkuduk to Akzharkyna (23 June 2026). The coordinates are N 53° 679′ 481″; E 071° 317′ 044″. The elevation is 123 m above sea level. The terrain is a plain (Figure 21). The plant community (land-use type) is wormwood–grass. The plant species include wormwood, fescue, couch grass, crested wheatgrass, and alyssum. The landscape aspect is yellowish-gray. The soil type is medium solonetz. The soil profile consists of the following horizons: A 0–12 cm, B_1 13–25 cm,

B_2 26–41 cm, BC 42–81 cm, and C 82–120 cm. Soil samples were collected from the following depths: 0–10 cm, 12–22 cm, 30–40 cm, 60–70 cm, and 90–100 cm.

Morphological Characteristics of the Medium Solonetz.

 Profile Structure of the Medium Solonetz	A 0–12 cm, dark gray, dry, loamy, loose, crumbly-granular, abundant roots; does not effervesce with HCl; clear transition in density. B_1 13–25 cm, dark brown, dry, heavy loam, dense, columnar-prismatic, many roots; does not effervesce with HCl; gradual transition. B_2 26–41 cm, brown, dry, heavy loam, dense, crumbly, with fine roots; effervesces with HCl; clear transition. BC 42–81 cm, dark brown with carbonate spots, dry, structureless, clayey, with isolated fine roots; strongly effervesces with HCl; carbonate spots; distinct transition. C 82–120 cm, brown with a pale-brown hue, fresh, clayey, structureless, with abundant carbonates; strongly effervesces with HCl.

The chemical composition data for the medium solonetz at study point No. 18 in the North Kazakhstan Region show that the humus content in the upper horizons ranges from 4.53 to 4.78% (Table 69). The CO_2 content of carbonates varies from 0.46 to 5.07%. The maximum value is observed in the parent material (5.07%), whereas the minimum value is recorded in the solonetzic horizon (0.36%). The content of total nitrogen ranges from 0.322 to 0.308%, while its hydrolyzable form varies from 47.6 to 61.6 mg/kg. The contents of available phosphorus and potassium are 128.0–102.0 and 1,740–1,000 mg/kg, respectively. The pH values range from 7.65 to 8.09, with the maximum value observed in the middle horizon, indicating a slightly alkaline soil reaction.



Figure 21 – General View of the Surface and Its Vegetation

Table 69 – Chemical Composition of the Medium Solonetz in the North Kazakhstan Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
18	0-10	4,53	0,322	128	1740	47,6	7,65	0,46
	12-22	4,78	0,308	102	1000	61,6	8,09	0,36
	30-40						7,92	1,64
	60-70						7,89	3,76
	90-100						7,99	5,07

In the composition of the water extract of the medium solonetz at study point No. 18 in the North Kazakhstan Region, chloride and sulfate ions predominate in the deeper horizons. At a total salt content of 0.410 and 0.389%, respectively, their toxic concentrations are 3.32–4.20 and 2.98–1.93 mg-eq per 100 g of soil, respectively. Among the cations, sodium predominates, with its maximum concentrations recorded in the lower horizons (3.52 and 3.66 mg-eq per 100 g of soil). These conditions characterize a deep sulfate–chloride type of moderate salinity in the crusted solonetz. Thus, the maximum accumulation of ions (Na^+, Cl^-, SO_4^{2-}, etc.) is observed in the 60–100 cm layer, indicating the accumulation and downward migration of soluble salts below the solonetzic horizon (Table 70).

The composition of exchangeable cations in the medium solonetz at study point No. 18 in the North Kazakhstan Region is characterized by a predominance of Ca^{2+}. Its content within the soil profile ranged from 13.78 to 21.38 mg-eq per 100 g of soil (Table 71). At the same time, the content of Mg^{2+} is also relatively high, reaching 9.44 mg-eq per 100 g of soil in the solonetzic horizon.

Table 70 – Ionic Composition of the Medium Solonetz in the North Kazakhstan Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
18	0-10		0,24	0,00	0,07	0,36	0,10	0,19	0,04	0,34
		0,053	0,015	0,000	0,002	0,017	0,002	0,002	0,001	0,013
	12-22		0,44	0,00	0,10	0,92	0,19	0,48	0,62	0,17
		0,105	0,027	0,000	0,004	0,044	0,004	0,006	0,014	0,007
	30-40		0,36	0,00	0,91	1,07	0,67	0,67	0,93	0,08
		0,151	0,022	0,000	0,032	0,051	0,013	0,008	0,021	0,003
	60-70		0,28	0,00	3,32	2,98	1,71	1,34	3,52	0,02
		0,410	0,017	0,000	0,118	0,143	0,034	0,016	0,081	0,001
	90-100		0,32	0,00	4,20	1,93	1,24	1,53	3,66	0,02
		0,389	0,020	0,000	0,149	0,093	0,025	0,019	0,084	0,001

Exchangeable Na^+ occurs in residual amounts and ranges from 0.11 to 1.04 mg-eq per 100 g of soil in the solonetzic and subsolonetzic horizons. The increased proportion of exchangeable Mg^{2+} in the B_1 solonetzic horizon indicates an increase in the magnesium saturation of the exchange complex and a more pronounced solonetzic process.

Table 71 – Composition of Exchangeable Cations of the Medium Solonetz in the North Kazakhstan Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
18	0-10	20,90	6,96	0,01	2,36
	12-22	21,38	9,44	0,18	1,37
	30-40	20,90	7,46	0,11	0,08
	60-70	19,00	9,94	1,04	0,07
	90-100	13,78	11,93	0,11	0,07

The particle-size distribution data for the medium solonetz of the study site No. 18 in North Kazakhstan Region indicate a heavy-loamy texture. The content of physical clay within the soil profile ranges from 52.664 to 58.397% (Table 72). The particle-size composition is dominated by the silt fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 72 – Particle-Size Distribution of Medium Solonetzes

Section	Sample depth, cm	A.S. N., %	Fraction content, % of absolutely dry soil
			Particle-size fractions, mm

		H2O	Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
18	0-10	3,46	8,059	21,918	15,745	8,701	19,474	26,103	54,278
	12-22	3,54	11,570	21,667	14,099	4,976	21,149	26,539	52,664
	30-40	3,42	11,721	19,114	10,768	15,324	26,092	16,981	58,397
	60-70	3,54	11,735	16,525	13,684	8,708	32,760	16,587	58,055
	90-100	3,42	8,925	16,525	16,152	2,899	36,861	18,637	58,397

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover at this site is 65% of the total area. The pasture type is wormwood–grass. The botanical composition consists of wormwood (60%), fescue (15%), couch grass (10%), crested wheatgrass (10%), and alyssum (5%) of the area. The yield of pasture herbage is 15.3 c/ha. The chemical composition of the forage showed that, in the air-dry state, the protein content was 15.00%, fat – 6.72%, fiber – 36.63%, nitrogen-free extractive substances (NFE) – 27.82%, and ash – 10.71%. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of forage, while the metabolizable energy content was 7.40 MJ.

Study Point No. 19. The soil profile was established in the Akzhar District of the North Kazakhstan Region, 300 m west of the village of Talshyk and 200 m west of the Ashchykol–Talshyk highway (24 June 2026). The coordinates of the soil profile are N 53° 644′ 497″; E 071° 866′ 139″. The elevation is 85 m above sea level. The terrain is a plain (Figure 22). The plant community (land-use type) is wormwood–fescue. The plant species include wormwood, fescue, goosefoot, and isolated specimens of crested wheatgrass. The landscape aspect is greenish-gray. The soil type is shallow solonetz. The soil profile consists of the following horizons: A 0–9 cm, B_1 12–23 cm, B_2 24–37 cm, BC 38–56 cm, and C 57–120 cm. Soil samples were collected from the following depths: 0–9 cm, 10–20 cm, 25–35 cm, 40–50 cm, and 90–100 cm.

The chemical composition data for the shallow solonetz at study point No. 19 in the North Kazakhstan Region show that the humus content in the upper horizons ranges from 1.93 to 1.77% (Table 73). The CO_2 content of carbonates varies from 0.39 to 4.28%. The maximum value is observed below the solonetzic horizon (4.28%), whereas the minimum value is recorded in the upper humus horizon (0.39%). The content of total nitrogen ranges from 0.126 to 0.126%, while its hydrolyzable form varies from 33.6 to 22.4 mg/kg. The contents of available phosphorus and potassium are 40.0–14.0 and 610–220 mg/kg, respectively. The pH values range from 7.72 to 8.45, with the maximum values observed in the middle and lower horizons, indicating a moderately alkaline soil reaction.

Morphological Characteristics of the Shallow Solonetz

 Profile Structure of the Shallow Solonetz	A 0–9 cm, gray, dry, crumbly-powdery, loamy, loose, with abundant roots; does not effervesce with HCl; abrupt transition in color and density. B_1 10–23 cm, dark brown, dry, columnar, heavy loam, with fine roots, dense; effervescence with HCl occurs toward the lower part of the horizon; clear transition. B_2 24–37 cm, dark brown, moist, crumbly, loamy, slightly compacted; carbonate streaks are present, with isolated roots; strongly effervesces with HCl; gradual transition. BC 38–56 cm, brown with a pale-brown hue, moist, structureless, slightly compacted, clayey, with carbonate spots; strongly effervesces with HCl; gradual transition. C 57–120 cm, darker than the overlying horizon, moist, slightly compacted, structureless, clayey, with carbonate spots; gypsum crystals occur; strongly effervesces with HCl.



Figure 22 – General View of the Surface and Its Vegetation

Table 73 – Chemical Composition of the Shallow Solonetz in the North Kazakhstan Region

Section	Depth, cm	Types of analysis						
		%		Available forms, mg/kg			pH	CO_2 of carbonates, %
		Humus	Total nitrogen	P_2O_5	K_2O	Hydrolyzable nitrogen		
19	0-9	1,93	0,126	40	610	33,6	7,72	0,39
	10-20	1,77	0,126	14	220	22,4	8,03	0,49
	25-35						8,38	4,28
	40-50						8,45	3,60
	90-100						8,22	2,13

In the composition of the water extract of the shallow solonetz at study point No. 19 in the North Kazakhstan Region, chloride and sulfate ions predominate starting from the solonetzic

horizon, reaching their maximum concentrations in the 25–35 and 40–50 cm layers. Against the background of a high total salt content (0.363–1.485%), their toxic concentrations increase with depth from 1.61 to 5.25 and from 3.48 to 18.03 mg-eq per 100 g of soil, respectively. Among the cations, sodium predominates, with its maximum concentration recorded in the 25–35 cm layer (13.50 mg-eq per 100 g of soil). These conditions characterize a chloride–sulfate type of very strong salinity in the shallow solonetz. Thus, the maximum accumulation of ions (Na^+, Cl^-, SO_4^{2-}, etc.) is observed practically throughout the entire soil profile, excluding the humus horizon, indicating the accumulation and downward migration of soluble salts below the humus horizon (Table 74).

Table 74 – Ionic Composition of the Shallow Solonetz in the North Kazakhstan Region

Section	Depth, cm	Total salt content, %	Alkalinity		Cl'	SO4 "	Ca++	Mg++	Na +	K +
			Total HCO_3^-	From normal carbonates as CO_3						
19	0-9		0,16	0,00	0,07	0,51	0,10	0,10	0,46	0,09
		0,054	0,010	0,000	0,002	0,024	0,002	0,001	0,011	0,003
	10-20		0,36	0,00	1,61	3,48	0,10	0,76	4,57	0,02
		0,363	0,022	0,000	0,057	0,167	0,002	0,009	0,105	0,001
	25-35		0,32	0,00	5,25	14,05	2,47	3,63	13,50	0,02
		1,285	0,020	0,000	0,186	0,674	0,049	0,044	0,310	0,001
	40-50		0,24	0,00	4,37	18,03	5,80	4,96	11,87	0,02
		1,485	0,015	0,000	0,155	0,866	0,116	0,060	0,273	0,001
	90-100		0,20	0,00	1,50	15,32	7,03	2,10	7,87	0,02
		1,149	0,012	0,000	0,053	0,735	0,141	0,026	0,181	0,001

Table 75 – Composition of Exchangeable Cations of the Shallow Solonetz in the North Kazakhstan Region

Section	Sampling depth, cm	Exchangeable bases, mg-eq./100 g of soil			
		Ca^{2+}	Mg^{2+}	Na^+	K^+
19	0-9	11,40	1,99	0,11	0,36
	10-20	7,13	7,46	1,38	0,07
	25-35	9,98	13,92	2,11	0,07
	40-50	15,41	7,95	0,26	0,05
	90-100	7,95	9,94	0,23	0,05

The composition of exchangeable cations in the shallow solonetz at study point No. 19 in the North Kazakhstan Region is characterized by a predominance of Ca^{2+}. Its content within the soil profile ranged from 7.13 to 15.41 mg-eq per 100 g of soil (Table 75). At the same time, the

content of Mg^{2+} is also relatively high, ranging from 7.46 to 13.92 mg-eq per 100 g of soil in the solonetzic and subsolonetzic horizons. The low content of exchangeable Na^{+} (1.38 mg-eq per 100 g of soil) in the B_1 solonetzic horizon indicates the relict nature of the sodium-related solonetzic process.

The particle-size distribution data for the solonetz of the study site No. 19 in North Kazakhstan Region indicate a medium-loamy texture. The content of physical clay within the soil profile ranges from 27.569 to 42.675% (Table 76). The particle-size composition is dominated by the sand fraction. A particularly sharp increase in the content of fine particles is observed at a depth of 90–100 cm, which is associated with the formation of the solonetzic horizon and affects the soil's hydro-physical properties, salt migration, and the intensity of solonetzization.

Table 76 – Particle-Size Distribution of the Solonetz

Section	Sample depth, cm	A.S. N., % H2O	Fraction content, % of absolutely dry soil						
			Particle-size fractions, mm						
			Sand		Silt			Clay	Physical clay
			1,0 -0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	< 0,01
19	0-9	1,34	27,671	35,029	9,730	7,703	13,379	6,487	27,569
	10-20	1,84	23,309	27,791	15,485	7,742	10,595	15,077	33,415
	25-35	2,52	21,748	33,114	2,462	4,924	21,338	16,414	42,675
	40-50	2,76	17,956	42,966	3,702	8,638	18,511	8,227	35,376
	90-100	3,58	35,677	26,571	7,052	3,734	18,668	8,297	30,699

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover is 55% of the total area. The pasture type is wormwood–fescue. The botanical composition consists of wormwood (80%) and fescue (20%) of the area. Crested wheatgrass and goosefoot occur as isolated specimens. The yield of pasture herbage is 13.5 c/ha. The coordinates are N 53° 38′ 66.5″, E 071° 51′ 96.2″. The chemical composition of the forage showed that, in the air-dry state, the protein content was 14.80%, fat – 6.61%, fiber – 35.10%, nitrogen-free extractive substances (NFE) – 28.53%, and ash – 11.80%. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of forage, while the metabolizable energy content was 7.37 MJ.

Pavlodar Region

Study Point No. 20. The study point is located in the Pavlodar District of the Pavlodar Region (Figure 23), on the above-floodplain terrace of the Irtysh River. Coordinates: N

52.637803°, E 76.864937°. Elevation: 105 m. The soil is a meadow-steppe solonetz, solonchakous, heavy loam. The vegetation is gray-wormwood dominated, with sparse fescue and feather grass. Gray wormwood – cop, fescue – sol, feather grass – un, sea lavender – un, sarsazan – un, licorice – un–sol. Vegetation cover is 60–70%. Plant height is 15–25 cm. The soil profile depth is 60 cm. The combined thickness of the A + B horizons is 30 cm. Effervescence and swelling begin at a depth of 30 cm. Fine salt streaks occur at a depth of 15–30 cm. The soil horizons are as follows: A_1 0–5 cm, B_1sn 5–15 cm, BCsn 15–30 cm, …



Figure 23 – Meadow-Steppe Solonetz, Solonchakous, Heavy Loam

0–5 cm – dark brownish-gray, dry, slightly compacted, with abundant roots, dusty–crumbly, medium loam.

