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Engineering and Process Infrastructure of the Agro-Industrial Complex

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ABSTRACT

Animal husbandry is a high-priority industry for national food security, as it covers the market needs for dairy and meat products. Its further advancement requires highly productive grazing land rich in water and armed with state-of-the-art engineering infrastructure. In the West Kazakhstan region, grazing land is mainly watered from dug and driven wells, dugout ponds, canals, water pipes, lakes, and rivers.

This paper analyzes the potential and utilization of grazing land in different landscapes of the West Kazakhstan region. The researchers have monitored the pasture water sources, the hydrology of surface water sources, the utilization rate of underground water sources within the dry steppes and semi-arid areas of the West Kazakhstan region; the monitoring results are presented herein. The paper also dwells upon the hydrochemical lab tests of water sampled from the sources the free-range locations are watered from.

Key words: West Kazakhstan, Animal Husbandry, Pasture, Grazing Land, Watering, Open Water Sources, Groundwater, Dug Wells, Driven Wells, Hydrochemistry.

1. INTRODUCTION

As the Republic of Kazakhstan is facing an ever greater threat to its food security, it needs to advance domestic food-making to be less dependent on food imports. Animal husbandry is crucial to food security. As such, it is a priority for the agro-industrial complex of the West Kazakhstan region, as its livestock products account for more than 60% of the GRP. The *Concept of the Regional Program for Agro-Industrial Complex Development in the West Kazakhstan Region* sets forth that in monetary terms, animal husbandry must rise by 40% to 149.8 billion tenge. This is only attainable by the rational use of land to provide grazing for farmers. In this regard, it is of paramount importance to create highly productive grazing land for the livestock to have high-quality fodder at low cost [1-5]. The world's best practices focus on using irrigated grazing land [6-8]. International scientists make a great emphasis on using groundwater to increase the moisture content of grazing land [9, 10]. Remote sensing methods are an increasingly popular solution for studying grazing land productivity and how it correlates with water availability [11-13].

Livestock productivity and animal husbandry prospects depend on pasture watering and livestock access to water [14-15].

2. METHODS

The research team studied the water sources used in free-range animal husbandry in dry steppes and semi-arid zones in the West Kazakhstan region.

Statistical data were processed and grouped by grazing lands. Grazing land data were processed in Excel 2010. The system analysis method and system approach were employed for greater data reliability.

Remote sensing data (space imagery) were processed to analyze the area and density of water sources.

In the dry steppes, grazing land stretches 580 km west-to-east, covering over three million ha. The researchers analyzed the free-range locations distributed evenly across the dry steppes of the West Kazakhstan region, covering 20 rural districts, 7 administrative districts.

In the semi-arid zone, grazing land stretches 600 km west-to-east, covering over 5.5 million ha. The researchers analyzed the free-range locations distributed evenly across the semi-arid zone of the West Kazakhstan region, covering 18 rural districts, 5 administrative districts.

All in all, the research effort covered 133 monitoring points, sampling water from 112 of them. Water sources were monitored in terms of their actual condition at specific locations; samples were subject to further quantitative and qualitative analysis.

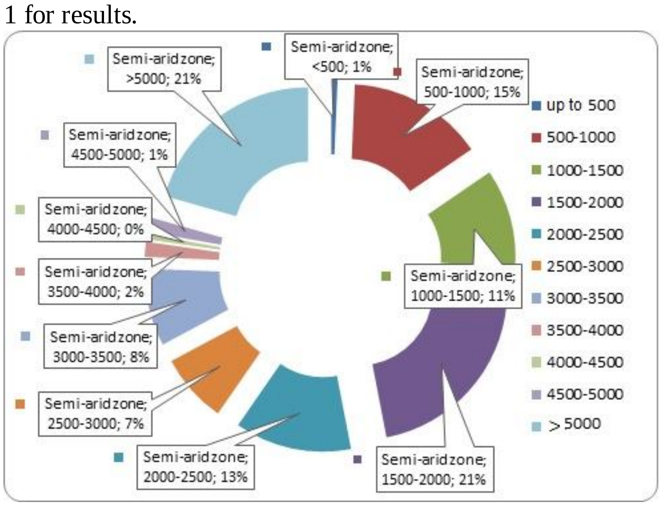
Water sampling was done according to appropriate GOSTs. Chemical analysis was outsourced to accredited labs, including Zhaiykgidrogeologiya, LLP as well as the Research Department of Zhangir Khan University.

