ABSTRACT

of the dissertation work of Iskakova Gulnaz entitled "Development of agroindustrial complex in the context of food and water security on the basis of rangelands use in Akmola region" submitted for the degree of Doctor of Philosophy (PhD) under the educational program 8D08603 – Water resource management using IT technologies

Relevance of the Research topic. Under the ongoing transformation of Kazakhstan's agrarian sector, the sustainable development of rangeland-based livestock production is increasingly determined by issues of water security. Uneven water availability across rangelands, seasonal variability of surface water resources, and the spatial remoteness of watering points significantly constrain the effective use of rangelands, contributing to land degradation and a decline in the productivity of the forage base. Despite the substantial share of rangelands in the structure of agricultural land, the water factor remains one of the key risks to the sustainability of the sector.

These challenges are particularly acute for Akmola Region, where the formation and spatial distribution of water resources directly affect rangeland accessibility and the possibilities for their rational use. Ensuring water security in rangeland areas requires an integrated approach that includes assessment of the condition of water bodies, optimization of the placement of watering infrastructure, and the application of modern digital technologies, remote sensing, and geographic information systems. The implementation of scientifically grounded measures in the field of rangeland water security is an essential prerequisite for the sustainable development of the agro-industrial complex, the preservation of the livestock forage base, and the strengthening of national food security.

Aim of the Study: The development of a Decision Support System (DSS) for rangeland management in Akmola Region based on the Google Earth Engine (GEE) platform, providing the integration of long-term Earth remote sensing data and geospatial analysis methods for a comprehensive assessment of rangeland productivity, water availability, and sustainability of rangeland resource use, with the objective of enhancing regional food and water security.

Objectives of the Study:

- To analyze the current condition of rangelands in Akmola Region with consideration of water availability and to identify spatial and temporal patterns of rangeland productivity;
- To assess the dynamics of rangeland net primary productivity (NPP) through the integration of field data and satellite observations (MODIS, Landsat, Sentinel) in relation to seasonal variations in surface water extent;
- To perform rangeland classification using cluster analysis and to identify ecologically distinct groups based on differences in floristic composition, soil and hydrological characteristics, and water accessibility;

- To adapt and test a geospatial rangeland carrying capacity model (GLCC) for regional conditions by integrating indicators of seasonal surface water extent and a water accessibility coefficient;
- To evaluate soil loss using the Rangeland Hydrology and Erosion Model (RHEM) as a function of water availability and vegetation cover density;
- To develop a sustainable rangeland management system incorporating rangeland rotation, regulation of grazing pressure, and the use of remote monitoring for assessing vegetation condition and water resources;
- To substantiate practical measures for ensuring food and water security through the rational use of rangelands and optimization of water availability.

Methods of the Research. Field surveys of rangelands and water sources; remote sensing (MODIS NPP, Landsat, Sentinel) for assessing vegetation dynamics and seasonal surface water extent; geoinformation modeling (GLCC, RHEM) with the integration of water accessibility indicators; cluster analysis of ecological and hydrological rangeland groups; statistical and correlation analysis of the relationships between rangeland productivity and water resources; modeling of grazing pressure and rangeland productivity incorporating a water accessibility coefficient.

Main provisions submitted for defense (validated scientific hypotheses and other findings constituting new knowledge):

- Spatial and temporal patterns of rangeland productivity in Akmola region have been identified, driven by seasonal dynamics of surface water and water resource availability, which determine rangeland carrying capacity and sustainability of their use.

- A geospatial livestock carrying capacity model (GLCC) has been developed and adapted, integrating remote sensing data, net primary productivity indicators, and water availability parameters, providing a comprehensive assessment of regional rangelands.

- A decision support system for sustainable rangeland management has been substantiated, based on remote monitoring and geospatial analysis, aimed at regulating grazing pressure and enhancing regional food and water security.

Description of the main research results. The analysis of rangelands in Akmola Region showed that forage base productivity varies considerably across space and time. Comparison of field data with satellite-derived NPP time series confirmed a strong dependence of rangeland productivity on water availability. Interannual variability of NPP during the period 2001–2019 indicates the influence of climatic factors, including droughts and temperature extremes.