5–15 cm – dark brown, dry, dense, sharply angular–crumbly, heavy loam.

15–30 cm – dark brown, dry, very dense, nutty–crumbly, heavy loam.

30–45 cm – yellowish dark brown, fresh, banded–crumbly, slightly compacted, light loam.

45 cm–bottom – yellowish brown, fresh, slightly compacted, heavy loam.

The soil profile has a well-defined solonetzic differentiation: a dense B_1sn horizon and a very dense nutty–crumbly BCsn horizon occur beneath the A_1 horizon. Visible salts are present from a depth of 15 cm, while effervescence with HCl begins at 30 cm. The humus content decreases from 1.58% in the 0–5 cm layer to 0.94–1.00% in the solonetzic horizons and to 0.34% at a depth of 32–42 cm. The soil reaction changes systematically from near-neutral (pH 6.84) to strongly alkaline (pH 9.91–10.04). Exchangeable Na^+ increases from 0.07 mg-eq per 100 g of soil in the upper horizon to 3.17 mg-eq at a depth of 17–27 cm and reaches 5.62 mg-eq

in the 50–60 cm layer, confirming a pronounced development of the solonetzic process (Table 77).

Table 77 – Chemical and Physicochemical Properties of the Meadow-Steppe Solonetz

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
20	0-5	1,58	0,140	0,33	10,44	2,98	0,07	0,28	13,77	6,84
	5-15	0,94	0,070	0,29	6,96	0,50	0,44	0,19	8,09	7,65
	17-27	1,00	0,070	0,33	5,96	0,50	3,17	0,07	9,70	8,28
	32-42	0,34	0,042	0,52	1,99	1,99	2,43	0,06	6,47	9,91
	50-60			0,65	2,49	1,99	5,62	0,02	10,12	10,04

According to the analytical data, the upper 27 cm of the soil profile have a light loam texture, with the content of physical clay ranging from 14.93 to 17.01%. Below this depth, the profile becomes medium loam, with physical clay contents of 26.07 and 25.73% at depths of 32–42 and 50–60 cm, respectively (Table 78). In the upper 15 cm, the content of water-soluble salts is low, ranging from 0.031 to 0.036%; however, their accumulation begins at a depth of 17–27 cm, and the total salt content in the 32–42 and 50–60 cm layers reaches 0.754 and 0.728%, respectively. Among the cations, the content of Na^+ increases sharply, reaching 9.50 and 8.95 mg-eq per 100 g of soil. Thus, the solonetzic properties are accompanied by a pronounced deep accumulative horizon of water-soluble salts (Table 79).

Table 78 – Particle-Size Distribution of the Meadow-Steppe Solonetz

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
20	0-5	16,66	56,24	10,11	2,02	10,11	4,85	16,99
	5-15	18,35	57,03	9,69	3,23	10,49	1,21	14,93
	17-27	25,10	44,93	12,96	3,65	12,56	0,81	17,01
	32-42	24,56	44,07	5,30	7,74	16,29	2,04	26,07

	50-60	21,56	39,01	13,70	4,98	14,11	6,64	25,73

Table 79 – Composition of Water-Soluble Salts in the Meadow-Steppe Solonetz, %/mg-eq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}
			Total HCO_3^-	From normal carbonates as CO_3						
20	0-5	0,036	0,015	0,000	0,002	0,008	0,002	0,001	0,005	0,002
			0,24	0,00	0,07	0,18	0,10	0,10	0,23	0,06
	5-15	0,031	0,012	0,000	0,000	0,010	0,002	0,001	0,005	0,001
			0,20	0,00	0,00	0,21	0,10	0,10	0,20	0,02
	17-27	0,107	0,032	0,002	0,006	0,035	0,002	0,001	0,025	0,005
			0,52	0,08	0,17	0,73	0,10	0,10	1,10	0,14
	32-42	0,754	0,156	0,022	0,037	0,325	0,010	0,003	0,219	0,004
			2,56	0,72	1,05	6,77	0,48	0,29	9,50	0,11
	50-60	0,728	0,212	0,034	0,024	0,273	0,004	0,008	0,206	0,001
			3,48	1,12	0,66	5,70	0,19	0,67	8,95	0,03

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover is 65–70% of the total area. The pasture type is wormwood-dominated with the participation of fescue. The botanical composition consists of wormwood (80%) and fescue (20%) of the area. Isolated specimens of broom wormwood, alyssum, izen, bluegrass, sarsazan, bird's knotweed, sea lavender, and goosefoot occur. The yield of pasture herbage is 7.0 c/ha. The chemical composition of the forage showed that, in the air-dry state, the protein content was 14.70%, fat – 5.62%, fiber – 34.40%, nitrogen-free extractive substances (NFE) – 31.92%, and ash – 10.52%. The yield of feed units at natural moisture content was 0.52 feed units per kilogram of forage, while the metabolizable energy content was 7.48 MJ.

Study Point No. 21. The study point is located in the Pavlodar District of the Pavlodar Region (Figure 24). Coordinates: N 52.638259°, E 76.805016°. Elevation: 110 m. The terrain is a broad interfluve surface. The soil is a meadow-chestnut, strongly solonetzic–solonchakous, heavy loam. The vegetation is a mixed-herb–grass–wormwood community. The plant species include gray wormwood (sp–cop), eastern wheatgrass (sol–sp), bluegrass (sol), sea lavender (sol), and izen (sol). Vegetation cover is 70–75%. Plant height is 10–15 cm, reaching 50–60 cm in sea lavender stands. The soil profile depth is 60 cm. The combined thickness of the A + B horizons is 15 cm. Strong effervescence with HCl begins at a depth of 15 cm. Large salt spots occur from a depth of 15 cm. The soil horizons are as follows: $A_{(}d_{)}$ 0–5 cm, B_1sn 5–15 cm, C_1zsn 15–30 cm, C_2zsn 30–45 cm, and C_3zsn 45 c

0–5 cm – brownish-gray, dry, compacted, with abundant roots, powdery–crumbly, medium loam.

5–15 cm – dark brown, moist, very dense, columnar–blocky, clayey.

15–30 cm – dark brown, slightly moist, slightly compacted, with numerous salt streaks and spots, clayey.



Figure 24 – Meadow-Chestnut, Strongly Solonetzic–Solonchakous, Heavy Loam Soil.

30–45 cm – brown, moist, slightly compacted, clayey, with numerous salt streaks and spots.

45 cm–bottom – slightly lighter in color and containing more salts; otherwise, similar to the overlying horizon.

The soil profile is characterized by a shallow depth, a very dense solonetzic horizon, and abundant salt accumulations beginning at a depth of 15 cm. The humus content is relatively high in the upper layer (3.10%), but decreases sharply to 1.61% at a depth of 5–15 cm and to 0.66% in the 17–27 cm layer. At the same time, the pH increases from 7.07 to 8.27–8.70. The changes in the cation exchange capacity are particularly pronounced: exchangeable Na^+ increases from 1.11 mg-eq per 100 g of soil in the upper horizon to 8.21 mg-eq at a depth of 17–27 cm and to 11.92 mg-eq in the 32–42 cm layer (Table 80).

Table 80 – Chemical and Physicochemical Properties of the Meadow-Chestnut, Strongly Solonetzic–Solonchakous Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
21	0-5	3,10	0,196	0,33	16,90	2,98	1,11	0,29	21,28	7,07
	5-15	1,61	0,126	0,26	9,44	3,48	0,26	0,07	13,25	7,34
	17-27	0,66	0,070	0,65	35,78	5,96	8,21	0,05	50,00	8,27
	32-42			1,14	41,25	9,94	11,92	0,09	63,20	8,62
	50-60			3,11	51,69	9,94	10,17	0,08	71,88	8,70

According to the analytical data, the upper 15 cm of the soil profile have a medium loam texture (24.40–27.73% physical clay), while below this depth the profile becomes markedly heavier, reaching heavy loam, with 40.60–44.82% physical clay. Thus, the increase in exchangeable Na^+ is accompanied by a pronounced increase in soil texture heaviness in the middle and lower parts of the profile (Table 81). The soil is characterized by very strong salinity: the total content of water-soluble salts increases from 0.082–0.205% in the upper 15 cm to 2.505% at a depth of 17–27 cm and remains at 2.069–2.160% down to a depth of 60 cm. The salt complex is strongly dominated by SO_4^{2-} and Na^+, with the content of the latter reaching 22.68–25.61 mg-eq per 100 g of soil (Table 82).

Table 81 – Particle-Size Distribution of the Meadow-Chestnut, Strongly Solonetzic–Solonchakous Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
21	0-5	17,66	37,48	17,13	5,71	13,46	8,56	27,73
	5-15	20,97	41,59	13,04	5,89	13,46	5,05	24,40
	17-27	8,91	35,87	12,46	5,81	24,08	12,87	42,77
	32-42	14,06	33,33	12,01	2,90	28,58	9,11	40,60
	50-60	12,04	33,18	9,96	5,81	28,64	10,38	44,82

Table 82 – Composition of Water-Soluble Salts in the Meadow-Chestnut, Strongly Solonetzic–Solonchakous Soil, %/mg-eq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
21	0-5	0,082	0,015	0,000	0,012	0,028	0,002	0,002	0,018	0,004

			0,24	0,00	0,35	0,59	0,10	0,19	0,80	0,09
	5-15	0,205	0,010	0,000	0,029	0,101	0,002	0,006	0,057	0,002
			0,16	0,00	0,80	2,11	0,10	0,48	2,46	0,04
	17-27	2,505	0,024	0,000	0,089	1,606	0,162	0,031	0,589	0,004
			0,40	0,00	2,52	33,45	8,08	2,58	25,61	0,10
	32-42	2,160	0,024	0,002	0,095	1,355	0,105	0,023	0,555	0,002
			0,40	0,08	2,69	28,24	5,23	1,91	24,14	0,05
	50-60	2,069	0,020	0,001	0,108	1,285	0,114	0,021	0,522	0,001
			0,32	0,04	3,04	26,76	5,70	1,72	22,68	0,03

Characteristics and Forage Value of the Vegetation Cover

The projective vegetation cover at this site is 75% of the total area. The pasture type is wormwood–grass–halophytic. The botanical composition consists of wormwood (70%), grasses (20%), and halophytes (10%) of the area. Isolated specimens of sea lavender, izen, bluegrass, bluegrass-type grass, eastern wheatgrass, alkali grass, sedge, and goosefoot are also found. The yield of pasture herbage is 11.5 c/ha. The chemical composition of the plants showed that, in the air-dry state, the protein content was 15.32%, fat – 6.71%, fiber – 37.23%, nitrogen-free extractive substances (NFE) – 26.45%, and ash – 11.20%. The yield of feed units at natural moisture content was 0.50 feed units per kilogram of forage, while the metabolizable energy content was 7.31 MJ.

Study Point No. 22. The study point is located in the Pavlodar District of the Pavlodar Region (Figure 25). Coordinates: N 52.650654°, E 76.854760°. Elevation: 111 m. The site is situated on an above-floodplain terrace near the shore of a saline lake. The soil is a meadow soil, weakly solonetzic–solonchakous, light loam. The vegetation is a mixed-herb–grass–wormwood community. The plant species include gray wormwood (cop), eastern wheatgrass (sol), alkali grass (sol), and sea lavender (sol). Vegetation cover is 55–60%, with a plant height of 25–30 cm. The soil profile depth is 70 cm. The combined thickness of the A + B horizons is 35 cm. Effervescence with HCl is absent. Fine salt streaks occur from a depth of 20 cm. The soil horizons are as follows: A 0–5 cm, B_1sn 5–20 cm, B_2sn 20–35 cm, C_1sk 35–55 cm, and C_2sk 55 cm–bottom.



Figure 25 – Meadow, Weakly Solonetzic–Solonchakous Soil

0–5 cm – dark brownish-gray, dry, compacted, with abundant roots, powdery–crumbly, light loam.

5–20 cm – dark brown, blocky, dry, very dense, heavy loam.

20–35 cm – brown, dry, sharply angular–crumbly, medium loam, sandy, with salt streaks.

35–55 cm – yellowish brown, moist, compacted, medium loam, with salt streaks.

55 cm–bottom – bright yellowish brown, moist, compacted, banded–blocky, medium loam.

The soil profile has a humus horizon A + B approximately 35 cm thick. The solonetzic horizons are compacted, with fine salt streaks appearing from a depth of 20 cm; effervescence with HCl is absent. The humus content is relatively uniform in the upper horizons, amounting to 2.90% in the 0–5 cm layer and 2.52% at a depth of 7–17 cm, after which it decreases to 1.13%. Exchangeable Na^+ content is low and gradually increases from 0.12 to 0.84–0.86 mg-eq per 100 g of soil. The pH ranges from 6.91 to slightly alkaline and alkaline values (Table 83).

Table 83 – Chemical and Physicochemical Properties of the Meadow, Weakly Solonetzic–Solonchakous Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
22	0-5	2,90	0,168	0,29	14,91	1,99	0,12	0,89	17,91	6,91
	7-17	2,52	0,098	0,26	12,43	1,99	0,34	0,75	15,51	7,38
	22-32	1,13	0,056	0,19	8,95	2,49	0,54	0,49	12,47	8,19
	40-50			0,26	7,46	3,48	0,86	0,33	12,13	7,47
	60-70			0,16	8,95	4,47	0,84	0,43	14,69	7,50

Table 84 – Particle-Size Distribution of the Meadow, Weakly Solonetzic–Solonchakous Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
22	0-5	22,23	48,87	3,66	6,92	15,47	2,85	25,24
	7-17	29,88	46,53	2,44	3,66	11,80	5,70	21,15
	22-32	28,73	51,42	3,24	1,62	10,54	4,46	16,61
	40-50	26,71	46,93	7,71	2,03	11,76	4,87	18,66
	60-70	20,89	34,28	13,45	11,01	17,93	2,45	31,38

Table 85 – Composition of Water-Soluble Salts in Meadow Slightly Solonetzic-Solontchak Soil, %/mg-eq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
22	0-5	0,031	0,012	0,000	0,001	0,009	0,002	0,001	0,004	0,002
			0,20	0,00	0,03	0,18	0,10	0,10	0,16	0,06
	7-17	0,031	0,012	0,000	0,000	0,010	0,002	0,001	0,005	0,001
			0,20	0,00	0,00	0,21	0,10	0,10	0,20	0,02
	22-32	0,072	0,020	0,000	0,001	0,032	0,002	0,006	0,010	0,001
			0,32	0,00	0,03	0,67	0,10	0,48	0,44	0,02
	40-50	0,379	0,012	0,000	0,047	0,196	0,013	0,008	0,092	0,011
			0,20	0,00	1,33	4,07	0,67	0,67	4,00	0,27
	60-70	0,548	0,010	0,000	0,138	0,215	0,025	0,014	0,133	0,014
			0,16	0,00	3,88	4,48	1,24	1,14	5,79	0,35

According to the particle-size analysis, the profile is predominantly light loamy: the content of physical clay ranges from 16.61 to 25.24%, while only the lower layer at a depth of 60–70 cm becomes medium loamy, with a physical clay content of 31.38% (Table 84). Salinity also exhibits a pronounced accumulative pattern: the total salt content is only 0.031–0.072% down to a depth of 32 cm, increasing to 0.379% at 40–50 cm and to 0.548% in the 60–70 cm layer; simultaneously, the Na^+ content increases to 4.00–5.79 mg-eq (Table 85). Overall, the profile is characterized by slight solonetzicity, with more pronounced deep salinity.