Lab-tested indicators were pH, turbidity, chloride content, ammonium nitrogen content, nitrite and nitrate content, total hardness, calcium and magnesium, dry residue, etc.

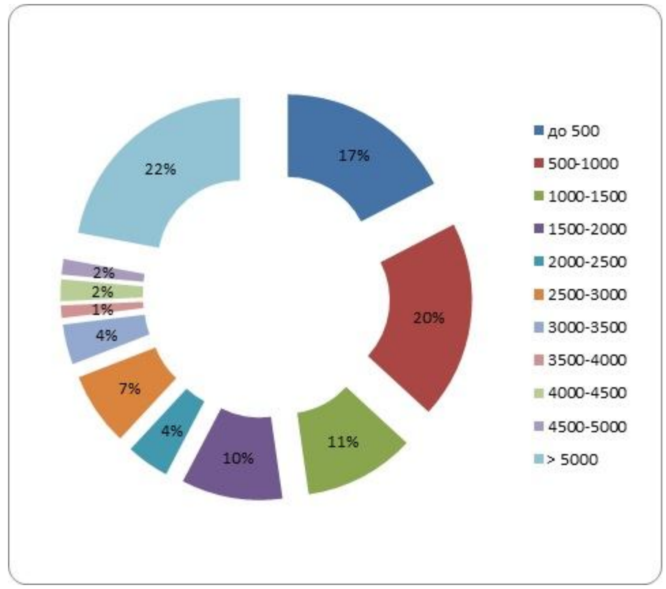
3. RESULTS

What drives the rapid advancement of animal husbandry in the West Kazakhstan region is the availability of vast and highly productive grazing land. The region contains 12 administrative districts. The pasture area totals 10,144.1 thousand ha, or 73.3% of the region. Largest grazing land is found in the Akzhaik District (2,048,093.0 ha), Zhanakala District (1,768,817.0 ha), Kaztal District (1,534,547.0 ha), and Bokey Orda District (1,376,488.0 ha).

While the sheer size of grazing land is important, the location of a farm is also a key factor of performance in animal husbandry. That is why grouping pastures in terms of their natural zoning is of scientific interest. The authors hereof grouped grazing land by dividing it into dry-steppe and semi-arid populations, each further subdivided into size-based subpopulations. The grouping interval was 500 ha. See Figure 1 for results.



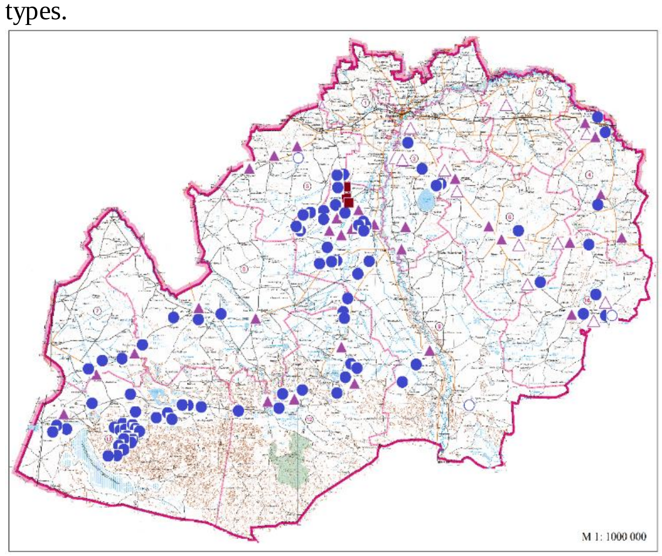
a)



b)

Figure 1: Grazing land in the dry steppes and in the semi-arid zone: distribution by area, ha and % of the total grazing land

To analyze the availability of water to the livestock, the team monitored the free-range locations in the dry steppes and in the semi-arid zone of the West Kazakhstan region. Figure 2 shows the water sampling points and specifies the source types.



