Name of the program: Development of a decision-making system for the production of main types of agricultural crops based on the adaptation of the DSSAT model for crop growth and development with the formation of an information database of scientific and technical documentation on agro-technologies for agribusiness entities in order to create Smart systems in agriculture

Relevance: Nowadays, in the agricultural production of the Northern and Central Kazakhstan, the growth of gross output's mainly achieved due to extensive factors. This's one of the main reasons for the low yield of cultivated crops and low economic indicators. Today, the agro-industrial complex of these regions does not show a significant increase in productivity and labor efficiency. Naturally, overcoming these problem is possible only with the widespread introduction of new technologies into production. It's known that the digitalization of agricultural production helps to increase the productivity of agricultural crops, reduce costs and increase labor productivity. In this regard, the transition to digital agriculture in the Northern and Central regions of Kazakhstan should be considered as one of the strategic goals of the development of the agro-industrial complex of Kazakhstan.

On the basis of this program, the creation of a decision-making system is planned to be carried out on the basis of the DSSAT model. The development of a decision-making system and crop modelling based on this system will be carried out in three soil-climatic zones: steppe zone-ordinary chernozems; steppe zone – southern chernozems; dry-steppe zone – dark chestnut soils.

On the basis of this program, it's planned to conduct research in the field of creating an open-access database of scientific and technical documentation for agricultural enterprises (Open API). Based on the activities carried out in the field of crop production and animal husbandry, a package of ready-made technical documentation will be formed, which will allow forming a single Database for the subjects of the agro-industrial complex of Northern and Central Kazakhstan. The database and decision-making system will be tested in the conditions of farms production activities in Northern and Central Kazakhstan and set into use. The implementation of the program results will contribute to the growth of the educational level of specialists, the intensity of the use of IT-technologies in agro-technological processes.

Aims. Implementation of the concept of "Smart" agriculture, including high-tech products of crop production and animal husbandry, including on the basis of new technical decisions.

Expected results

Upon completion of the program:

- Experimental studies of the main types of agricultural crops (cereals, legumes, oilseeds and forage) with different sowing dates, seeding rates, fertilization of three different soil and climatic zones will be carried out;
- Simulation of the growth and development of crops will be carried out. Modeling of the main types of crops will be carried out in DSSAT in three different soil and climatic zones, including using retrospective data (previously conducted experiments);
- DSSAT models of major crops will be validated under production conditions. A decision-making system will be developed on the basis of the research carried out with the possibility of changing climatic and soil parameters in order to extrapolate to other soil and climatic zones of Kazakhstan. This system will be tested in agricultural enterprises;
- methodological recommendations will be developed for modeling the growth and development of agricultural crops within the framework of the created decision-making system. Based on this methodology, a module will be developed on an open-source solution with open access (openAPI) for the possibility of connecting and using its module by agribusiness entities in order to simulate the growth and development of crops within the framework of the created decision-making system;
- young specialists will be involved in research, incl. 5 undergraduates and 5 bachelors. At least 3 articles will be published in foreign cited databases (at least Q3) and at least 6 articles in journals recommended by KKSON.

At the end of the project, the system with all source codes, database and technical documentation must be transferred to state ownership.

In order to fulfill the set task - building a database of scientific and technical documentation (standards, reference books, classifiers, etc.) for the production of livestock and crop products with open access (Open API):

- a package of ready-made technical documentation will be formed for all types of agricultural technologies and the livestock sector (current standards, reference books, classifiers, etc.). A single Database will be created for agribusiness entities interested in introducing digitalization of production and management processes in animal husbandry and crop production (cereals, legumes, oilseeds and forage);

- a database will be developed, which will include registers, regulatory and reference information on types of agricultural crops (taking into account the species, phenophase, seed weight, optimal sowing parameters, sowing temperature, seeding rates, seeding depth, soil pH, etc.), types of fertilizers (taking into account the type of fertilizers, formulation, nutrients, etc.), types of soil, types of plant protection products (taking into account the types of pesticides, formulation, composition, cultivated crop, processing method, processing time, restrictions, multiplicity, consumption rates, etc.), by types of seeds (taking into account basic information, biological characteristics, disease resistance, seeding rates, zoning, etc.), by types of diseases and by types of weeds, as well as uniform classifiers, registers and normative and reference information on all types of livestock activities (including according to the "Statistical Classifier of Products (Services) of Agriculture, Forestry and Fisheries VK-003 RED" approved by the Order of the Chairman of the Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan dated 05.12.2014 No. 69). All specified registers, classifiers, regulatory and reference information will be consolidated from officially registered according to sources, regulatory legal acts, regulatory reference information and other official sources of the Republic of Kazakhstan as of the final date of adoption, taking into account the use and application of international, uniform identifiers of world standards, divided into groups and subgroups for intuitive use of data in the database;

- young specialists will be involved in research, incl. 2 undergraduates and 2 bachelors. At least 2 articles will be published in foreign cited databases (at least Q3) and at least 3 articles in journals recommended by KKSON.