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover of the soil accounts for 55–60% of the total area. The pasture type is wormwood–grass–kermek. The botanical composition of the vegetation consists of wormwood (65%), grasses (25%), and kermek (10%) of the area. The herbage includes sedge, wormwood (reed-like wormwood and tarragon wormwood), alkali grass, licorice, and knotgrass. The yield of pasture herbage is 14.5 c/ha. The chemical composition of the forage showed that, in the air-dry state, the protein content was 16.83%, fat 6.22%, fiber 36.70%, nitrogen-free extractive substances (NFE) 25.81%, and ash 11.00%. The yield of feed units at natural moisture content was 0.51 feed units per kilogram of forage, while the metabolizable energy content was 7.49 MJ.

Research point No. 23. Located in Aksu District of Pavlodar Region (Figure 26). Coordinates N 52.251429° E 76.746271°. H = 118 m. Almost flat plain on the left bank of the Irtysh River. Soil: Dark chestnut solonetzic-solonchak heavy loamy soil. Vegetation is wormwood-dominated. Height – 7–15 cm. Projective cover – 30–40%. Depth – 85 cm. A+B = 22 cm. Effervescence from the surface. Carbonates from 50 cm. Horizons: A 10–5, AB 5–15, B1 15–22, BC 22–50, C2 50–bottom.



Figure 26 – Dark Chestnut Solonetzic-Solontchak Soil

0–5 cm — Gray, dry, compacted, dusty-cloddy, heavy loam.

5–15 cm — Brownish-gray, fresh, compacted, cloddy, heavy loam.

15–22 cm — Brown, dry, dense, cloddy, heavy loam.

22–50 cm — Light brown, fresh, dense, blocky, clayey.

50 cm – bottom — Variegated clay of reddish and greenish shades, with carbonates and salts.

The solonetzic profile is well morphologically expressed by a dense horizon; effervescence is observed from the surface, while carbonate spots appear below 50 cm. The humus content ranges from 1.97 to 2.42% in the upper 15 cm and decreases to 1.49% in the 15–22 cm layer. The reaction is alkaline throughout the studied profile (pH 8.04–8.67). Exchangeable Na increases from 0.09 mg-eq in the upper horizon to 2.79 mg-eq at a depth of 5–15 cm and 3.89 mg-eq in the 15–22 cm layer (Table 86).

Table 86 – Chemical and Physicochemical Properties of Dark Chestnut Strongly Solonetzic-Solodized Soil

Section	Sample depth, cm	Humus, %	Total nitrogen,	CO_2,%	Exchangeable bases, mg-eq/100 g	pH water

			%		Ca	Mg	Na	K	Total	
23	0-5	1,97	0,24	1,21	22,28	6,93	0,09	0,67	29,97	8,29
	5-15	2,42	0,17	1,97	19,31	8,91	2,79	0,04	31,05	8,67
	15-22	1,49	0,15	1,71	14,85	16,34	3,89	0,04	35,12	8,36
	30-40			1,64						8,35
	75-85			2,42						8,04

Analytically, the upper horizon is medium loamy (33.09% physical clay), but from a depth of 5 cm, the profile becomes heavy loamy and clayey: the content of physical clay increases to 55.53–60.82%, reaching 69.11% at a depth of 75–85 cm. Particularly significant is the accumulation of silt, the content of which increases from 19.44 to 49.84% (Table 87).

Table 87 – Particle-Size Distribution of Dark Chestnut Strongly Solonetzic-Solodized Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
23	0-5	7,80	17,75	41,37	3,72	9,93	19,44	33,09
	5-15	7,05	15,04	22,38	26,11	5,80	23,62	55,53
	15-22	5,19	12,33	21,66	8,75	10,83	41,24	60,82
	30-40	1,42	16,50	22,92	5,83	7,50	45,83	59,17
	75-85	2,35	7,18	21,36	9,22	10,05	49,84	69,11

The total content of water-soluble salts increases from 0.091% in the upper horizon to 0.670–0.805% in the middle part of the profile, reaching 1.969% at a depth of 75–85 cm. The lower layer is characterized by high contents of SO_4^{2-}, Ca^{2+}, Mg^{2+}, and Na^{+} (Table 88). Thus, the profile combines strong solonetzicity, pronounced illuvial textural differentiation, and deep salinization.

Table 88 – Composition of Water-Soluble Salts in Dark Chestnut Strongly Solonetzic-Solonchak Soil, %/mg-eq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
23	0-5	0,091	0,044	0,001	0,001	0,022	0,008	0,005	0,008	0,003
			0,72	0,04	0,04	0,46	0,39	0,39	0,36	0,08
	5-15	0,133	0,066	0,002	0,022	0,006	0,004	0,002	0,033	0,000
			1,08	0,08	0,61	0,13	0,20	0,20	1,43	0,00

	15-22	0,670	0,044	0,001	0,330	0,057	0,020	0,018	0,202	0,000
			0,72	0,04	9,31	1,18	0,98	1,47	8,76	0,00
	30-40	0,805	0,044	0,001	0,337	0,149	0,029	0,030	0,216	0,000
			0,72	0,04	9,49	3,11	1,47	2,45	9,40	0,00
	75-85	1,969	0,041	0,001	0,311	1,032	0,216	0,107	0,260	0,001
			0,68	0,04	8,77	21,49	10,78	8,82	11,31	0,03

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover of the soil accounts for 40–50% of the total area. The pasture type is wormwood-dominated. The botanical composition consists of wormwood (Artemisia) – 85% and bassia (Bassia) – 15% of the area. Alyssum, izen, slender meadow grass, Murtok, Discurainia, and Climacoptera also occur as single specimens. The yield of pasture herbage is 8.0 c/ha. Chemical analysis of the plants showed that, in the air-dry state, the protein content was 17.70%, fat – 6.61%, fiber – 32.50%, nitrogen-free extractive substances (NFES) – 29.30%, and ash – 10.34%. The yield of feed units at natural moisture content was 0.55 feed units per kilogram of feed, while the metabolizable energy content was 8.02 MJ.

Research Point No. 24. It is located in Aksu District of Pavlodar Region (Figure 27). Coordinates: N 52.300541°, E 76.705338°. Elevation: 143 m. The site is situated on an undulating plain, with the soil pit established on a watershed surface. Soil: medium-loamy dark chestnut medium-solonetzic solonchak soil. The vegetation is wormwood-dominated. Vegetation height: 50–70 cm. Projective cover: 70%. Soil pit depth: 75 cm. Thickness of the A+B horizons: 25 cm. Effervescence begins at a depth of 15 cm. White carbonate spots occur from 25 to 50 cm. Horizons: A_1 0–4 cm, AB 4–15 cm, B_1sn 15–25 cm, C_1k 25–55 cm, C_2k 55 cm–bottom.



Figure 27 – Dark Chestnut Medium-Solonetzic-Solonchak Soil

0–4 cm — dark brownish-gray, moist, compacted, root-filled, powdery, weakly crumbly, medium loamy.

4–15 cm — dark brown, moist, compacted, dusty-cloddy, medium loamy.

15–25 cm — brown, dry, dense, blocky with vertical structural units, heavy loamy.

25–55 cm — whitish light brown with white carbonate spots, dusty-blocky, medium clayey.

55 cm–bottom — yellowish brown, dry, dense, indistinctly blocky, medium clayey.

The profile has an A+B thickness of approximately 25 cm; a dense solonetzic horizon occurs at a depth of 15–25 cm, while carbonate accumulations appear below 25 cm. The humus content rapidly decreases from 2.01% in the 0–4 cm layer to 0.83–0.73% in the middle part of the profile. The pH ranges from 6.53 in the upper horizon to 8.47–8.64 in the lower horizons. Exchangeable Na is practically absent in the upper 15 cm (0.04–0.06 meq), but increases to 2.02 meq/100 g in the solonetzic horizon (Table 89).

Table 89 – Chemical and Physicochemical Properties of Dark Chestnut Medium-Solonetzic-Solonchak Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
24	0-4	2,01	0,17	0,4	5,45	2,48	0,04	0,26	8,23	6,53
	5-15	0,83	0,1	0,29	4,95	3,96	0,06	0,02	8,99	7,72
	15-25	0,73	0,11	1,36	6,93	10,89	2,02	0,02	19,86	8,47
	30-40	0,48	0,06	4,69	19,6	6,37	1,36	0,02	27,35	8,49
	65-75			3,17						8,64

According to the analytical data, the upper 15 cm is light loamy (19.78–22.62% physical clay), whereas from a depth of 15 cm, the profile becomes medium loamy, with 33.87–35.01% physical clay, maintaining a similar texture down to the lower part of the profile (Table 90).

Table 90 – Particle-Size Distribution of Dark Chestnut Medium-Solonetzic-Solonchak Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
24	0-4	29,93	38,15	9,29	5,66	8,08	8,89	22,62
	5-15	21,84	49,51	8,88	2,02	10,09	7,67	19,78

	15-25	7,04	73,99	0,82	8,57	13,88	11,43	33,87
	30-40	13,52	31,53	19,95	4,07	9,77	21,17	35,01
	65-75	50,12	1,18	13,80	8,12	9,74	17,05	34,90

Salinization sharply intensifies below the solonetzic horizon: the total salt content reaches 1.563% in the 30–40 cm layer and remains high (0.765%) at a depth of 65–75 cm; chlorides, sulfates, and sodium play a significant role (Table 91).

Table 91 – Composition of Water-Soluble Salts in Dark Chestnut Medium-Solonetzic-Solonchak Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
24	0-4	0,036	0,012	0,000	0,003	0,011	0,002	0,002	0,003	0,003
			0,20	0,00	0,07	0,22	0,10	0,20	0,12	0,08
	5-15	0,047	0,020	0,000	0,003	0,013	0,002	0,002	0,008	0,000
			0,32	0,00	0,07	0,26	0,10	0,20	0,36	0,00
	15-25	0,428	0,041	0,001	0,126	0,116	0,010	0,007	0,128	0,000
			0,68	0,04	3,55	2,41	0,49	0,59	5,56	0,00
	30-40	1,563	0,022	0,000	0,305	0,756	0,200	0,064	0,217	0,000
			0,36	0,00	8,60	15,75	10,00	5,28	9,42	0,00
	65-75	0,765	0,027	0,001	0,286	0,199	0,031	0,036	0,187	0,000
			0,44	0,04	8,06	4,14	1,57	2,94	8,13	0,00

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 55% of the total area. The pasture type is wormwood-dominated, with the participation of grasses, including feather grass (Stipa) and slender meadow grass. The botanical composition consists of wormwood – 95% and grasses – 5% of the area. Alyssum also occurs as isolated specimens. The yield of pasture herbage is 6.5 c/ha. Chemical analysis of the plants showed that, in the air-dry state, the protein content was 16.34%, fat – 5.93%, fiber – 35.20%, nitrogen-free extractive substances (NFES) – 29.69%, and ash – 9.52%. The yield of feed units at natural moisture content was 0.53 feed units per kilogram of feed, while the metabolizable energy content was 7.67 MJ.

Research Point No. 25. It is located in Aksu District of Pavlodar Region (Figure 28). Coordinates: N 52.250853°, E 76.396080°. Elevation: 128 m. The site is situated on a gently undulating plain. Soil: heavy-loamy dark chestnut strongly solonetzic-solonchak soil. The vegetation is dominated by slender meadow grass and feather grass, with gray wormwood. Feather grass (Stipa) – rare, slender meadow grass – sporadic, gray wormwood – sporadic-

solitary, feather grass (Stipa lessingiana) – solitary. Vegetation height: 15–25 cm. Projective cover: 50–60%. Soil pit depth: 85 cm. Thickness of the A+B horizons: 35 cm. Effervescence begins at the surface. Carbonates occur from 35 cm to the bottom as whitish spots; they are sparse down to 65 cm and moderately abundant below. Horizons: A_1d 0–5 cm, B_1sn 5–23 cm, B_2 23–35 cm, C_1k 35–65 cm, C_2 65 cm–bottom.

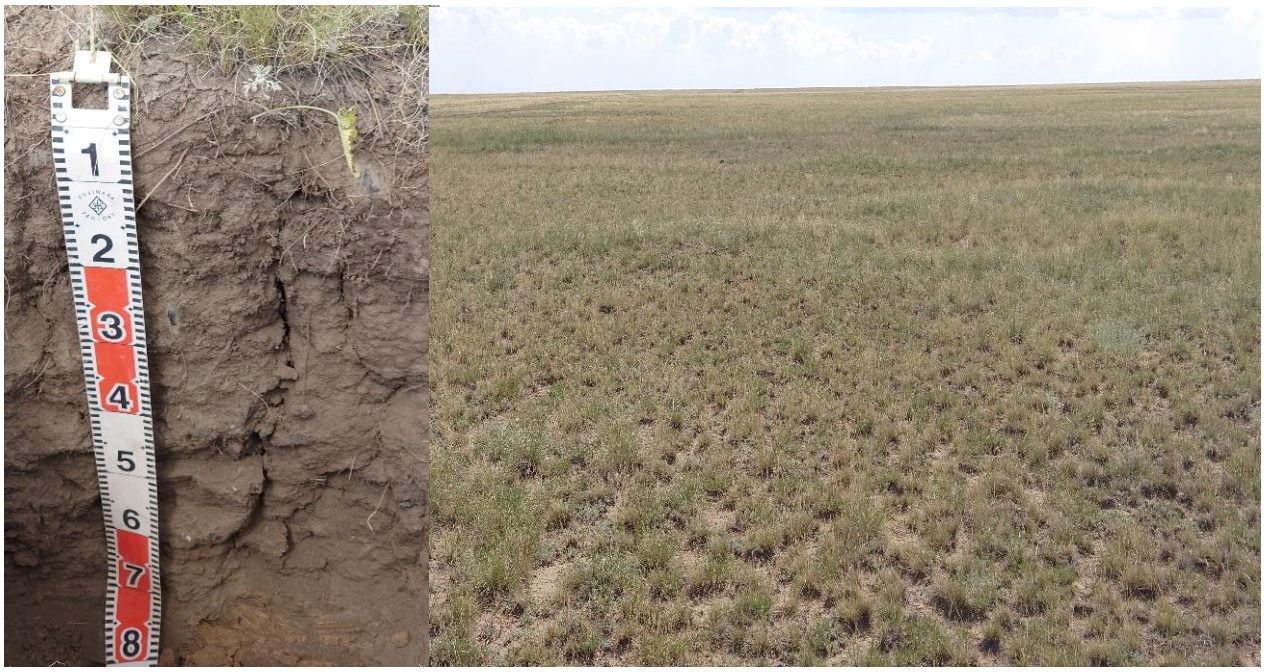


Figure 28 – Dark Chestnut Strongly Solonetzic-Solonchak Heavy-Loamy Soil

0–5 cm — dark brownish-gray, fresh, compacted, strongly root-filled, powdery, medium loamy.

5–23 cm — dark brown, fresh, dense, blocky-nutty, with isolated roots, heavy loamy.

23–35 cm — brown, dry, dense, dusty-cloddy, heavy loamy.

35–65 cm — dirty brown with numerous carbonate spots, blocky, heavy loamy.

65 cm–bottom — yellowish brown, dry, dense, with fewer carbonate spots, medium loamy.

Table 92 – Chemical and Physicochemical Properties of Dark Chestnut Solonetzic-Solonchak Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
25	0-5	3,05	0,14	0,33	9,41	3,96	0,01	0,39	13,77	6,68
	8-18	1,94	0,13	0,4	13,86	17,33	2,95	0,13	34,27	7,83
	24-34	0,83	0,07	3,17	8,91	13,86	0,80	0,13	23,70	8,91
	45-55			2,32						8,51
	75-85			1,79						8,62

The 85-cm profile is calcareous from the surface, with carbonate accumulations occurring from a depth of 35 cm. The humus content decreases from 3.05% in the upper horizon to 1.94% in the 8–18 cm layer and 0.83% at a depth of 24–34 cm. The pH increases from 6.68 to 7.83 and then to 8.91. Exchangeable Na is minimal in the upper horizon (0.01 meq/100 g), sharply increases to 2.95 meq/100 g in the 8–18 cm layer, and then decreases to 0.80 meq/100 g (Table 92).