Legend
Water sampled from:
▲ Rivers and canals
● Wells and driven wells
■ Dugouts
△ Dried rivers and canals
○ Depleted wells, dried canals

Figure 2: Schematic map of water sampling points

When dealing with pasture irrigation, it is important that water meets the sanitary and epidemiological standards. Table 1 presents the results of hydrochemical lab tests of water sampled from surface sources in the fall of 2018.

Table 1: Hydrochemical tests of the West Kazakhstan region's rivers

Sampling point	pH	Total hardness, mg equiv./l	Mineralization, mg/l
Ural River, village of Chapayevo	7.99 to 8.03	4.75 to 5.50	364 to 609
Ural River, village of Taipak	7.47 to 8.06	4.65 to 5.5	466 to 841
Ural River, village of Zharsuat	7.71 to 7.91	4.55 to 13.5	566 to 595
Ural River, village of Yanvartsevo	8.07 to 8.53	5.6 to 55.0	497 to 1,100
Ural River, village of Koshim	8.01 to 8.20	5.2 to 5.5	372 to 531
Bolshoy Uzen River	7.45 to 7.79	12.5 to 13.0	1,041 to 1,480
Maly Uzen River	-*	6.8 to 11.8	876 to 1,705
Chizha-1 River	7.26	10.4	1,074
Chizha-2 River	-	11.3	1,921
Shiderti River	7.02	10.0	1,144
Olenty River	7.55	75.0	6,683
Ashchyuzek River	7.43 to 8.58	150.0 to 210.0	16,670 - 25,146
Ashchy River	7.81 to 7.85	19.0 to 70.0	2,296 to 3,693
Ashchysai River	7.6	80.0	6,362
Utva River	7.1	6.2	420
Bagyrlai River	7.13	5.3	655

Table 2 presents the results of hydrochemical lab tests of water sampled from underground sources in the fall of 2018. For analysis, dry-steppe water sources are grouped by design, i.e. into dug and driven wells.

Table 2: Hydrochemical tests of the West Kazakhstan region's underground water sources

Researched district	Source type	pH	Total hardness, mg equiv./l	Mineralization, mg/l
Dry steppes				
Kaztal District	Dug well	7.23	10.0	490
	Driven well	-*	22.2	1,439
Taskala District	Dug well	7.07	7.5	404
	Driven well	-	6.5	1,161
Akzhaik District	Dug wells	6.64 to 7.84	4.3 to 150.0	343 to 11,857
	Driven wells	6.87 to 7.74	5.5 to 100.0	609 to 8,016
Syrym District	Dug well	7.12	14.5	2,075
Karatobe District	Dug wells	7.09	3.8 to 13.5	347 to 1,129
	Driven wells	7.16 to 7.37	2.4 to 11.0	200 to 1,220
Shyngyrlau District	Dug wells	7.18 to 1.29	5.1 to 16.5	461 to 2,392
	Driven well	7.3	4.1	354
Semi-arid zone				
Zhanakala District	Dug wells	6.79 to 7.27	5.6 to 40.0	339 to 5,165
Bokey Orda District	Dug wells	6.73 to 7.52	3.6 to 34.4	259 to 3,689
	Driven wells	7.18 to 7.93	4.6 to 29.0	595 to 6,215
Zhanybek District	Dug wells	7.21	9.5 to 13.6	740 to 972
	Driven well	7.34	13.5	2,686
Akzhaik District	Dug wells	7.01 to 7.85	5.5 to 60.0	287 to 4,337
Karatobe District	Driven well	7.36	2.4	662

4. DISCUSSION

4.1 Grazing Land Zoning

In the West Kazakhstan region, grazing land is localized in four types of landscape: steppes, dry steppes, semi-arid zone, and desert, see Figure 3.

Most of the grazing land is concentrated in the semi-arid zone and in the dry steppes (73% and 23.65% of total grazing land, respectively). Steppes and deserts account only for 2.66% and 0.69% of the grazing land, respectively.