At the end of the project, the system with the created database with all the source codes, the database and technical documentation will be transferred to state ownership.

Results obtained in 2021

Test sites were organized in North-Kazakhstan Agricultural Experimental Station and “Naydorovskoe" LLP: 80.0 ha in North-Kazakhstan AES and 96.76 ha in "Naydorovskoye" LLP. On these test sites, against the background with various doses of mineral fertilizers, varieties of agricultural crops were studied under conditions of various sowing dates and seeding rates: spring wheat, peas, flax, sunflower. The conducted studies have shown that increased seed count resulted in higher density of planting. A similar pattern was observed in all varieties of agricultural crops without exception, regardless of the backgrounds and the timing of sowing. Productivity of crop varieties was largely determined by the sowing time and seeding rate. The use of mineral fertilizers had a significant impact on the productivity of varieties of various crops. For example, increase in yield of spring soft wheat varieties, when cultivated with the use of fertilizers, in comparison with the control, ranged from 2.3 c/ha to 4.9 c/ha, oil flax by 2.9-4, 2, peas 21.6-3.2. At the same time, it should be noted that the highest level of increase in yield against a fertilized background was observed in the varieties of spring soft wheat in the late sowing period (May 25) at a seeding rate of 4.0 million viable seeds per 1 ha. In agronomic practice, there is a notion of optimal seeding rate, which contributes to the formation of crops with a sufficient number of productive stems to obtain a potential yield under various weather conditions. In our studies, the productivity of spring soft wheat and spring triticale varieties in

LLP "North-Kazakhstan AES" and LLP "Naidorovskoye" did not decrease at higher seeding rates. This indicates that in subsequent years, on the basis of test sites, it is necessary to conduct additional research of increased seeding rate, which will allow to establish the optimal seeding rate for the studied varieties of spring soft wheat and spring triticale, which in turn will contribute to obtaining the maximum yield under various weather conditions. Plant density in the germination phase of the Baiterek sunflower hybrid in the experiment increased with an increase in seeding rates. A similar pattern was observed both on fertilized sites and those without fertilization. Preservation of sunflower hybrid plants before harvesting, regardless of sowing dates and cultivation backgrounds, was also determined by the seeding rate. This indicator in the conducted studies reached the highest value, regardless of the sowing period, at a seeding rate of 65 thousand germinating seeds per 1 ha. The seeding rates influenced the height of Baiterek sunflower hybrid plants. The height of plants in this hybrid increased with an increase in the seeding rate. The tallest plants in the experiment were plants grown with a high seeding rate of 65,000 germinating seeds per 1 ha. The plant height of the sunflower hybrid Baiterek decreased with a decrease in the seeding rate, however, the diameter of the basket and the number of seeds in the basket increased. A similar pattern was observed regardless of the timing of sowing and the background of cultivation of this crop. Based on monitoring surveys, it was found that on wheat crops in the tillering phase; and sunflower in the phase of 2-6 pairs of true leaves (precursor of pairs); triticale in the tillering phase (predecessor of oil flax); oil flax in the “Christmas tree” phase and peas in the phase of 4-8 true leaves (precursor wheat), a high degree of weed infestation with a perennial root shoot weed (the predominant species) was revealed - gray cumin (Cursium incanum), which formed clumps on experimental plots (the number reached 3 -10 species/m2). Weed infestation of agricultural crops was also found to be from medium to high degree by the following annual and minor weed species (the number reached from 20 to 100 pcs/m2): medicinal dandelion (Taraxacum officinale), common wild oats (Avenafatua), black velcro (Lappyla squarrosa), chicken millet (Echinochloa crusgalli), field weed millet (Echinochloa crusgalli), bindweed mountaineer (Fallopia convolvulus), upturned schiriza (Amaranthus retroflexus), tenacious bedstraw (Galium aparíne). In the reporting year, activities were carried out in full to develop preliminary theoretical and applied aspects for modeling the main parameters of varieties of various crops in the DSSAT system using the Aina spring soft wheat variety as an example. The results obtained are only preliminary, but very promising. They reflect the work that is currently being conducted at the University of Florida (USA) in cooperation with NAO “Kazakh Agrotechnical University. S. Seifullin”. On the basis of this program, preliminary parameters for modeling in the DSSAT system of varieties of other crops - cereals, legumes, oilseeds, fodder crops - were also obtained. Database of scientific and technical documentation (standards, reference books, classifiers, etc.) for the production of livestock and crop products with open access (Open API) has been created. An analysis of international experience in the formation of a database of regulatory and technical documentation was carried out. Separate aspects of the package of technical documentation on the main types of agricultural technologies and the livestock sector have been formed, and the concept of the structure of the Database for the subjects of the agro-industrial complex has been developed, taking into account classifiers, registers and reference information on the main types of agricultural technologies and the livestock sector. Separate aspects of the package of technical documentation on the main types of agricultural technologies and livestock sector have been formed (development of the concept of the structure of the Database for the subjects of the agro-industrial complex). Preliminary parameters of a unified database for agribusiness entities have been developed. On the basis of LLP "SPC of Grain Farming named after A.I. Barayev”, agrotechnical measures were taken to prepare the steam predecessor for the test site for 2022. The experimental data obtained on the basis of the test sites of North-Kazakhstan AES and Naidorovskoye LLP were processed mathematically in order to obtain the average values necessary to build the DSSAT system. In the reporting year, preliminary modeling of varieties for the climatic conditions of Northern and Central Kazakhstan was carried out on the basis of