The textural differentiation is very pronounced: the upper layer is medium loamy, containing 27.91% physical clay, whereas the 8–18 cm horizon contains 65.44% physical clay and 52.11% silt, indicating a clayey texture.

Thus, the maximum content of exchangeable Na coincides with a sharp accumulation of fine-dispersed material (Table 93). In the lower part of the profile, a distinct salt-accumulation horizon is formed, corresponding to the solonetzic-solonchak nature of the soil (Table 94).

Table 93 – Particle-Size Distribution of Dark Chestnut Solonetzic-Solonchak Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
25	0-5	19,52	36,39	16,18	5,66	9,30	12,95	27,91
	8-18	12,65	15,24	6,67	5,42	7,92	52,11	65,44
	24-34	16,16	19,52	11,13	2,47	13,61	37,11	53,19
	45-55	24,42	27,97	3,69	4,52	16,83	22,57	43,92
	75-85	26,37	25,61	5,34	5,75	8,62	28,32	42,68

Table 94 – Composition of Water-Soluble Salts in Dark Chestnut Solonetzic-Solonchak Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
25	0-5	0,033	0,015	0,000	0,003	0,007	0,002	0,001	0,006	0,001
			0,24	0,00	0,07	0,14	0,10	0,10	0,24	0,01
	8-18	0,098	0,037	0,000	0,017	0,015	0,002	0,001	0,027	0,000
			0,60	0,00	0,47	0,30	0,10	0,10	1,17	0,00
	24-34	0,566	0,059	0,002	0,203	0,106	0,008	0,006	0,184	0,000
			0,96	0,08	5,73	2,21	0,39	0,49	8,02	0,00
	45-55	1,648	0,032	0,001	0,267	0,839	0,196	0,054	0,259	0,001

			0,52	0,04	7,52	17,47	9,80	4,40	11,28	0,04
	75-85	0,913	0,037	0,001	0,248	0,329	0,059	0,026	0,214	0,001
			0,60	0,04	6,98	6,85	2,94	2,15	9,32	0,01

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 70–75% of the total area. The pasture type is grass–gray wormwood. The botanical composition consists of grasses – 70%, wormwood – 25%, and izen – 5% of the area. Grudnitsa also occurs as isolated specimens in the herbage. The yield of pasture herbage is 6.0 c/ha. Chemical analysis of the plants showed that, in the air-dry state, the protein content was 13.64%, fat – 5.72%, fiber – 36.81%, nitrogen-free extractive substances (NFES) – 26.09%, and ash – 14.30%. The yield of feed units at natural moisture content was 0.47 feed units per kilogram of feed, while the metabolizable energy content was 6.78 MJ.

Research Point No. 26. It is located in Aksu District of Pavlodar Region (Figure 29). Coordinates: N 51.988472°, E 76.553584°. Elevation: 132 m. The site is situated on an undulating plain with a pronounced microrelief. Soil: medium-loamy dark chestnut solonetzic-solonchak soil. The vegetation is dominated by feather grass and wormwood. Gray wormwood – common, feather grass (Stipa) – sporadic, izen – solitary, tarragon wormwood – solitary, sedge – solitary. Projective cover: 50–55%. Vegetation height: 15–25 cm. Soil pit depth: 60 cm. Thickness of the A+B horizons: 25 cm. Effervesce nce begins at 13 cm. No visible carbonates are observed. Salt spots occur from 25 cm to the bottom. Horizons: A_1d 0–5 cm, AB 5–13 cm, B_1sn 13–25 cm, C_1sk 25–40 cm, C_2sk 40 cm–bottom.

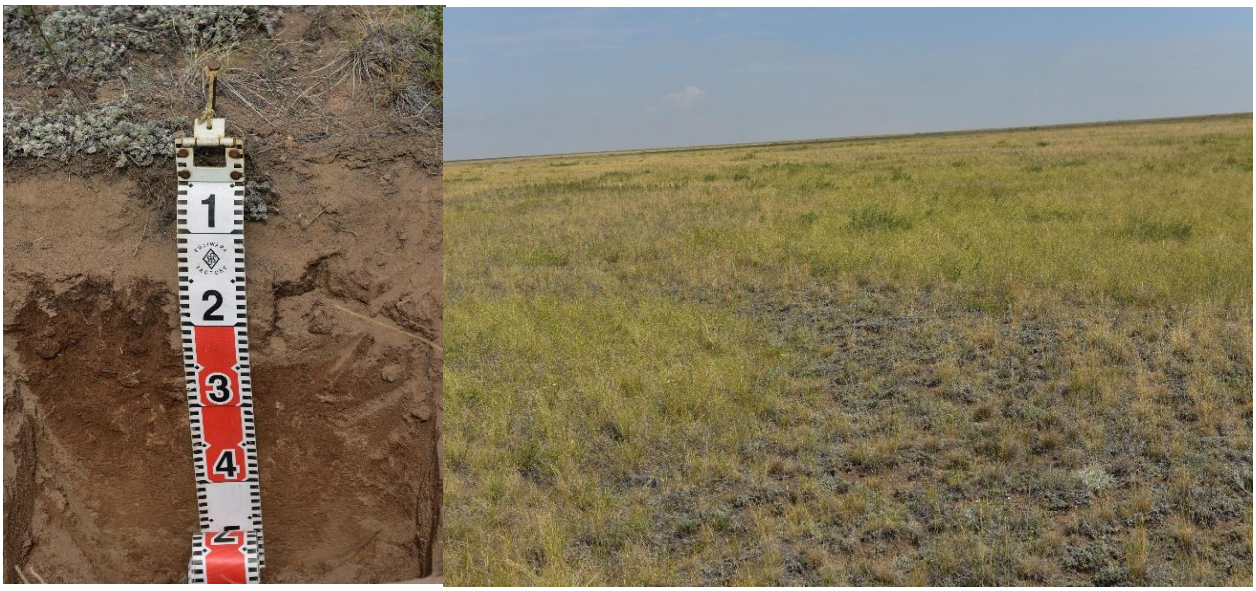


Figure 29 – Dark Chestnut Solonetzic-Solonchak Soil

0–5 cm — gray, dry, compacted, cloddy-dusty, light loamy, sandy, strongly root-filled.

5–13 cm — light brown, dry, compacted, with roots, dusty-cloddy, medium loamy.

13–25 cm — brown, dry, very dense, blocky, with vertical structural units, clayey.

25–40 cm — reddish brown, moist, with salt spots, structureless, heavy loamy.

40 cm–bottom — slightly lighter in color, with a greater amount of salts; otherwise similar to the preceding horizon.

The thickness of the A+B horizons is approximately 25 cm; carbonate accumulation begins at a depth of 13 cm, while visible salts appear from 25 cm. The profile is clearly differentiated into a humus-rich upper part, a compacted solonetzic horizon, and underlying salt-bearing horizons. With increasing depth, alkalinity and signs of salt accumulation become more pronounced (Table 95).

Table 95 – Chemical and Physicochemical Properties of Dark Chestnut Solonetzic-Solonchak Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
26	0-5	1,71	0,154	0,26	8,95	0,50	0,11	0,01	9,57	6,47
	5-13	0,86	0,098	0,19	6,96	2,49	0,14	0,02	9,61	7,05
	14-24	0,91	0,084	0,33	8,95	11,93	1,40	0,02	22,30	8,34
	27-37	0,34	0,070	1,47	37,77	10,44	0,12	0,02	48,35	8,27
	50-60			3,76	9,44	9,44	0,89	0,02	19,79	8,43

Based on the particle-size analysis, the profile should be characterized according to the laboratory-determined values of physical clay, taking into account their variation across the soil horizons (Table 96).

Table 96 – Particle-Size Distribution of Dark Chestnut Solonetzic-Solonchak Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
26	0-5	48,93	21,59	21,81	0,81	6,06	0,81	7,67
	5-13	42,79	24,50	11,71	4,85	12,52	3,64	21,00
	14-24	31,12	24,19	7,45	3,31	18,21	15,73	37,24
	27-37	28,32	26,41	5,40	2,08	18,27	19,52	39,87
	50-60	24,33	23,12	10,68	5,75	21,76	14,37	41,88

The water extract clearly indicates the depth at which salinization begins: the total salt content is only 0.042% in the 0–5 and 5–13 cm layers, then increases to 0.639% at a depth of

14–24 cm and 0.969% in the 27–37 cm layer. The Na^+ content increases accordingly to 7.63 and 9.73 meq/100 g, respectively, and remains high (9.56 meq/100 g) at a depth of 50–60 cm. Sulfate concentrations also increase sharply in the lower part of the profile (Table 97).

Table 97 – Composition of Water-Soluble Salts in Dark Chestnut Solonetzic-Solonchak Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
26	0-5	0,042	0,029	0,000	0,002	0,000	0,004	0,002	0,003	0,001
			0,48	0,00	0,07	0,00	0,19	0,19	0,15	0,02
	5-13	0,042	0,012	0,000	0,005	0,012	0,002	0,001	0,009	0,001
			0,20	0,00	0,14	0,25	0,09	0,09	0,38	0,02
	14-24	0,639	0,032	0,000	0,061	0,346	0,006	0,018	0,176	0,001
			0,52	0,00	1,71	7,22	0,28	1,51	7,63	0,02
	27-37	0,969	0,027	0,000	0,098	0,541	0,053	0,025	0,224	0,001
			0,44	0,00	2,76	11,28	2,65	2,08	9,73	0,02
	50-60	0,734	0,032	0,002	0,120	0,340	0,009	0,012	0,220	0,001
			0,52	0,08	3,39	7,09	0,47	0,95	9,56	0,02

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 50–55% of the total area. The pasture type is wormwood–feather grass. The botanical composition consists of wormwood – 75%, feather grass (Stipa) – 23%, and slender meadow grass – 2% of the area. Parmelia, wormwood, tarragon, meadowsweet, sedge, reed wormwood, and carnation also occur as isolated specimens. The yield of pasture herbage is 6.5 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 15.00%, fat – 6.11%, fiber – 33.74%, nitrogen-free extractive substances (NFES) – 30.49%, and ash – 11.60%. The yield of feed units at natural moisture content was 0.52 feed units per kilogram of feed, while the metabolizable energy content was 7.50 MJ.

Research Point No. 27. It is located in Aksu District of Pavlodar Region (Figure 30). Coordinates: N 52.007309°, E 76.526867°. Elevation: 129 m. The site is situated on a gentle slope of a cuesta descending toward a saline depression. Soil: heavy-loamy solonetz–solonchak soil. The vegetation is wormwood–grass–kokpek dominated. Kokpek (Atriplex cana) – sporadic, Kochia prostrata – solitary, Gmelin's sea lavender (Limonium gmelinii) – solitary, seashore sea lavender (Limonium) – solitary, wormwood (Artemisia) – solitary to sporadic. Projective cover: 40–50%. Vegetation height: 15–20 cm. Soil pit depth: 45 cm. Thickness of the A+B horizons: 15 cm. Effervescence occurs from the surface to a depth of 30 cm; below 30 cm, no effervescence is

observed. Salts occur from 15 cm as sharply defined spots. Horizons: A_1ksn 0–5 cm, Bsn 5–15 cm, C_1sk 15–30 cm, C_2sk 30 cm–bottom.

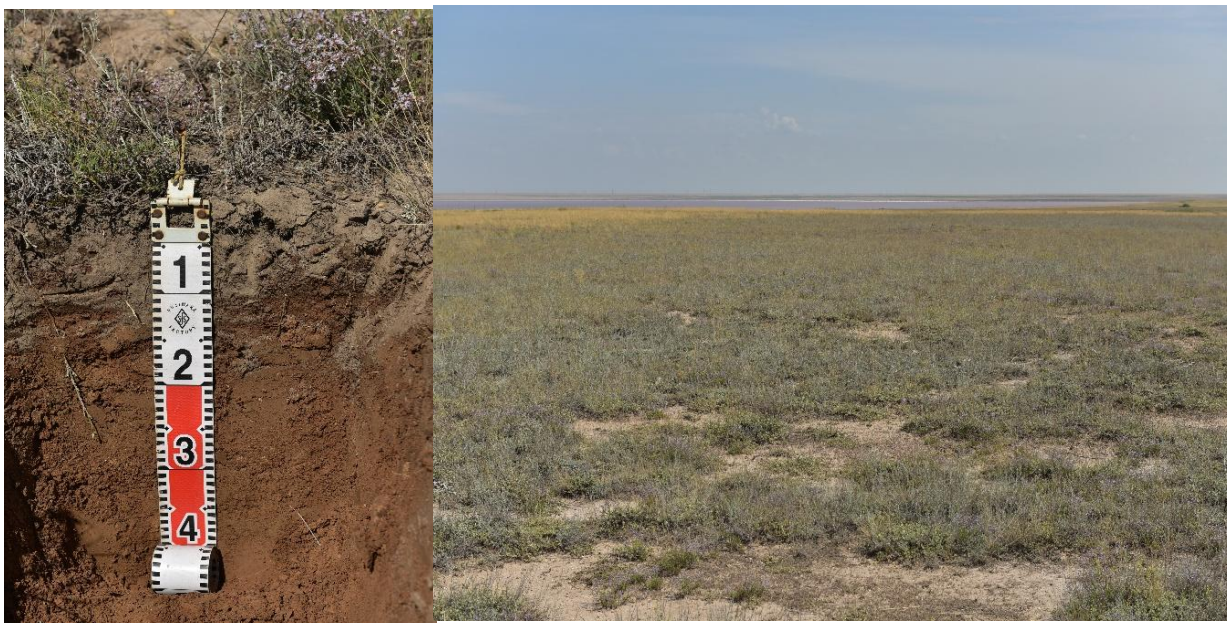


Figure 30 – Heavy-Loamy Solonetz–Solonchak Soil

0–5 cm — dark brown, fresh, very dense, blocky, with sparse roots, heavy loamy.

5–15 cm — brown, moist, compacted, indistinctly blocky, heavy loamy.

15–30 cm — reddish brown, moist, compacted, structureless, heavy loamy, with salts.

30 cm–bottom — similar to the preceding horizon, but without visible salts.

The soil is formed on a gentle slope of a cuesta descending toward a saline depression. The profile is shallow, with an A+B thickness of only 15 cm. The solonetzic horizon is dense; effervescence occurs from the surface to a depth of 30 cm, while sharply defined salt spots appear from 15 cm. Morphologically, the combination of features associated with the solonetzic process and intense salinization is particularly pronounced (Table 98).

Table 98 – Chemical and Physicochemical Properties of Solonetz–Solonchak Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
27	0-5	1,86	0,140	0,29	8,95	10,44	8,30	0,02	27,71	7,49
	5-15	0,77	0,084	1,11	14,41	14,41	13,00	0,02	41,84	8,01
	17-27	0,50	0,056	2,42	14,91	12,92	0,68	0,02	28,53	8,09
	35-45			3,47	9,44	10,93	23,89	0,02	44,28	8,21

Particle-size analysis confirms the heavy-textured nature of the solonetzic part of the profile (Table 99). The water extract shows a strong accumulation of salts in the lower part of the

profile: in the 35–45 cm layer, the total salt content reaches 1.274%, with Cl^- content of 14.16 meq, SO_4^{2-} content of 6.01 meq, and Na^+ content of 18.42 meq. This confirms the transition from the solonetzic horizon proper to strongly saline material and supports the classification of the soil as a solonetz–solonchak (Table 100).