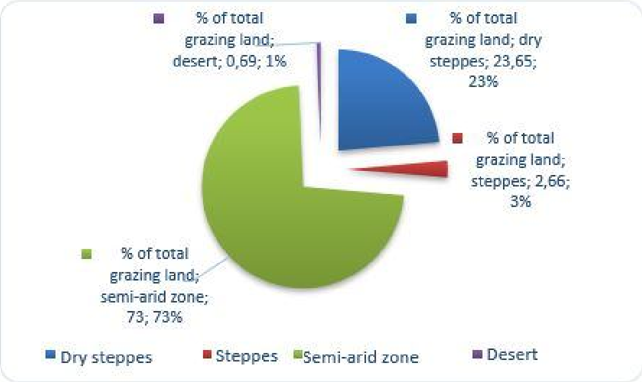


Figure 3: Grazing land area by landscape

The analysis shows the difference in the zoning of semi-arid and dry-steppe grazing land. Private farms in the dry steppes are mainly (19.44%) pastures sized 500 to 1,000 ha. Pastures under 500 ha account for 17.41%, pastures sized 1,000 to 1,500 ha account for 10.91%, and those sized 1,500 to 2,000 ha – for 9.93%.

The semi-arid zone is dominated by pastures sized 1,500 to 2,000 ha (20.64%). Pastures sized 500 to 1,000 ha account for 14.77%, pastures sized 2,000 to 2,500 ha account for 12.68%, and those sized 1,000 to 1,500 ha – for 10.88%.

Thus, whereas pastures under 500 ha are significant in the dry steppes, they make up for a relatively small part of the semi-arid grazing land. Pastures exceeding 3,000 ha in the area are negligible in both of the analyzed landscapes.

The availability of water for pastures and free-range locations is fundamental for the efficient land use.

4.2 Surface Water Sources

Watering is a major problem for semi-arid pastures, where half of the grazing land remains under-utilized due to lack of water. Irrigating hayfields and pastures remains problematic for the dry steppes, too. In a severely arid climate, water management is key to agricultural development, sustainability, and intensification.

The region under consideration is extremely diverse in terms of landscape. It stretches from the north southwards, which produces a whole sequence of geographical zones with varying availability of water, be it from the surface or underground sources. Significant diversity is observed in the hydrogeology of the studied water sources.

Monitoring shows that surface waters from rivers, canals, ponds, and reservoirs are used to irrigate the pastures in case underground waters are not available, are of low quality or yield.

The right bank of the Ural River branches into multiple canals of the Ural-Kushum irrigation system. In this area, rivers and canals are dense. In areas adjacent to irrigation systems, water is supplied from continuous or intermittent irrigation canals that carry water from rivers or major reservoirs. If an irrigation canal is intermittent, i.e. only active at times, backup water is required when it is inactive. Water is stocked in smaller ponds and reservoirs. In the studied region, free-range locations are all in the vicinity of irrigation canals. These locations feature man-made ponds filled with water from the canals.

The southwest and the northwest of the semi-arid zone have low concentrations of rivers and canals due to natural zoning. Half of this part of the region is in grave need of watering of its grazing lands.

The grazing land in the West Kazakhstan region is watered to a great extent from rivers and local water streams, mainly from the Ural, Bolshoy Uzen, Maly Uzen, Ulenta, Kaldygaity, and Buldyrty Rivers, the basins of which feature major irrigation systems. The rivers are distributed unevenly in the region, are snow-fed, have fast current, and feature a significant variance of the annual runoff.

Water in the region mainly comes from the Ural River with the left-bank tributaries Yembulatovka, Bykovka, Rubezhka, and Shagan, as well as the right-bank tributaries Yelek, Utva, and Barbastau. In 2017, the annual average water level of the Ural River was 214 cm as measured by the hydrology station in the village of Kushum, whereas the annual average runoff was 263 m^3/c. Runoff totaled 8.28 km^3/year. In 2018, the spring freshet peaked at 459 cm on April 16 as measured by the hydrology station in the town of Uralsk, which is far below the average perennial level of 591 cm.

Through the Kushum River, the Ural River feeds the Ural-Kushum irrigation system (the UKIS) that waters 2,177 hectares of grazing land. During the freshet of 2017, the UKIS took 282.84 million m^3 of water from the Ural River.

The UKIS water quality can be evaluated by the samples taken from the Kushum River. The Kushum River, fed from the Ural River, is pH-neutral, hard, moderately fresh in terms of mineralization, magnesium/calcium sulfate/chloride water as sampled at the Amaner Communal Farm.