the following indicators: soil NO_3 content (Nitrogen); soil NH_4 content (Ammonium); soil P (Phosphorus); soil moisture at different depths; dry plant biomass; leaf area index; plant productivity and its structural indicators.

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Results obtained in 2022

1) Soils of the examined plots located in three farms LLP “NK AES” and LLP «SPCGF named A.Baraev», LLP Naydorovskoye by physical and chemical indices are typical for the study areas. Farms are characterized by medium, high and low content of mobile phosphorus. On backgrounds with fertilizers on dark chestnut and chernozem soils there is a higher content of phosphorus than on the control. Provision of nitrate nitrogen is mostly low. Potassium content is high and very high. Soil pH values in LLP “NK AES” and LLP «SPCGF named A. Baraev» are neutral and slightly alkaline, in Naydorovskoe LLP - slightly alkaline and alkaline.

Humus content on common chernozems and southern chernozems - medium and low supply,on dark chestnut soils - low supply.

For farms the most effective method of increasing soil fertility is the introduction of nitrogen and phosphorus fertilizers, bringing them to the optimum value to increase crop productivity. In this regard, these farms should strictly comply with all elements of zonal agricultural technology, fertilizersystems, the order of alternation of crops in the rotation, it is widely practiced sowing perennial grasses, legumes, also need to strictly comply with the entire technological cycle of soil treatment.

2) On the basis of three farms located in different soil and climatic zones LLP “NK AES” (steppe zone, ordinary chernozems, North Kazakhstan region), LLP «SPCGF named A. Baraev» (steppe zone, dark-chestnut soils, Akmola region), " Naidorovskoye" LLP (dry steppe zone, dark- chestnut soils, Akmola region) were created test sites, where the influence of sowing dates, seeding rates on growth and development of plants, their productivity was studied on backgrounds with the introduction of different doses of mineral fertilizers. As a result of the conducted experiments and statistical analysis (multifactor analysis of variance) the reliability of influence of the studied factors on the crop yield was shown. However, the share of influence of these factors (terms and norms of sowing, background) in the current year was different in different agroclimatic zones. For example, the share of influence of feeding conditions was the highest in LLP “NK AES” and varied depending on the crop 51.3 - 72.5%, the share of

influence of seeding rates depending on the crop was 4.6 - 40.4%, the share of terms of sowing was 4.3 - 22.7%. In LLP «SPCGF named A. Baraev» the share ofinfluence of different factors had the following maximum values: seeding rate - 70.9%, feeding conditions - 41.6% and sowing dates - 10.8%. In LLP "Naidorovskoe" the share of participation in variability of a crop of the studied factors was distributed as follows: terms of sowing - to 59,6 %, seeding norm - to 35,8 %, conditions of a food - to 29,6 %. Such distribution of influence of factors on crop yield is determined by soil-climatic conditions, which were formed in these zones in the current year, and availability of moisture during vegetation period of plants.

3) Phenological observations of plant growth and development were carried out for all crops, field seed germination and safety of plants depending on sowing dates, seeding rate, feeding conditions were studied. On all variants of the experiment insignificant fluctuations on these signs are marked. The correlation dependence between the elements of yield structure (number of productive stems per m2, productive bushiness, number of grains per spike, weight of grains per spike, weight of1000 grains, plant height for grain legumes and oilseeds: number of plants at harvest per m2, numberof bolls (seeds) per plant, number of seeds per plant, weight of seeds per plant, weight of 1000 grains), biometric indices (accumulation of dry biomass, leaf surface area) with yield of grain was shown. Weakly and strongly correlating traits were determined. For example, high correlation between the number of productive stems per m2 - r=0,6 - 0,8, leaf area - r=0,5 - 0,7, accumulation of biomass - r=0,7 - 0,8, weight of grains per plant - r=0,5 - 0,9 showed depending on the variety. Most of other studied traits had medium to low correlation. All phenological data, soil characteristics (soil propertiesand soil-agrochemical data), climatic indicators (daily minimum and maximum temperatures), agro- technologies of cultivation in each farm were used in parameterization and as input parameters in modeling plant growth and development, crop yield forecasting in DSSAT CMP.