Table 99 – Particle-Size Distribution of Solonetz–Solonchak Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
27	0-5	31,12	23,00	11,99	5,79	16,95	11,16	33,89
	5-15	29,45	12,34	6,33	1,69	17,72	32,48	51,89
	17-27	20,52	13,39	9,26	1,68	18,94	36,20	56,83
	35-45	25,49	13,37	11,65	4,16	20,79	24,54	49,49

Table 100 – Composition of Water-Soluble Salts in Solonetz–Solonchak Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
27	0-5	1,610	0,017	0,000	0,682	0,325	0,034	0,015	0,536	0,001
			0,28	0,00	19,23	6,77	1,70	1,23	23,33	0,02
	5-15	1,790	0,027	0,000	0,645	0,481	0,025	0,020	0,593	0,001
			0,44	0,00	18,18	10,01	1,23	1,61	25,78	0,02
	17-27	1,719	0,027	0,000	0,620	0,461	0,030	0,020	0,561	0,001
			0,44	0,00	17,48	9,60	1,51	1,61	24,38	0,02
	35-45	1,274	0,027	0,000	0,502	0,289	0,015	0,017	0,424	0,001
			0,44	0,00	14,16	6,01	0,76	1,42	18,42	0,02

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 50–55% of the total area. The pasture type is kokpek–grass–wormwood. The botanical composition consists of kokpek (Atriplex cana) – 55%, grasses – 30%, and wormwood – 15% of the area. Sea lavender (Limonium), alkali grass (Puccinellia), Kochia prostrata, and slender meadow grass also occur as isolated specimens. The yield of pasture herbage is 7.6 c/ha. Chemical analysis of the plants showed that, in the air-dry state, the protein content was 16.34%, fat – 7.31%, fiber – 32.00%, nitrogen-free extractive substances (NFES) – 25.83%, and ash – 15.30%. The yield of feed units at natural moisture

content was 0.52 feed units per kilogram of feed, while the metabolizable energy content was 7.50 MJ.

Research Point No. 28. It is located in Aksu District of Pavlodar Region (Figure 31). Coordinates: N 52.075150°, E 76.431687°. Elevation: 119 m. The site is situated on a flat plain. Soil: clayey steppe solonetz with solonchak features. The vegetation is wormwood–kokpek–feather grass, with parmelia occurring on the soil surface. Feather grass (Stipa) – common, kokpek (Atriplex cana) – solitary, wormwood (Artemisia) – solitary, sea lavender (Limonium) – solitary, Kochia prostrata – solitary. Projective cover: 50–60%. Vegetation height: 15–25 cm. Soil pit depth: 50 cm. Thickness of the A+B horizons: 25 cm. Salts occur from 40 cm. Strong effervescence begins at 25 cm. Horizons: A_1 0–10 cm, Bsn 10–25 cm, C_1 25–40 cm, C_2 40 cm–bottom.



Figure 31 – Steppe Solonetz with Solonchak Features

0–10 cm — grayish dark brown, moist (after rain), strongly root-filled, medium loamy.

10–25 cm — brown, dry, very dense, columnar-nutty, clayey.

25–40 cm — dark brown, fresh, compacted, banded-cloddy, heavy loamy.

40 cm–bottom — brown, fresh, compacted, with salt spots, heavy loamy.

The profile has a well-developed, very dense columnar-nutty solonetzic horizon at 10–25 cm. Effervescence begins at 25 cm, while visible salts appear from 40 cm. The humus content decreases from 2.18% in the upper layer to 1.45–1.51% in the middle part of the profile.

Exchangeable Na increases from 0.31 meq/100 g to 2.39 meq/100 g in the solonetzic horizon and reaches 5.17 meq/100 g in the lower layer; the pH increases from 7.02 to 8.27–8.35 (Table 101).

Table 101 – Chemical and Physicochemical Properties of Steppe Solonetz with Solonchak Features

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
28	0-10	2,18	0,168	0,19	11,93	2,98	0,31	0,19	15,41	7,02
	12-22	1,45	0,154	0,29	9,44	9,44	2,39	0,01	21,28	7,79
	27-37	1,51	0,112	3,27	8,45	15,41	2,01	0,02	25,89	8,35
	45-55			2,45	4,73	8,89	5,17	0,02	36,81	8,27

Textural differentiation is exceptionally pronounced: the upper horizon is medium loamy (35.96% physical clay), while at a depth of 12–22 cm, the physical clay content increases to 53.75%, and below this depth it reaches 61.05–65.31%. At the same time, the proportion of silt increases from 10.62% to 40.14–43.54%; therefore, most of the profile is analytically classified as clayey (Table 102). Salinization progressively intensifies with depth: the total salt content increases from 0.050% to 0.306%, 0.876%, and 1.669%, while the Na^+ content increases from 0.41 to 20.87 meq (Table 103).

Table 102 – Particle-Size Distribution of Steppe Solonetz with Solonchak Features

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
28	0-10	13,59	24,72	25,74	4,09	21,25	10,62	35,96
	12-22	16,90	16,02	13,33	10,83	24,58	18,33	53,75
	27-37	15,95	9,62	13,38	14,22	6,69	40,14	61,05
	45-55	12,96	13,77	7,96	12,98	8,79	43,54	65,31

Table 103 – Composition of Water-Soluble Salts in Steppe Solonetz with Solonchak Features, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
28	0-10	0,050	0,017	0,000	0,006	0,013	0,002	0,002	0,009	0,001

			0,28	0,00	0,17	0,26	0,09	0,19	0,41	0,02
	12-22	0,306	0,044	0,002	0,047	0,113	0,002	0,003	0,088	0,008
			0,72	0,08	1,33	2,36	0,09	0,28	3,82	0,21
	27-37	0,876	0,054	0,002	0,267	0,248	0,004	0,006	0,296	0,001
			0,88	0,08	7,52	5,18	0,19	0,47	12,89	0,02
	45-55	1,669	0,041	0,000	0,378	0,690	0,051	0,028	0,480	0,001
			0,68	0,00	10,67	14,37	2,55	2,27	20,87	0,02

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 80% of the total area. The pasture type is feather grass–kokpek–wormwood. The botanical composition consists of feather grass (Stipa) – 50%, kokpek (Atriplex cana) – 30%, and wormwood (Artemisia) – 20% of the area. Parmelia, sea lavender (Limonium), and Kochia prostrata also occur in the vegetation cover. The yield of pasture herbage is 6.5 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 14.20%, fat – 7.61%, fiber – 37.44%, nitrogen-free extractive substances (NFES) – 28.02%, and ash – 9.62%. The yield of feed units at natural moisture content was 0.52 feed units per kilogram of feed, while the metabolizable energy content was 7.41 MJ.

East Kazakhstan Region

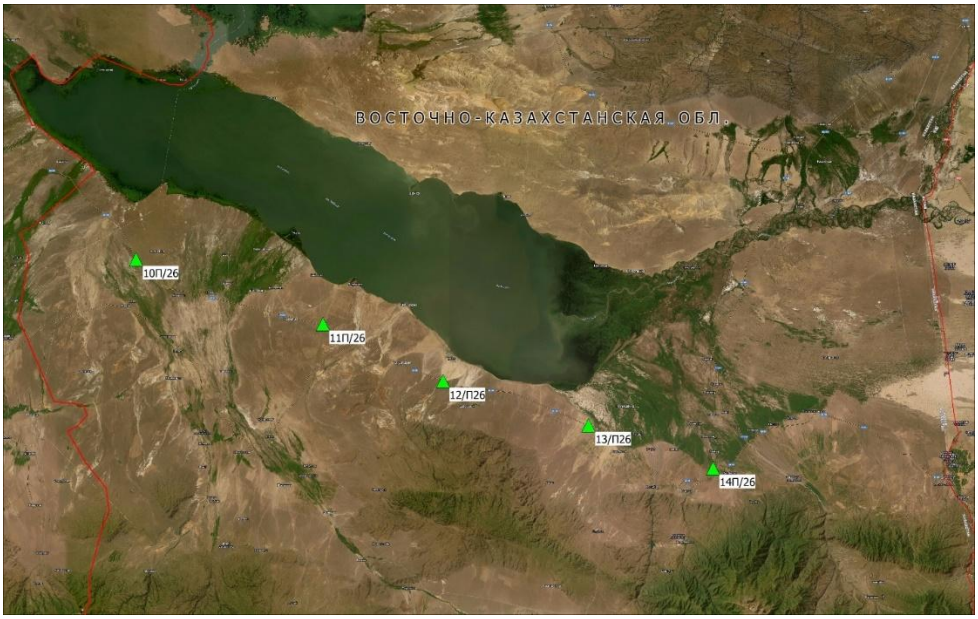


Figure 32 – Route Map of Ground-Based Survey of Solonetzic Lands on Pastures in East Kazakhstan Region

Research Point No. 29. It is located in Tarbagatai District of East Kazakhstan Region (Figure 33). Coordinates: E 47.913731°, N 83.309826°. Elevation: 411 m. The site is situated on a low plain adjacent to Lake Zaysan. Soil: heavy-loamy meadow solonetz with solonchak features. The vegetation is dominated by Kochia prostrata. Projective cover: 40–45%. Vegetation height: 10–15 cm. Soil pit depth: 50 cm. Thickness of the A+B horizons: 25 cm. Effervescence occurs from the surface. No visible salts are observed. Horizons: A_1k 0–5 cm, B_1sn 5–15 cm, B_2sn 15–25 cm, C_1 25–40 cm, C_2 40 cm–bottom.



Figure 33 – Meadow Solonetz with Solonchak Features

0–5 cm — light gray, dry, fine-pored crust, compacted, heavy loamy.

5–15 cm — dirty brown, dry, very dense, blocky, clayey.

15–20 cm — brown, dry, dense, sharply edged nutty, clayey.

25–40 cm — dirty brown, dry, dense, sharply edged cloddy, heavy loamy.

40 cm–bottom — yellowish brown, dry, compacted, indistinctly blocky, heavy loamy.

The profile is formed on a low plain near Lake Zaysan. A surface crust and very dense blocky and sharply edged nutty solonetzic horizons are characteristic. Effervescence occurs from the surface. The upper horizon is low in humus, with a humus content of 0.44%, and has a strongly alkaline reaction (pH 9.64). Already in the 0–5 cm layer, the exchangeable Na content is 2.31 meq/100 g, while the sum of exchangeable bases is only 7.81 meq/100 g, indicating a very high degree of saturation of the soil exchange complex with sodium (Table 104).

Table 104 – Chemical and Physicochemical Properties of Meadow Solonetz with Solonchak Features

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
29	0-5	0,44	0,084	1,96	3,98	0,50	2,31	1,02	7,81	9,64
	5-15	0,40	0,084	3,27	2,49	0,50	4,59	1,77	9,35	10,01
	15-25	0,32	0,070	4,58	0,50	5,47	16,48	2,00	24,45	10,06
	27-37	0,20	0,042	5,07	1,49	2,49	17,02	1,99	22,99	10,11
	40-50			4,42	0,50	3,48	5,39	1,59	10,96	10,21

Table 105 – Particle-Size Distribution of Meadow Solonetz with Solonchak Features

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
29	0-5	13,79	57,24	7,65	8,86	6,44	6,04	21,33
	5-15	14,05	37,68	7,71	6,49	14,20	19,87	40,56
	15-25	6,80	41,12	7,33	8,14	14,65	21,97	44,76
	27-37	6,38	39,04	6,52	16,29	6,11	25,66	48,07
	40-50	14,53	48,12	4,06	6,09	6,90	20,30	33,29

Particle-size analysis confirms the heavy texture of the solonetzic part of the profile, with an accumulation of fine-dispersed fractions (Table 105). The combination of high alkalinity, a substantial proportion of exchangeable Na, a dense solonetzic horizon, and the accumulation of water-soluble salts determines the strongly pronounced solonetzic character of the soil (Table 106).

Table 106 – Composition of Water-Soluble Salts in Meadow Solonetz with Solonchak Features, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
29	0-5	0,394	0,085	0,014	0,016	0,168	0,006	0,003	0,103	0,012
			1,40	0,48	0,45	3,51	0,28	0,28	4,48	0,32
	5-15	0,693	0,229	0,007	0,026	0,230	0,009	0,017	0,155	0,025

			3,76	0,24	0,73	4,79	0,47	1,42	6,75	0,64
	15-25	1,066	0,259	0,082	0,019	0,456	0,006	0,006	0,296	0,024
			4,24	2,72	0,52	9,50	0,28	0,47	12,89	0,62
	27-37	0,802	0,276	0,034	0,029	0,255	0,005	0,011	0,204	0,023
			4,52	1,12	0,80	5,30	0,24	0,94	8,86	0,59
	40-50	0,800	0,242	0,046	0,019	0,292	0,002	0,003	0,224	0,018
			3,96	1,52	0,52	6,09	0,09	0,28	9,73	0,46

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 45–50% of the total area. The pasture type is Kochia prostrata-dominated, with the participation of chiy and wormwood. The botanical composition consists of Kochia prostrata – 55%, chiy – 20%, and wormwood – 25% of the area. Alkali grass (Puccinellia) and wormwood also occur as isolated specimens. The yield of pasture herbage is 17.0 c/ha. Chemical analysis of the plants showed that, in the air-dry state, the protein content was 13.81%, fat – 5.93%, fiber – 34.00%, nitrogen-free extractive substances (NFES) – 33.14%, and ash – 9.83%. The yield of feed units at natural moisture content was 0.53 feed units per kilogram of feed, while the metabolizable energy content was 7.52 MJ.

Research Point No. 30. It is located in Tarbagatai District of East Kazakhstan Region (Figure 34). Coordinates: E 47.790327°, N 83.840453°. Elevation: 461 m. The site is situated on a gently undulating piedmont plain descending northward toward Lake Zaysan. Soil: light-loamy brown desert weakly solonetzic soil. The vegetation is wormwood-dominated with ephemerals. Gray wormwood – common, feather grass (Stipa lessingiana) – solitary, alyssum – solitary to sporadic, Discurainia – solitary. Projective cover: 55–60%. Vegetation height: 15–25 cm. Soil pit depth: 45 cm. Thickness of the A+B horizons: 35 cm. Effervescence occurs from the surface. Fine carbonate spots appear from 20 cm, while numerous sharply defined spots occur from 35 cm. Horizons: A_1k 0–5 cm, B_1sn 5–20 cm, B_2k 20–35 cm, C_1k 35 cm–bottom.





Figure 34 – Light Chestnut Brown Desert Weakly Solonetzic Soil

0–5 cm — grayish light brown, dry, with sparse pores, crusty, medium loamy.

5–20 cm — dark brown, dense, with sparse pores, blocky, heavy loamy.

20–35 cm — light brown, compacted, dry, dense, banded-cloddy, heavy loamy.

35 cm–bottom — whitish brown, dry, dense, with numerous carbonate spots, dusty-blocky, heavy loamy.

The soil is formed on a gently undulating piedmont plain descending toward Lake Zaysan, under wormwood vegetation with ephemerals. The profile is relatively shallow, with an A+B thickness of about 35 cm. Effervescence occurs from the surface; fine carbonate spots appear from a depth of 20 cm and become numerous and sharply defined from 35 cm. Beneath the crusty A_1k horizon (0–5 cm) lies a dense, blocky solonetzic B_1sn horizon (5–20 cm), underlain by the carbonate B_2k and C_1k horizons. Morphologically, the profile is characterized by compaction of the middle part and a distinct increase in carbonate content with depth.

The soil is low in humus: the humus content is 0.64% in the 0–5 cm layer, decreases to 0.46% at a depth of 7–17 cm, and rises again to 0.64% in the 22–32 cm layer. The soil reaction is alkaline throughout the profile: pH 8.46 in the upper horizon, 8.22 in the 7–17 cm layer, and 8.62–8.85 in the underlying layers. The CO_2 content of carbonates systematically increases with depth, from 0.16% in the 0–5 cm layer to 0.49% at a depth of 22–32 cm and 2.09% in the 35–45 cm layer, which is consistent with the morphologically observed accumulation of carbonates. Ca predominates in the soil exchange complex; however, Mg plays a notable role in the upper part, with a content of 3.48 meq/100 g compared with 4.97 meq/100 g of Ca in the 0–5 cm layer. The content of exchangeable Na is low, ranging from 0.13 to 0.22 meq/100 g, with a slight maximum in the solonetzic horizon at 7–17 cm; below this horizon, its content decreases to 0.11–0.13 meq/100 g. Thus, the analytical indicators correspond to a weak degree of solonetzicity of the soil (Table 107).