Pastures in the northwest of the West Kazakhstan region are mainly watered from the Bolshoy/Maly Uzen Rivers. In 2017, the annual average water level of the Bolshoy Uzen River was 500 cm as measured in the village of Kayindy, whereas the annual average runoff was 2.42 m^3/c. Runoff totaled 76.3 million m^3/year. In 2018, the freshet was low; the system has 445.7 thousand ha of watered pastures.

If sampled in the village of Chapayevo, the Ural's water is low-alkaline, moderately hard, moderately fresh water. If sampled in the village of Taipak, it is neutral to low-alkaline, moderately hard, fresh to moderately fresh water. If sampled in the village of Zharsuat, it is low-alkaline, moderately hard to hard, moderately fresh water. If sampled in the village of Yanvartsevo, it is low- to medium-alkalinity, moderately hard to very hard, fresh to low-brackish water. If sampled in the village of Khoshim, it is low-alkaline, moderately hard, moderately fresh to fresh water.

Water from the Bolshoy Uzen River is neutral to low-alkaline (pH 7.46 to 7.79), very hard, low-brackish, calcium/sodium chloride, magnesium/sodium chloride water.

In the Maly Uzen River, the water level averaged at 275 cm in 2017 as measured by the hydrology station in the village of Bostandyk; the annual average runoff was 1.03 m^3/s, totaled 32.6 million m^3. Its basin contains the Maly Uzen Irrigation

System (the MUIS) that waters 323.7 thousand ha of grazing land. The Bolshoy/Maly Uzen Rivers are also fed extra water from the Saratov Region to maintain their runoff.

The Maly Uzen River's water is moderately hard to hard (6.8 to 11.8 mg/l), moderately fresh to low-brackish (876 to 1,705 mg/l), calcium/sodium chloride, magnesium/sodium chloride water.

The north of the semi-dry zone contains the small rivers of Obshchy Syrt: Chizha-1 and Chizha-2, other rivers of the Chizhinsky, Durinsky, and Balyktinsky spates. Water from the Chizha-1/2 Rivers is hard, low-brackish, calcium/sodium sulfate/chloride water and calcium-sodium chloride/sulfate water, respectively.

The left bank of the Ural River contains a number of small rivers: Bolshaya and Malaya Ankata, Olenty, Buldurty, Kaldygaity, Zhaksybai, Shiderti, and somewhat larger Yelek and Utva Rivers. Most of the rivers flow down from the Podural Plateau and carry their waters to the Baigutin Depression. The Shiderti River has neutral, hard, low-brackish, calcium/sodium chloride/sulfate water. The Olenty River has low-alkaline, very hard, brackish, magnesium/calcium/sodium sulfate/chloride water.

Smaller rivers in the west of the region have mostly low-alkaline and neutral waters, although the Ashchiuzek River is alkaline (pH 8.58). The rivers are mainly very hard except the Bagyrlai Rigid in the village of Atameken (5.3 mg/l).

The southward rivers of the region are mainly low-brackish except Ashchiuzek (low-saline to saline at 16,670 to 25,146 mg/l), Ashchy in Shyngyrlau (brackish at 3,693 mg/l), Ashchysai (high-brackish at 6,362 mg/l), Utva and Bagyrlai (fresh and moderately fresh at 420 and 655 mg/l, respectively).

In general, the left bank of the Ural River has no canal-based pasture irrigation, as the few canals that are available are inactive. Despite the average river density, smaller streams and pools go dry in summer. Due to low summertime runoff, surficial watering does not seem a viable option.

4.3 Underground Water Sources

In most of the region, pastures are irrigated with groundwater. In hydrogeological terms, the region can be divided into northeast and southwest.

Northeast comprises the Shyngyrlau, Borili, and Taskala Districts, as well as parts of the Terekti District; north of the Karatobe District, Syrym District, and Kaztal District; parts of the Bayterek District.

Northeast has better hydrogeology than southwest. Its aquifers are associated with anisometric sands in the valleys, or with broken chalk, sand, gaize, and somewhat rarer broken sandstone in the watersheds. Groundwater runs at depths from 3 to 15 meters in the valleys, 30 to 80 meters in watersheds. The flowrate varies from 0.5 to 15 l/s; in the northeast, most of the sources have flowrates in range of 5 to 3 l/s.