4) To improve the DSSAT CSM system for gene modeling of wheat heading time prediction in the conditions of Northern Kazakhstan, molecular genetic studies on known adaptability genes (Vrn - vernalization and Ppd - photoperiod) were carried out. At the first stage, the wheat varieties under study were analyzed for homogeneity and typicality by the most informative gliadins spare proteins, and also their genotyping by the known genes of vorivation (Vrn) and photoperiod (PpD) was carriedout. The genetic structure of cultivars with typical for the conditions of Northern Kazakhstan alleles of gliadin encoding loci: Gli-A1 (f, a), Gli-B1 (e, l), Gli-D1 (a, b), Gli-A2 (i, k, b), Gli-B2 (t, o) and Gli-D2 (p, l). The results of genotyping for the genes of vernalization and photoperiod showed the presence of Vrn-A1a and Vrn A1 (J) alleles in all varieties (except for cultivar Granny). Also in varieties Aina, Shortandinskaya-95 improved allele Vrn-B1c is found. The presence of dominant alleles of spring wheat genes indicates the spring type of development of these varieties of wheat, alsofor high latitude spring wheat varieties are characterized by strict sensitivity to the length of day and the presence of the allele Ppd-D1b.

5) In each farm, UAVs of both helicopter and airplane type, equipped with multispectral cameras, were flown and overflown over the fields at different phases of plant growth and development. Up to 1500 aerial images were acquired, divided into 5 channels (RGB, IR, NIR). All obtained images were loaded into the supercomputer for further processing. NDVI indices were calculated using these channels this year. Spectral signatures of healthy and damaged plants with different diseases were also collected and soil conditions were studied. According to the spectral curve, it was found that the effect of the disease on wheat is concluded in the interval between 700 and 1450 nanometers.

6) Based on the data collected during multifactorial field experiments conducted at test sites in Northern and Central Kazakhstan during the growing seasons of 2021 and 2022, preliminary parameters were determined for three models CERES-Wheat, CROPGRO-Pea and OILCROP-Sunflower from DSSAT CSM, i.e. for cereals, pulses and oilseeds, respectively. At this stage, to calculate these parameters, we used data on phenology (date of flowering and ripening), crop yield, yield components (number of grains, grain weight), weather data (daily

maximum and minimum temperatures, precipitation and solar radiation) in each zone, based on which we calculated genetic coefficients for each variety. Preliminary mathematical calculations using CERES-Wheat, CROPGRO-Pea and OILCROP-Sunflower models showed good agreement between the simulated and observed values on the dates of flowering and ripeness in all crops under study. Thus, wheat varieties Aina, Granny, Shortandinskaya-2012 and triticale Rossinka had reliable values of conformity index D and degree of dispersion between simulated and observed values of RMSE. In wheat they were D=0.74 - 0.98, RMSE = 0.7-1.0; in triticale they were D=0.97, RMSE = 0.7. The same correspondence (i.e. reliability) between these traits (observed and modeled) was observed in pea cultivar Aksaysky mustachy-55. However, analysis of OILCROP-Sunflower model calibration results shows relatively low correspondence between simulated and observed values (number of days) from sowing to flowering and maturity, as shown by low D value (0.1-0.2) and high RMSE 8-12.9 for Baiterek variety. For all crops on yield data, additional calculations with inclusion of other auxiliary parameters of the model are required.

7)The research carried out on flax within the framework of this program allowed us to introducea new model for flax into the DSSAT CSM system. The program CSM-CROPGRO is used as a template. To adapt this program, data from field experiments on flax varieties Kustanaiskii Yantarnyi and Lirina for the two-year growing season (2021 - 2022) are collected, analyzed and processed. The collected data include phenology, growth, yield and yield components. Based on them, experimental files (Weather, SBuild, XBuild, ATCreate version 4.8.0.0) were prepared for model run, as well as measured data files for calibration.

8) Within the framework of this program, online and offline seminars were conducted by the developers of this model from Florida University (USA) to build human resources capacity on the use of DSSAT CSM simulation model for yield forecasting and as a decision support system. A total of 18 people from KATU named after S. Seifullin were trained.

9) System architecture, client-server part of the IS, database design has been developed, the knowledge base including normative-technical documentation on agroindustrial complex, reference information, classifiers to facilitate searching of appropriate materials, as well as methodological manuals on farming have been developed. Scenarios for the use of the system by different groups of users were distributed. Functionality of sending methodological recommendations for review by experts in the field of agriculture was developed. Cataloguing of the downloaded materials is provided, their ways of structured storage in a single place and visualization are taken into account.

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