Table 107 – Chemical and Physicochemical Properties of Brown Desert Weakly Solonetzic Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
30	0-5	0,64	0,084	0,16	4,97	3,48	0,13	0,14	8,72	8,46
	7-17	0,46	0,070	0,33	6,46	1,49	0,22	0,09	8,26	8,22
	22-32	0,64	0,070	0,49	8,45	0,99	0,13	0,02	9,59	8,62
	35-45			2,09	7,46	3,98	0,11	0,02	11,57	8,85

According to the particle-size analysis, the entire profile has a light-loamy texture. The physical clay content is 14.52% in the 0–5 cm layer, increases to 20.64% in the solonetzic horizon at 7–17 cm, and reaches a maximum of 24.38% at a depth of 22–32 cm, after which it slightly decreases to 22.33% in the 35–45 cm layer. At the same time, the silt content (<0.001 mm) increases particularly markedly, from 1.61% in the surface horizon to 9.31% in the 7–17 cm layer and 13.41% at a depth of 22–32 cm. Thus, despite the overall light-loamy texture, pronounced profile differentiation of the fine-dispersed material is observed, with its accumulation in the middle part of the profile (Table 108).

Table 108 – Particle-Size Distribution of Brown Desert Weakly Solonetzic Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
30	0-5	16,36	58,23	10,89	6,05	6,86	1,61	14,52
	7-17	14,30	58,59	6,47	4,05	7,28	9,31	20,64
	22-32	18,20	55,80	1,63	5,28	5,69	13,41	24,38
	35-45	13,36	63,10	1,22	6,50	5,68	10,15	22,33

Very little water-soluble salts are present: their total content is 0.025% in the 0–5 cm layer, 0.023% at a depth of 7–17 cm, 0.041% in the 22–32 cm layer, and 0.046% at a depth of 35–45 cm. The content of water-soluble Na^+ also remains low, ranging from 0.08 to 0.15 meq. In the lower part of the profile, total alkalinity increases slightly to 0.52 meq; however, no pronounced accumulation of chlorides or sulfates is observed. Thus, current salinization of the profile is practically absent, while the weak solonetzicity is primarily associated with the properties of the soil exchange complex and some accumulation of fine-dispersed material in the middle part of the profile (Table 109).

Table 109 – Composition of Water-Soluble Salts in Brown Desert Weakly Solonetzic Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
30	0-5	0,025	0,015	0,000	0,002	0,001	0,002	0,001	0,002	0,002
			0,24	0,00	0,07	0,01	0,09	0,09	0,08	0,05
	7-17	0,023	0,015	0,000	0,001	0,001	0,002	0,001	0,002	0,001

			0,24	0,00	0,03	0,03	0,09	0,09	0,08	0,03
	22-32	0,041	0,024	0,000	0,001	0,005	0,004	0,002	0,002	0,002
			0,40	0,00	0,03	0,09	0,19	0,19	0,10	0,05
	35-45	0,046	0,032	0,002	0,002	0,000	0,004	0,002	0,003	0,003
			0,52	0,08	0,07	0,00	0,19	0,19	0,15	0,06

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 55–60% of the total area. The pasture type is wormwood-dominated with the participation of feather grass. The botanical composition consists of wormwood – 90%, alyssum – 7%, and feather grass (Stipa) – 3% of the area. Fenugreek, cornflower, and parmelia also occur as isolated specimens. The yield of pasture herbage is 7.0 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 15.00%, fat – 5.81%, fiber – 35.20%, nitrogen-free extractive substances (NFES) – 31.69%, and ash – 8.93%. The yield of feed units at natural moisture content was 0.53 feed units per kilogram of feed, while the metabolizable energy content was 7.55 MJ.

Research Point No. 31. It is located in Tarbagatai District of East Kazakhstan Region (Figure 34). Coordinates: N 47.681474°, E 84.181165°. Elevation: 473 m. The site is situated on a piedmont plain descending toward Lake Zaysan. Soil: clayey desert solonetz with solonchak features. The vegetation is Anabasis salsa-dominated. Anabasis salsa – common, Eremopyrum – solitary, and Lepidium – solitary. Projective cover: 30–35%. Vegetation height: 5–10 cm. Soil pit depth: 65 cm. Thickness of the A+B horizons: 35 cm. Effervescence occurs from the surface. Sharply defined carbonate spots occur at 20–35 cm. Horizons: A_1sn 0–10 cm, B_1sn 10–20 cm, B_2sn 20–35 cm, C_1k 35–50 cm, C_2 50 cm–bottom.



Figure 35 – Desert Solonetz with Solonchak Features

0–10 cm — light gray, dry, dense, with a layered crust, heavy loamy.

10–20 cm — light brown, dry, very dense, blocky, clayey.

20–35 cm — brown, dry, dense, nutty, clayey.

35–50 cm — yellowish brown, dry, dense, with carbonate spots, blocky, clayey.

50 cm–bottom — yellowish brown, dry, compacted, without visible spots, heavy loamy.

The profile is formed on a piedmont plain descending toward Lake Zaysan. The upper 35 cm consist of dense solonetzic horizons; effervescence begins at the surface, while sharply defined carbonate spots are observed at a depth of 20–35 cm. The soil is extremely low in humus, with a content of 0.46–0.67% in the upper 20 cm, and is alkaline (pH 8.62–8.64). Exchangeable Na increases from 0.54 meq/100 g in the upper layer to 1.48 meq/100 g at a depth of 10–20 cm (Table 110).

Table 110 – Chemical and Physicochemical Properties of Desert Solonetz with Solonchak Features

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
31	0-10	0,46	0,098	4,91	15,41	8,45	0,54	0,19	24,59	8,62
	10-20	0,67	0,070	4,09	16,40	8,95	1,48	0,02	26,85	8,64
	22-32	0,72	0,070	4,09	21,87	7,95	0,04	0,07	29,93	7,84
	37-47	0,63	0,056	4,71	15,41	11,43	0,11	0,02	26,97	8,00
	55-65			4,74	13,92	9,44	0,99	0,11	24,46	8,02

This is the heaviest profile in terms of particle-size composition among the profiles examined. The physical clay content is 83.45% in the 0–10 cm layer, 82.41% at a depth of 10–20 cm, and remains very high throughout the profile, ranging from 69.80% to 78.60%, with 75.17% in the lower layer. The silt fraction reaches 43.21–47.83%. Thus, the entire profile is analytically classified as clayey, predominantly heavy clayey (Table 111).

Table 111 – Particle-Size Distribution of Desert Solonetz with Solonchak Features

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01

31	0-10	0,27	2,16	14,12	20,76	16,19	46,50	83,45
	10-20	0,40	5,12	12,07	16,23	19,15	47,03	82,41
	22-32	1,54	8,73	19,94	13,30	13,30	43,21	69,80
	37-47	0,29	9,46	11,65	19,55	11,23	47,83	78,60
	55-65	0,64	7,99	16,20	13,29	27,82	34,05	75,17

Salinization intensifies sharply below 20 cm: the total salt content increases from 0.084–0.107% in the upper part of the profile to 0.921% at a depth of 22–32 cm (Table 112).

Table 112 – Composition of Water-Soluble Salts in Desert Solonetz with Solonchak Features, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
31	0-10	0,084	0,044	0,002	0,005	0,012	0,002	0,002	0,018	0,001
			0,72	0,08	0,14	0,24	0,09	0,19	0,80	0,02
	10-20	0,107	0,046	0,002	0,014	0,015	0,002	0,001	0,028	0,001
			0,76	0,08	0,38	0,30	0,09	0,09	1,24	0,02
	22-32	0,921	0,024	0,000	0,174	0,427	0,098	0,017	0,180	0,002
			0,40	0,00	4,90	8,89	4,91	1,42	7,81	0,04
	37-47	0,813	0,027	0,000	0,428	0,060	0,045	0,014	0,236	0,003
			0,44	0,00	12,06	1,24	2,27	1,13	10,26	0,09
	55-65	0,808	0,027	0,000	0,211	0,296	0,042	0,010	0,220	0,003
			0,44	0,00	5,94	6,17	2,08	0,85	9,56	0,06

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for no more than 30–35% of the total soil surface. The pasture type is Anabasis salsa-dominated. The botanical composition consists of Anabasis salsa – 85% and Eremopyrum – 15%. Lepidium also occurs as an isolated species. The yield of pasture herbage is 7.5 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 16.84%, fat – 4.28%, fiber – 35.21%, nitrogen-free extractive substances (NFES) – 35.58%, and ash – 9.12%. The yield of feed units at natural moisture content was 0.48 feed units per kilogram of feed, while the metabolizable energy content was 7.28 MJ.

Research Point No. 32. It is located in Zaysan District of East Kazakhstan Region (Figure 36). Coordinates: N 47.596843°, E 84.594816°. Elevation: 442 m. The site is situated on a lakeside terrace of Lake Zaysan. Soil: heavy-loamy brown desert solonetzic soil. The vegetation is ephemeral–wormwood with Isegec. Wormwood (Artemisia) – sporadic, alyssum – solitary to sporadic, Isegec – solitary, Discurainia – isolated, Ebelik – isolated. Projective cover: 40–50%. Vegetation height: 15–25 cm. Soil pit depth: 60 cm. Thickness of the A+B horizons: 35 cm. Effervescence occurs from the surface. Carbonate spots occur at 35–50 cm. Gravel is present as isolated inclusions throughout the profile. Horizons: A_1k 0–5 cm, B_1sn 5–17 cm, B_2 17–35 cm, C_1k 35–50 cm, C_2 50 cm–bottom.

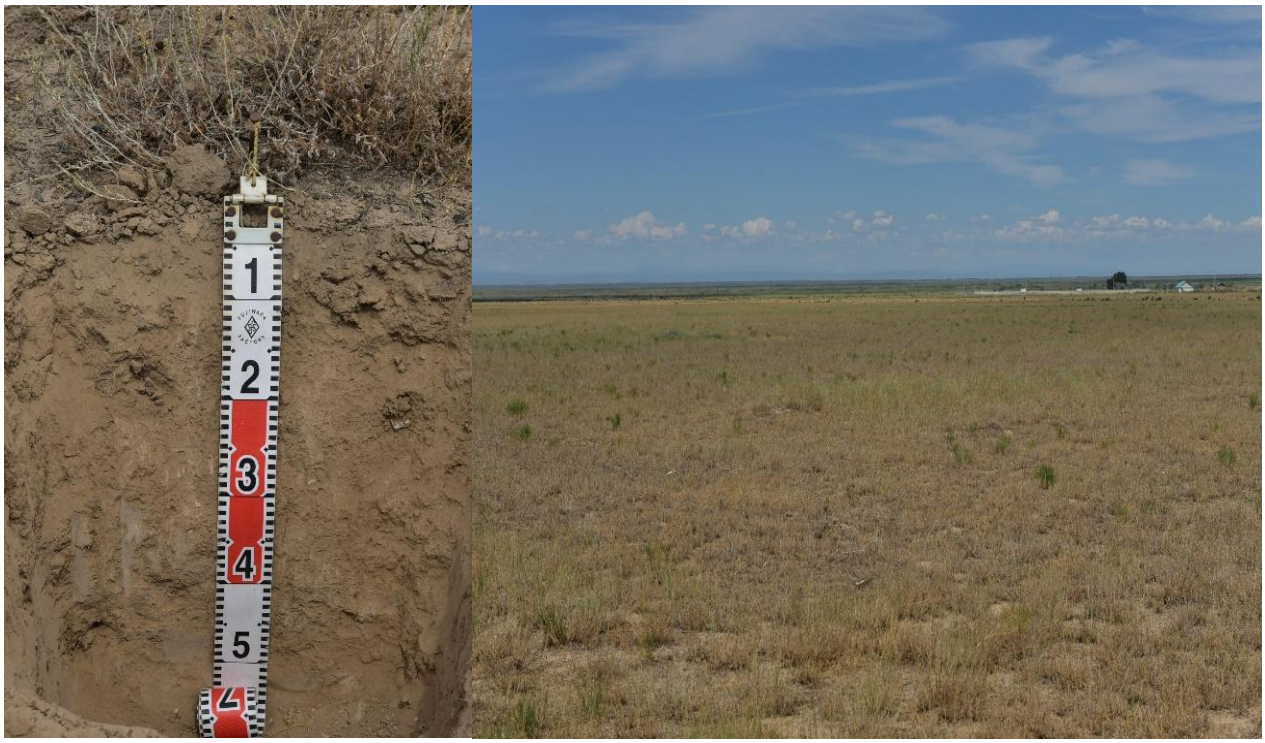


Figure 36 – Heavy-Loamy Brown Desert Solonetzic Soil

0–5 cm — grayish light brown, dry, with a dense crust, heavy loamy.

5–17 cm — brown, dense, dry, blocky, heavy loamy.

17–35 cm — brown, dry, compacted, cloddy, heavy loamy.

35–50 cm — whitish brown, with carbonate spots, dusty-blocky, heavy loamy.

50 cm–bottom — yellowish brown, compacted, dry, banded-blocky, medium loamy.

The profile is characterized by a dense surface crust and a solonetzic horizon at 5–17 cm; effervescence occurs from the surface, while carbonate spots are observed in the 35–50 cm layer. The soil has a low humus content, with 1.08% humus in the upper horizon. The soil reaction is

alkaline from the surface (pH 8.60). In the upper layer, the exchangeable Na content is 0.13 meq/100 g, while the sum of exchangeable bases is 15.61 meq/100 g (Table 113).

Table 113 – Chemical and Physicochemical Properties of Brown Desert Solonetzic Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
32	0-5	1,08	0,140	0,39	11,93	2,98	0,13	0,57	15,61	8,60
	6-16	0,77	0,084	1,64	5,96	3,48	0,23	0,09	9,76	8,71
	21-31	0,63	0,070	3,43	9,44	4,97	0,13	0,02	14,56	8,71
	37-47	0,73	0,056	3,92	11,43	3,98	0,09	0,02	15,52	8,75
	50-60			4,42	7,95	4,97	0,09	0,02	13,03	8,94

Particle-size distribution data show some differentiation in the middle part of the profile, with the texture changing from light loamy to medium loamy in the solonetzic horizon (Table 114). The water extract indicates that salinization develops predominantly in the lower part of the profile; among the water-soluble components, sulfates and Na^+ play a significant role (Table 115).

Table 114 – Particle-Size Distribution of Brown Desert Solonetzic Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
32	0-5	11,10	40,58	20,30	8,93	9,74	9,34	28,02
	6-16	9,57	35,90	23,61	9,77	10,99	10,18	30,93
	21-31	10,44	34,12	24,46	9,38	3,26	18,35	30,98
	37-47	10,33	32,53	25,71	11,43	9,80	10,20	31,43
	50-60	6,70	35,50	30,94	5,70	7,33	13,84	26,87

Table 115 – Composition of Water-Soluble Salts in Brown Desert Solonetzic Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	$SO4^{-2}$	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
32	0-5	0,042	0,022	0,000	0,002	0,006	0,002	0,003	0,001	0,005
			0,36	0,00	0,07	0,13	0,09	0,28	0,04	0,14

	6-16	0,041	0,029	0,000	0,001	0,001	0,004	0,003	0,001	0,001
			0,48	0,00	0,03	0,02	0,19	0,28	0,04	0,02
	21-31	0,044	0,029	0,002	0,001	0,003	0,006	0,002	0,002	0,001
			0,48	0,08	0,03	0,06	0,28	0,19	0,08	0,02
	37-47	0,064	0,029	0,001	0,004	0,014	0,006	0,003	0,007	0,001
			0,48	0,04	0,10	0,29	0,28	0,28	0,29	0,02
	50-60	0,081	0,041	0,005	0,005	0,013	0,002	0,005	0,014	0,001
			0,68	0,16	0,14	0,28	0,09	0,38	0,61	0,02

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for no more than 40–45% of the total soil surface. The pasture type is wormwood–ephemeral. The botanical composition consists of wormwood – 90% and ephemerals – 10%. Alyssum, ebelik, Discurainia, fenugreek, and leafless barnyard grass also occur. The yield of pasture herbage is 7.5 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 14.93%, fat – 6.34%, fiber – 35.18%, nitrogen-free extractive substances (NFES) – 32.68%, and ash – 7.23%. The yield of feed units at natural moisture content was 0.55 feed units per kilogram of feed, while the metabolizable energy content was 7.78 MJ.