Southwest comprises the Bokey Orda District, Zhanybek District, Zhanakala District, Akzhaik District, and Kaztal District, most of the Karatobe and Syrym Districts, and parts of the Terekti District.

It is located within the Caspian Lowlands, where undrinkable saline waters prevail. Freshwater is sporadic and is present in the form of separate freshwater pockets on top of saline groundwater. The pockets are associated with saucer-shaped depressions, arroyos, and bedplates. In the pockets, water is located 2 to 12 meters deep, the water output is low, the flowrate is fractions of a liter per second, the mineralization is unstable: up to a gram when opening a dug/driven well, then rising to 3-5 g/l. Snow melting and rainfalls provide water that is filtered and resupplies the pocket. The process is cyclic and repeats over several years.

As evidenced by monitoring, groundwater is extracted via dug and driven wells. Such wells are 5 to 20 meters deep, although some go down as far as 25 to 30 m. Dug wells have a flow rate of 0.3 to 3.6 m^3/h.

In the northwestern dry steppes, the dug wells of the Kaztal and Taskala Districts reach as deep as 7.64 to 12.96 m, while some driven wells go as deep as 32 meters.

In the right bank of the Ural River, the dug wells of the Akzhaik District are 3.9 to 6.1 meters deep. Some of them reach as much as 18 to 28 meters in depth.

In the center of the Ural right bank, reinforced-concrete dug wells in the Zhanakala and Akzhaik Districts are 2.89 to 7.15 meters deep. In the east of the Ural right bank, the dug-well depth is 12.6 meters. The driven wells reach a depth of 21 meters.

Monitoring the dug wells in the UKIS-covered area shows the existing dug wells are primitive and lack any kind of water pumping. In pastures, dug wells are usually equipped with modern deep pumps, with chain pumps being relatively layer. Most of the free-range locations in the southwestern semi-arid zone associated with the Volga-Ural sand basin use shallow groundwater extracted from low-rate aquifers via dug and driven wells. In this region, most of the dug wells were excavated by hand and reinforced with wooden logs; they are shallow and poor in water. The dug wells in the Bokey Orda District can be as shallow as 3.1 to 4.35 meters, as water runs right under the surface. Driven wells are rare here. They are 18 to 21 meters deep. In this part of the zone, there is a stack of dug wells reaching depths of 5.49 to 11.3 meters.

In the northwestern semi-arid zone associated with the sor basin of the Bokey Orda/Zhanybek Districts, the dug wells reach depths of 11 to 12.7 meters. The driven wells in the same districts go 50 to 57 meters deep.

In the west of the Ural left bank, reinforced-concrete dug wells in the Akzhaik District are 5.2 to 10 meters deep.

Here, many free-range locations have 5.17 to 7.68 meters deep dug wells in the southeastern dry steppes (Syrym and Karatobe Districts). The walls of the dug wells are reinforced with reinforced-concrete rings. The driven wells in the Karatobe District are 20 to 22 meters deep. The driven wells in the west of the left bank are 22 to 30 meters deep.

In the eastern semi-arid part of the Karatobe District, the driven wells go as deep as 32 m.

In the northeastern dry steppes of the Shyngyrlau District, dug wells have depths of 4.24 to 4.99 meters while some driven wells go as deep as 50 m.

As a rule, dug wells are used to extract groundwater from the first subsurface aquifer, usually found above the 25-meter "milestone". Aquifer depth, power, and flowrate determine the operating depth of a dug well. To provide uninterrupted water supply for the herd, the waterhead must be at least three meters high.

Driven wells extract artesian water from 25 meters and deeper as well as groundwater from strong aquifers: boulder and gravel layers, broken bedrock. The well design should insulate the aquifer to protect it from surface pollutions. The driven-well depth depends on the aquifer depth as well as on the well flowrate. Minimum operating requirements to the well depend on the pump design performance as well as on how deep it is to be mounted. The final diameter of the well must suffice for the estimated flow rate as well as for placing a filter if so designed. Filters are absolutely necessary when extracting water from loose and unstable rocks.