Cluster analysis identified five ecologically distinct rangeland groups differing in floristic composition, biomass, vegetation cover density, and water availability. The geospatial GLCC model estimated average available forage productivity (AF) ranging from 26 to 1322 kg/ha, while the calculated sustainable grazing rate varied from 0.10 to 0.17 livestock units per hectare, with local maxima reaching up to 0.5. Distances

greater than 3 km from water sources reduced productivity by 10–30 percent, highlighting the key role of the water factor.

Results from the RHEM model indicated annual soil losses of 0.5–8 t/ha, with the highest values observed on slopes where vegetation cover density was below 60 percent. Erosion risk increased under the combined effects of low vegetation cover and moisture deficit, directly affecting water security and the resilience of rangeland ecosystems.

The implementation of seasonal rangeland rotation and the establishment of paddock boundaries within 2–3 km of watering points were shown to ensure more uniform use of forage resources, promote vegetation recovery, and reduce the need for winter feed. Grazing and rest periods are recommended to alternate based on NPP dynamics and interannual variability in productivity, while grazing norms should be adapted according to water availability clusters.

Based on the integrated analysis, a sustainable rangeland management system was developed, incorporating rotational grazing, adjustment of stocking rates to moisture conditions and soil fertility, and the application of remote monitoring tools (Google Earth Engine, MODIS, Sentinel) for assessing rangeland condition. Adaptation and testing of the geospatial GLCC model confirmed its applicability for planning rangeland rotation, optimizing watering infrastructure, and enhancing food and water security at the regional level.

Justification of the novelty and significance of the obtained results.

- For the first time, a geospatial livestock carrying capacity model (GLCC) was adapted and tested for the conditions of Kazakhstan with explicit consideration of water availability, including seasonal surface water extent and a water accessibility coefficient;
- A rangeland classification was developed based on hydrological and floristic characteristics, enabling the formulation of differentiated management strategies;
- Principles of sustainable rangeland management were elaborated that account for the spatial distribution and dynamics of regional water resources, thereby contributing to enhanced food and water security.

Relevance to priority areas of scientific development or government programs. The scientific research conducted within the framework of the dissertation was included as an integral component of the activities implemented under the technical assistance project of the Ministry of Agriculture of the Republic of Kazakhstan, financed by the Asian Development Bank, TA 9476-KAZ POZO (51305-001) “Republic of Kazakhstan – Assessment of the Resource Base for the Development of the Meat Value Chain in Akmola Region,” implemented during the period 2019–2021.

Description of the doctoral candidate’s contribution to the preparation of each publication. The personal contribution of the applicant consisted of independently conducting field surveys of rangelands in Akmola Region, including the collection of data on floristic composition, productivity, and soil cover condition, as well as carrying out cartographic studies. The applicant processed and analyzed remote

sensing data (MODIS, Landsat, Sentinel) and calculated the dynamics of net primary productivity (NPP) and seasonal surface water extent.

In addition, the applicant adapted and tested a geospatial livestock carrying capacity model (GLCC) for the conditions of Kazakhstan, incorporating indicators of water availability, a water accessibility coefficient, and terrain characteristics.

Based on the dissertation materials, the applicant prepared and published the following outputs: three articles in journals indexed in the Scopus database with percentiles of 50, 79 (Q2), and 93 (Q1); one article in the “Bulletin of Science of S. Seifullin Kazakh Agrotechnical University” (Astana, 2023); one article in the proceedings of the International Scientific and Practical Conference of Young Scientists and Students dedicated to the 90th anniversary of Academician K. S. Sabdenov; one book in Russian and one book in English published by the Food and Agriculture Organization of the United Nations (FAO, 2024, Budapest, Hungary).

The work performed by the applicant provided the scientific basis for the publications, enabled comprehensive analysis and modeling of regional rangeland resources, and constituted a personal contribution to the development of sustainable rangeland management approaches and digital tools for assessing rangeland conditions.

Scope and Structure of the Dissertation. The dissertation consists of an introduction, four chapters, a conclusion, and a list of references comprising 155 sources. The total volume of the dissertation, including appendices, is 135 pages of typed text. The dissertation is illustrated with 17 tables and 49 figures.