Research Point No. 33. It is located in Zaysan District of East Kazakhstan Region (Figure 37). Coordinates: N 47.514495°, E 84.947955°. Elevation: 495 m. The site is situated on a lakeside terrace of Lake Zaysan. Soil: heavy-loamy meadow magnesium-solonetzic soil. The vegetation is meadow-type, consisting of diverse herbaceous species and wormwood with grasses. Tall wormwood (Artemisia) – sporadically common, prostrate bedstraw (Galium) – solitary, Kentucky bluegrass (Poa pratensis) – solitary, spurge (Euphorbia) – solitary, feather grass (Stipa) – isolated. Projective cover: 80–85%. Vegetation height: 40–50 cm. Soil pit depth: 70 cm. Thickness of the A+B horizons: 70 cm. Effervescence is absent. No visible carbonates are observed. Horizons: A_1sn 0–10 cm, B_1sn 10–20 cm, B_2 20–35 cm, B_3bur 35–50 cm, B_4 50 cm–bottom.

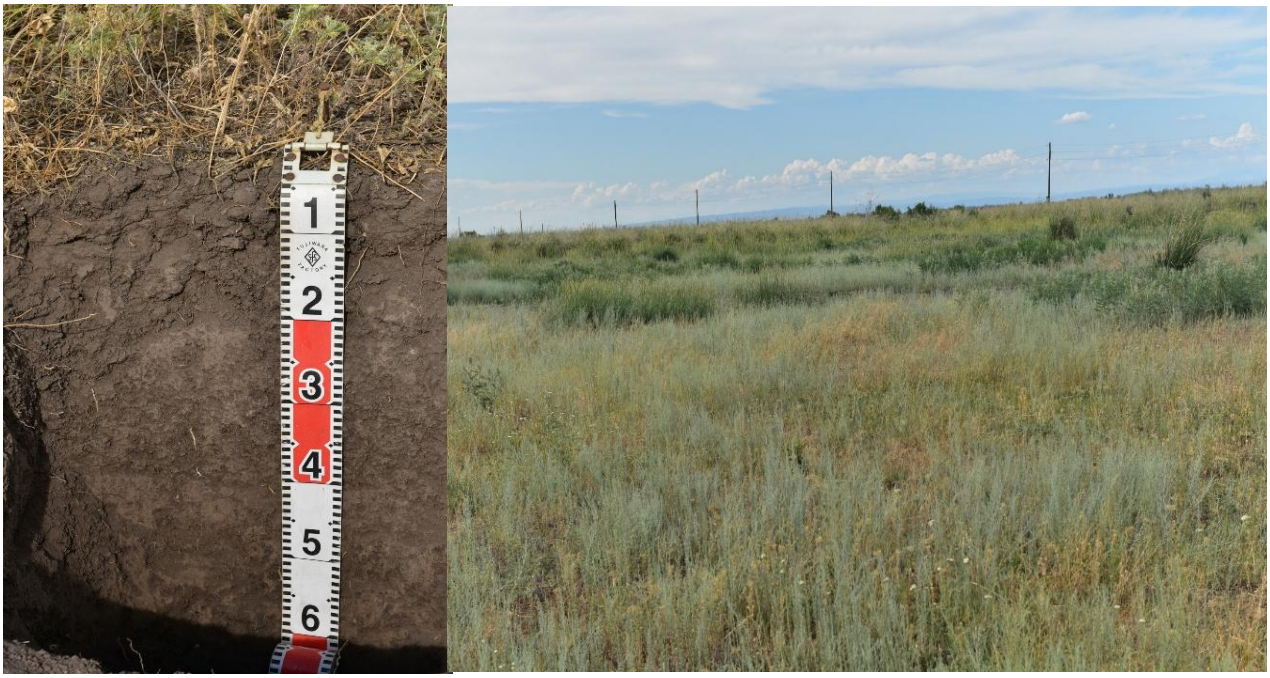


Figure 37 – Meadow Magnesium-Solonetzic Soil

0–10 cm — dark grayish, dry, compacted, with roots, coarse cloddy, slightly layered, heavy loamy.

10–20 cm — brownish gray, dry, very dense, blocky, heavy loamy.

20–35 cm — dark grayish, dry, dense, cloddy-nutty, heavy loamy.

35–50 cm — dark gray, dry, dense, nutty, heavy loamy.

50 cm–bottom — dark gray, dry, dense, sharply edged cloddy.

Table 116 – Chemical and Physicochemical Properties of Meadow Magnesium-Solonetzic Soil

Section	Sample depth, cm	Humus, %	Total nitrogen, %	CO_2,%	Exchangeable bases, mg-eq/100 g					pH water
					Ca	Mg	Na	K	Total	
33	0-10	4,24	0,252	0,16	19,38	7,46	0,13	1,66	28,63	7,42
	10-20	3,31	0,210	0,26	20,38	7,46	0,05	0,85	28,74	7,72
	22-32	3,07	0,210	0,23	21,37	6,46	0,09	0,33	28,25	7,75
	37-47	3,00	0,168	0,33	24,85	2,98	0,11	0,01	27,95	7,67
	60-70	3,07	0,196	0,36	24,85	5,47	0,13	0,01	30,46	7,77

The soil is formed on a lakeside terrace of Lake Zaysan under well-developed meadow vegetation. The entire 70-cm profile studied belongs to the A+B system; effervescence and visible carbonate accumulations are absent. The upper part is well humified: humus content is 4.24% in the 0–10 cm layer, 3.31% at a depth of 10–20 cm, and approximately 3.0% below. The soil reaction is slightly alkaline, with pH values ranging from 7.42 to 7.77. Ca and Mg clearly

predominate in the soil exchange complex, with Mg content reaching 7.46 meq/100 g in the upper 20 cm, while exchangeable Na is very low, at 0.05–0.13 meq/100 g. This is consistent with the magnesium nature of the solonetzicity (Table 116).

According to the particle-size distribution, the profile is heavy-textured and relatively homogeneous: the physical clay content ranges from 49.63 to 58.04%, while the silt content ranges from 20.65 to 25.71%. Thus, the profile is predominantly heavy loamy, without a pronounced textural contrast between the upper and lower parts (Table 117).

Table 117 – Particle-Size Distribution of Meadow Magnesium-Solonetzic Soil

Section	Depth, cm	Fraction content, % on an absolutely dry soil basis						
		Fraction sizes, mm						
		Sand		Silt			Clay	Physical clay
		1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
33	0-10	10,18	19,20	16,93	14,87	18,17	20,65	53,69
	10-20	7,92	20,95	21,51	8,27	19,85	21,51	49,63
	22-32	11,25	13,05	18,20	11,58	23,16	22,75	57,50
	37-47	9,16	17,45	15,34	12,85	19,49	25,71	58,04
	60-70	15,15	15,40	16,54	12,40	17,78	22,74	52,91

Unlike solonetzic solonchaks, the content of water-soluble salts is extremely low: their total content ranges from only 0.025 to 0.071%, while water-soluble Na^+ is predominantly 0.03–0.07 meq. Therefore, current salinization is practically absent (Table 118).

Table 118 – Composition of Water-Soluble Salts in Meadow Magnesium-Solonetzic Soil, %/meq

Section	Depth, cm	Total salt content, %	Alkalinity		Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
			Total HCO_3^-	From normal carbonates as CO_3						
33	0-10	0,071	0,032	0,000	0,002	0,016	0,004	0,005	0,001	0,012
			0,52	0,00	0,07	0,32	0,19	0,38	0,03	0,32
	10-20	0,055	0,017	0,000	0,002	0,022	0,002	0,007	0,001	0,004
			0,28	0,00	0,07	0,45	0,09	0,57	0,03	0,11
	22-32	0,025	0,017	0,000	0,001	0,000	0,002	0,001	0,002	0,002
			0,28	0,00	0,03	0,00	0,09	0,09	0,07	0,06
	37-47	0,041	0,015	0,000	0,006	0,010	0,002	0,006	0,001	0,001
			0,24	0,00	0,17	0,22	0,09	0,47	0,03	0,03
	60-70	0,025	0,010	0,000	0,004	0,004	0,002	0,002	0,001	0,002
			0,16	0,00	0,10	0,09	0,09	0,19	0,03	0,05

Characteristics and Feed Value of the Vegetation Cover

The projective vegetation cover accounts for 80–85% of the total soil surface. The pasture type is wormwood–forb–grass. The botanical composition consists of wormwood – 65%, forbs – 25%, and grasses – 10%. The vegetation includes crested wheatgrass, Kentucky bluegrass, Eremopyrum, prostrate bedstraw, bindweed, yarrow, spurge, feather grass, yellow sweet clover, alyssum, and Camphorosma. The yield of pasture herbage is 15.0 c/ha. Chemical analysis of the forage showed that, in the air-dry state, the protein content was 14.64%, fat – 7.31%, fiber – 30.62%, nitrogen-free extractive substances (NFES) – 36.22%, and ash – 7.72%. The yield of feed units at natural moisture content was 0.59 feed units per kilogram of feed, while the metabolizable energy content was 8.19 MJ.

PART IV

Development of a digital map of solonetz lands in the Republic of Kazakhstan

In accordance with the 2026 research methodology, ground verification is a fundamentally important component of the remote sensing and GIS assessment of solonetz lands. The coordinates of monitoring plots, soil profile characteristics, and data on vegetation cover and pasture productivity provide a link between remotely detected features and actual soil properties.

The results of the 2026 field studies in five regions of Kazakhstan confirmed the presence of various morphological and genetic varieties of solonetz soils. In particular, shallow, medium and shallow solonchakic solonetz soils were studied in Abai region; shallow and medium solonetz soils in Kostanay region; and shallow, medium and crusted solonetz soils in North Kazakhstan region. Meadow-solonetz, meadow-solonchak, steppe, shallow and crusted varieties were identified in Pavlodar region, while meadow, desert and solonetzic varieties were identified in East Kazakhstan region.

The field study results also showed that the remote sensing signatures of solonetz soils can vary considerably depending on moisture conditions and vegetation cover. For example, at one of the desert solonetz plots in East Kazakhstan region, projective vegetation cover was 30-35%, whereas at a plot with solonetzic meadow soil and a shallow groundwater table it reached 80-85%.

This confirms the need for a multicomponent mapping model in which satellite data are considered together with soil information and ground observations.

In Figure 1, the spatial locations of the monitoring points allow the degree of their geographical correspondence with the delineated solonetz polygons to be assessed. This

comparison provides a basis for independent validation of the mapping results and subsequent refinement of the boundaries of solonetz areas.

Overall, the results of spatial and attribute processing make it possible to identify solonetz soils within the full set of soil polygons by successively differentiating solonetzic and solonchak soils. The resulting final layer, SOLONCY_KZ_FIN, contains 205 spatial polygons with a total area of 17,55 million ha.

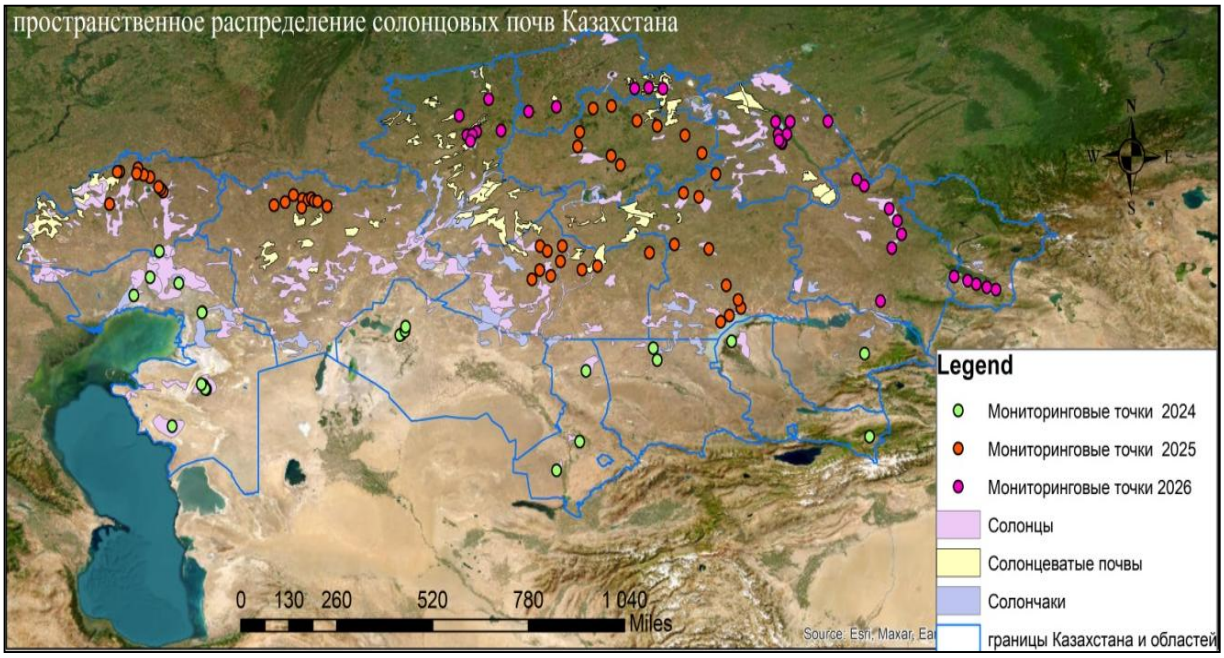


Figure 1 – Map of the spatial distribution of solonetz areas in Kazakhstan produced through spatial and attribute selection

The substantial variability in polygon areas indicates the complex mosaic pattern of solonetz soil distribution in Kazakhstan. The spatial pattern of solonetz soils is determined by the combined effects of soil, landscape, hydrological and biological factors.

The results of the 2026 research confirm the need to integrate soil mapping information, ground observations, multi-year remote sensing data and GIS technologies. Multi-year MODIS, Sentinel-2 and Landsat data make it possible to account for seasonal and interannual variability in vegetation cover; however, NDVI cannot be regarded as a stand-alone diagnostic indicator of solonetz soils. Its use is most effective in combination with SAVI, BSI, Salinity Index, Top-Soil Grain Size Index and ground verification results.