In most of the dry steppes and semi-arid zone, pastures rely on groundwater from different aquifers.

In the northwestern dry steppes, water from the Kaztal District's dug well is pH-neutral, fresh at 490 mg/l, and hard. The dug-well water in the Taskala District is neutral, fresh at 404 mg/l, moderately hard. The Kaztal/Taskala Districts' driven-well water is low-brackish (1,439 and 1,161 mg/l, respectively); however, the districts have very hard and moderately hard water, respectively.

In the right bank of the Ural River, the Akzhaik District has numerous dug wells of water, mostly neutral, though sometimes low-alkaline. In terms of mineralization, water varies from fresh to low-saline at 343 to 11,587 mg/l. In terms of total hardness, wells provide moderate, hard, and very hard water, split evenly. The Akzhaik District's driven-well water is mostly neutral, though low-alkaline water is also present there. There is considerable difference in salinity though: water can be moderately fresh (609 to 884 mg/l), low-brackish (1,558 to 2,670 mg/l), brackish (3,982 mg/l), and high-brackish (6,446 to 8,016 mg/l). This is very hard water mostly, although single sources of moderately hard and hard water exist.

In the center of the right bank, the Zhanakala District has dug wells of fresh to high-saline water, ranging from 339 to 5,165 mg/l; neutral. This is mostly hard and very hard water, although single sources of moderately hard water exist.

In the southwestern semi-arid zone, the Bokey Orda District has numerous dug wells of neutral water with some rare wells of low-alkaline water. Water is mainly fresh here at 259 to 482 mg/l, or moderately fresh at 621 to 859 mg/l, with some instances of low-brackish (1,010 mg/l) and brackish (3,536 to 3,689 mg/l) water. Water varies in total hardness from soft to very hard. In the Bokey Orda District, water varies from neutral to low-alkaline, from moderately fresh to high-brackish (595 to 6,215 mg/l), mainly very hard with single instances of moderately hard and hard water.

In the northwestern semi-arid zone, he Zhanybek District has dug wells of neutral, moderately fresh (740 to 972 mg/l) water ranging from hard to very hard. The driven-well water here is neutral, low-brackish at 2,686 mg/l, very hard.

In the west of the left bank, the Akzhaik District has dug wells of mainly neutral, sometimes low-alkaline water. In terms of mineralization, water is fresh to moderately fresh at 287 to 930 mg/l, although single sources of brackish water exist (4,026 to 4,337 mg/l).

In the left bank of the Ural River, the southeastern dry steppes, the Syrym District has dug wells of neutral, low-brackish (2,075 mg/l), and hard water. Water from the dug wells of the Karatobe District is fresh to low-brackish at 347 to 1,129 mg/l; pH-neutral. This is soft-to-hard water. The Karatobe District's driven wells supply fresh to low-brackish water at 200 to 1,220 mg/l, which is pH-neutral. This is soft-to-hard water.

In the eastern semi-arid zone, the Karatobe District has driven wells of pH-neutral freshwater at 662 mg/l. The water is soft. In the northeastern dry steppes, the Shyngyrlau District has dug wells of neutral, moderately hard to hard, fresh to low-brackish (461 to 2,392 mg/l) water. The Shyngyrlau District's driven-well water is neutral, moderately hard, and fresh (354 mg/l).

Grazing land analysis will potentially guide the pasture watering efforts to use easily accessible groundwater of the first subsurface aquifers.

Restoring the water infrastructure by the common use of groundwater will help enlarge the sufficiently productive pastures to sustain livestock.

5. CONCLUSION

Free-range animal husbandry will skyrocket only if it can use grazing land efficiently, which requires state-of-the-art infrastructure and watering.

The analysis shows that the dry steppes in the West Kazakhstan region mainly use open-source water from rivers, canals, and ponds. In the semi-arid zone, pastures mainly rely on groundwater.

In territories adjacent to irrigation systems, free-range locations use water from man-made ponds with artificial watering sites. This solution is cost-effective and plausible, although its ability to keep water quality within acceptable limits is questionable.

Meanwhile, ever more pastures use driven wells. In most areas, such wells range from 25 to 35 meters in depth.

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