Based on the results of the 2024-2026 research, a final interactive electronic map of solonetz lands in pastures was developed using GIS technology at a scale of 1:1 000 000 for seventeen administrative regions of the Republic (based on 108 monitoring plots): Atyrau, Mangystau, Turkestan, Zhambyl, Almaty, Kyzylorda, Zhetysu, Karaganda, Ulytau, Akmola,

West Kazakhstan, Aktobe, Abai, Kostanay, North Kazakhstan, Pavlodar and East Kazakhstan regions (Figure 2). https://arcg.is/0DmLyb4

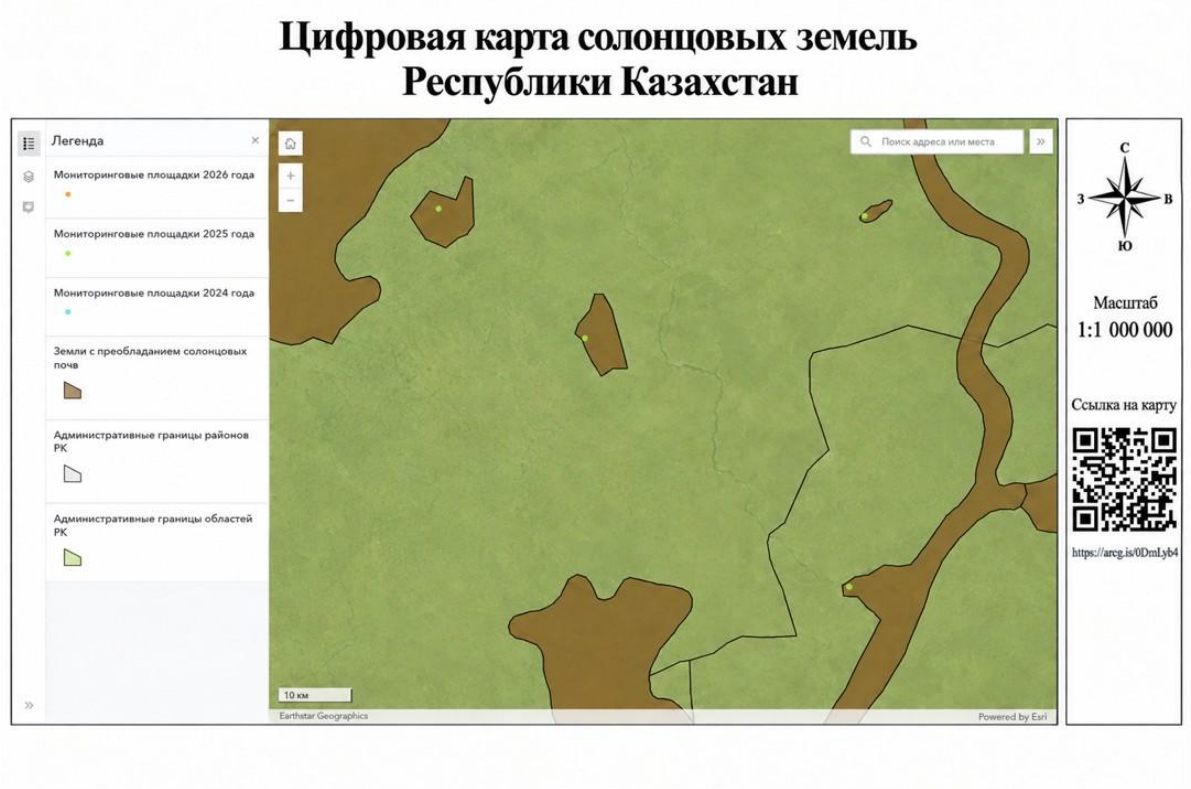


Figure 2 – Digital map of solonetz lands in the Republic of Kazakhstan

A database of solonetz lands in pastures has been established using GIS technologies https://www.kaznaru.edu.kz/ru/pages/13

The database enables timely updating of information and its application in agricultural planning, sustainable pasture use and land reclamation.

The total areas of solonetz lands by region (according to the report and the maps produced) are presented in Table 1.

The GIS platform and statistical database provide a basis for developing regional programmes for the restoration and sustainable use of degraded lands, as well as for long-term monitoring of the condition of Kazakhstan's pasture resources.

Table 1 shows the areas of saline soils on pastures.

Table 1 – The area of saline soils on pastures in the Republic of Kazakhstan.

No	Name of	The area of saline soils, thousand hectares

	the regions	
1	Mangystau Region	
2	Atyrau Region	
3	Kyzylorda Region	
4	Turkestan Region	
5	Zh	

	amby l Regi on	
6	Al maty Regi on	
7	Zh ety su Regi on	
8	Ak m ola Regi on	
9	Ak to be Regi on	
1 0	W est Ka za	

	khstan Regi on	
11	Karaganda Regi on	
12	Ulytau Regi on	
13	Abay Regi on	
14	Kostanay Regi on	
15	North	

	Kazakhstan Region	
16	Pavlodar Region	
17	East Kazakhstan Region	
Total area		

Table 2 – Types and degrees of salinity in saline soils on pastures in the Republic of Kazakhstan

Research point /	Coordinates	Soil type	Degree of salinity

Monitoring platform			
Atyrau Region			
1	N47°707'07, E052°879'22.	Small salt shaker	Strongly saline
2	N47°887'83, E051°549'40	Small salt shaker	Strongly saline
3	N47°338'70, E051°114'70	Cork salt shaker	Strongly saline
4	N46°822'40, E 053°801'95	Small salt shaker	Strongly saline
5	N46°815'82, E 053°785'98	Medium salt ness	Strongly saline
Mangystau Region			
6	N44°485'67, E 053°914'75	Gray-brown	Deeply saline-sodic magnesium-rich
7	N44°472'88, E053°965'15	Medium salt nes	Deeply saline-sodic

		s	magnesium-rich
8	N44°061'51, E052°194'03	Small salt shaker	Strongly saline
9	N43°681'74, E052°116'31	Gray-brown	Strongly saline
10	N43°344'62, E052°615'25	Gray-brown	Medium-saline
Turkestan Region			
11	N 45°01$^{'}$ 40,9$^{"}$; E 68 ^{O} 51$^{'}$ 35,5$^{"}$	Solonets is a desert crust	Strongly saline
12	N 41^{0}59^{I} 47,1^{II} E 67^{0}42^{I} 20,9^{II}	Gray-brown	Slightly saline
13	N 42 52$^{/}$31.9$^{//}$ E 68 36$^{/}$40.8$^{//}$	Meadow-gray soil	Strongly saline
Zhetysu Region			
14	46° 19$^{'}$ 05,0$^{"}$ 81° 12$^{'}$ 33,7$^{"}$	Meadow-desert salt lick	Slightly saline magnesium-rich
15	N 49°35′10,2″ E 79°46′42,1″	Meadow solonetz	Strongly saline
16	N 45°33′45,3″ E 79°47′33,7″	Meado	Slightly

		w	saline
17	46° 19$^{'}$ 05,0$^{"}$; 81° 12$^{'}$ 33,7$^{"}$	Meadow-desert salt lick	Slightly saline magnesium-rich
Zhambyl Region			
18	N 45°21′54,8″ E 71°39′03,2″	Desert salt lick	Strongly saline
19	N 45°43′33,5″. E 71°29′59,3″	Gray-brown desert-like	Slightly saline
Almaty Region			
20	46,264139; 74,324545.	Takhir-shaped	Medium-saline
21	43° 1' 35.58". 79° 59' 17.35"	Meadow	Strongly saline
Kyzylorda Region			
22	N 46° 09$^{'}$ 08,9$^{"}$. E 61° 37$^{'}$ 15,0$^{"}$	Desert salt lick	Strongly saline
23	N 46° 07$^{'}$ 46,7$^{"}$. E 61° 33$^{'}$ 10,3$^{"}$	Desert salt lick	Strongly saline
24	N 46° 14$^{'}$ 35,8$^{"}$. E 61° 45$^{'}$ 23,9$^{"}$	Desert salt lick	Strongly saline
25	N 46° 22$^{'}$ 53,4$^{"}$. E 61° 46$^{'}$ 51,1$^{"}$	Desert salt lick	Strongly saline
Karaganda Region			
1	N 46° 530' 784", E 074°146' 130"	Mediu	Deeply

		m salti nes s	salin e-so dic
2	N 46°721' 132", E 074°483' 838"	Me diu m salti nes s	Stro ngly salin e
3	N 46° 949' 820", E 074°941' 162"	Sm all salt sha ker	Stro ngly salin e
4	N 47°199' 144", E 074° 827' 975"	Me diu m salti nes s	Stro ngly salin e
5	N 47°645' 370", E 074° 365' 029"	Sm all salt sha ker	Dee ply sligh tly salin e
6	N 48° 756' 219", E 073° 681' 798"	Sm all salt sha ker	Stro ngly salin e
7	N 48° 890' 700", E 072°333' 273"	Cor k salt sha ker	Stro ngly salin e
8	N 50°469' 737", E 072° 687' 368"	Sm all salt sha ker	Med ium-salin e
9	N 51°040' 035", E 073° 956' 100"	Sm all salt sha ker	Stro ngly salin e
10	N 50° 346' 582", E 073° 289' 311"	Sm all salt sha	Stro ngly salin e

		ker	
Ulytau Region			
11	N 48° 639' 417", E 071° 347' 464"	Small salt shaker	Strongly saline
12	N 48° 229' 394", E 069° 306' 406"	Small salt shaker	strongly saline
13	N 48° 122' 130", E 068° 700' 593"	Medium saltiness	Slightly saline-sodic magnesium-rich
14	N 47° 936' 965", E 007° 481' 389"	Light chestnut	Slightly saline residual
15	N 47° 822' 188", E 066° 737' 940"	Small salt shaker	Medium-saline
16	N 48° 105’ 711", E 067° 043’ 747"	Small salt shaker	Strongly saline
17	N48°841'375", E 067°061'471"	Cork salt shaker	Strongly saline
18	N 48°689' 067", E 067°344' 075"	Cork salt shaker	Strongly saline
19	N 48° 838' 903", E 067° 932' 118"	Small salt sha	Strongly saline

		ker	
20	N 48° 374' 403", E 067° 854' 285"	Small salt shaker	Slightly saline-sodic magnesium-based
Akmola Region			
21	N 51° 313' 935", E 070° 209' 884"	salt block	Strongly saline
22	N 51° 600' 993", E 069° 850' 032"	salt block	Strongly saline
23	N 51° 883' 090", E 068° 529' 880"	Small meadow salt lick	Strongly saline
24	N 52° 323' 206", E 068° 611' 116"	Small meadow salt lick	Slightly saline-sodic magnesium-based
25	N 53° 046' 727", E 069° 140' 717"	Small salt shaker	Deeply saline magnesium soil
26	N 53° 116' 890", E 069° 859' 629"	Small salt shaker	Medium-saline
27	N 52° 667' 836", E 070° 861' 389"	Sm	Stro

		all salt shaker	ngly saline
28	N52°511'532", E071°651'485"	Small salt shaker	Strongly saline
29	N 52° 223' 521", E 072° 742' 756"	salt block	Medium-saline
30	N 51° 683' 408", E 073° 408' 963"	Small salt shaker	Strongly saline
Aktobe Region			
31	N 50,280431º, E 57,736493º	Solonets steppe	Deep-middle columnar
32	N 50,254651º, E 57,953029º	Chestnut	Slightly saline
33	N 50,297157º, E 58,080788º	Meadow-desert salt lick	Strongly saline
34	N 50,219143º, E 58,194353º	Chestnut	Medium-saline
35	N 50,205311º, E 58,325471º	Solonets steppe	Strongly saline
36	N 50,400845º E 57,37 545º	Meadow-chestnut	Strongly saline

37	N 50,182491º E 57, 049101º	Solonets steppe	Strongly saline
38	N 50,050770 º E 58,702365º	Solonetz	Strongly saline
39	50.014 829º E 57. 701 498º	Chestnut	слабосолонцеватая
40	N 50,086763 º E 56,618554º	Chestnut	слабосолонцеватая
West Kazakhstan Region			
41	N 50,506914º E 52,26408º	Solonetz	Strongly saline
42	N 50.585 831º E 52. 170 676º	Meadow-steppe salt lick	Strongly saline
43	N 50.652015º E 52. 081550º	Steppe salt lick	Strongly saline
44	N 50.950 187º E 51.744 657º	Steppe salt lick	Strongly saline
45	N 51,020283 º E 51,495 817º	Chestnut	Slightly saline
46	N 51,218016º E 51,272661º	Chestnut	Slightly saline
47	N 51.116 833º E 50.557786º	Steppe salt lick	Strongly saline

48	N 50.126092º E 50.161923º	Chestnut	Strongly saline
49	N 51,108436º E 50,462800º	Steppe salt lick	Strongly saline
50	51.054148º E 51.222784º	Chestnut	Slightly saline
Abay Region			
1	N 47°59$^{'}$ 39,9$^{"}$. E 080° 25$^{'}$ 18,1$^{"}$	Small salt shaker	Strongly saline
2	N 48°786$^{'}$ 340$^{"}$. E 080° 861$^{'}$ 024$^{"}$	Small salt shaker	Medium-saline
3	N 48°203$^{'}$ 764$^{"}$. E 081° 240$^{'}$ 189$^{"}$	Medium saltiness	Slightly saline-sodic magnesium-based
4	N 49°605$^{'}$ 869$^{"}$. E 081° 073$^{'}$ 478$^{"}$	Small salt shaker	Slightly saline-sodic magnesium-based
5	N 49°973$^{'}$ 473$^{"}$. E 080° 750$^{'}$ 224$^{"}$	Small salt shaker	Deeply slightly saline magnesium

			soil
6	N 50°689$^{'}$ 608$^{"}$. E 079° 775$^{'}$ 617$^{"}$	Small salt shaker	Strongly saline
7	N 50°869$^{'}$ 117$^{"}$. E 079° 483$^{'}$ 883$^{"}$	Small salt shaker	Deeply slightly saline magnesium soil
Kostanay Region			
8	N 52° 194′ 513″, E 065° 297′ 767″	Medium meadow salt lick	Deeply slightly saline magnesium soil
9	N 52° 334, 424″; E 064° 561′ 630″	Small salt shaker	Strongly saline
10	N 52° 222′ 908″; E 064° 174′ 586″	Medium salti ness	Deeply slightly saline magnesium soil
11	N 52° 108′ 604″; E 064° 259′ 007″	Small salt shaker	Deeply slightly saline magnesium soil

12	N 52° 050′ 146″; E 064° 314′ 076″	Small salt shaker	Deeply slightly saline magnesium soil
13	N 52° 822′ 525″; E 063° 883′ 803″	Small salt shaker	Deep-middle columnar
14	N 53° 316′ 224″; E 065° 035′ 295″	Medium saltiness	Deeply slightly saline magnesium soil
North Kazakhstan Region			
15	N 52° 950′ 278″; E 066° 602′ 816″	Small salt shaker	Deeply saline-sodic
16	N 52° 092′ 972″; E 067° 683′ 165″	Medium saltiness	Deep-middle columnar
17	N 53° 651′ 484″; E 070° 769′ 105″	salt block	Strongly saline
18	N 53° 679′ 481″; E 071° 317′ 044″.	Medium saltiness	Deeply slightly saline magnesi

			um soil
19	N 53° 644′ 497″; E 071° 866′ 139″	Small salt shaker	Medium-saline
Pavlodar Region			
20	N 52,637803O, E 76,864937O	Meadow-steppe saltlick	Strongly saline
21	N 52,638259^{O} E 76,805016^{O}	Meadow-chestnut	Strongly saline
22	N 52,650654^{O} E 76,854760^{O}	Meadow	Slightly saline
23	N 52,251429^{O} E 76,746271^{O}	Dark chestnut	Strongly saline
24	N 52,300541^{O} E 76,705338^{O}	Dark chestnut	Medium-saline
25	N 52,250853^{O} E 76,396080^{O}	Dark chestnut	Strongly saline
26	N 51,988472^{O} E 76,553584^{O}	Dark chestnut	Medium-saline
27	N 52,007309^{O} E 76,526867^{O}	Solonetz - solonchak	Strongly saline
28	N 52,075150O E 76,431687O	Ste	Stro

		ppe salt lick	ngly salin e
East Kazakhstan Region			
29	E 47,913731^{O} N 83,309826^{O}	Me ado w solo netz	Stro ngly salin e
30	E 47,790327 ^{O} N 83,840453 ^{O}	Bro wn des ert	Slig htly salin e
31	N 47,681474^{O} E 84,181165^{O}	Des ert salt lick	Dee ply sligh tly salin e
32	47,596843^{O} E 84,594816^{O}	Bro wn des ert	Slig htly salin e
33	N 47,514495^{O} E 84,947955^{O}	Me ado w	Slig htly salin e mag nesi um-r ich