THESIS

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Investigation of ecologically safe technologies of spring wheat production in Kazakhstan

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1. INTRODUCTION

1.1 Significance of ecologically safe crop production

Approximately one-third of the calories ingested by humans come from grain crops, making them an essential component of the diet (SOTO-GÓMEZ & PÉREZ-RODRÍGUEZ, 2022). The primary grain-producing and exporting nations are Kazakhstan, Russia, and Ukraine. Over the next few decades, (LIEFERT et al. 2010), these nations are predicted to rise to prominence in the global grain market and significantly contribute to meeting the projected demand for grains from a steadily growing worldwide population (TILMAN et al. 2011, OECD/FAO, 2012, RAY et al. 2013), Kazakhstan, with its vast agricultural landscape, has become one of the world's leading spring wheat producers. In meeting the demands of a global market, its agriculture industry has undergone a transformation that combines traditional farming practices with modern techniques. This synthesis is integral to the success of the country's spring wheat production. Traditional methods of spring wheat production in Kazakhstan rely heavily on the use of chemical fertilizers, pesticides, and herbicides. These methods have negative impacts on the environment, including soil degradation, water pollution, and loss of biodiversity. Agriculture in Central Asia has been hampered by the region's declining natural environment, which has resulted in poor crop yields of worse quality and endangered the country's food security (QI & KULMATOV, 2008).

The worldwide development agenda through 2030 is outlined in the Sustainable Development Goals (SDGs) (UNITED NATIONS GENERAL ASSEMBLY, 2015). Due to the agenda's numerous entry points, agriculture ought to reclaim its position as the primary force behind the security of food and nutrition, the achievement of inclusive and sustainable economic growth, the mitigation of environmental harm, and the enhancement of the welfare and resilience of the most marginalized population (OMILOLA & ROBELE, 2017).

Ecological agriculture is broader than organic, and includes, in addition to the generally accepted positions of producing safe and high-quality food by minimizing soil cultivation, using organic and natural mineral fertilizers, introducing a system of alternating crop rotation fields, and preserving soil fertility, the environment, and the environmental safety of its production. (KUNDIUS, 2017).

The investigation of ecologically safe methods of spring wheat production in Kazakhstan has significant implications for food security, environmental sustainability, and the agricultural sector. The findings of this study will contribute to the knowledge base on sustainable agriculture, informing policymakers, farmers, and other stakeholders about the potential for adopting ecologically safe methods. The research outcomes will support evidence-based decision-making, promote sustainable agricultural practices, and contribute to the achievement of the United Nations Sustainable Development Goals.

1.2 Problem statement and research objectives

The research problem addressed in this thesis revolves around identifying, analysing, and promoting current ecologically safe and sustainable technologies within the spring wheat production sector in Kazakhstan. This involves assessing the effectiveness, feasibility, and economic implications of these technologies, as well as understanding the obstacles and opportunities for their adoption.

Research will aim to document success stories and best practices from within the industry. This will provide valuable insights into what works well and can be replicated by other farmers. These solutions may include policy recommendations, technological advancements, or best practices that can enhance the sustainability and competitiveness of Kazakhstan's spring wheat production. In addition, the study also demonstrates to farmers how investments in the agricultural sector to create environmentally friendly agriculture will lead to a wide range of benefits, including environmental protection, improving soil and water quality, biodiversity conservation, and economic benefits. These methods are necessary to solve the environmental problems facing the agricultural sector and ensure food security in a changing world.

Research Questions:

- What are the successful practices and strategies employed within Kazakhstan's spring wheat industry that have demonstrated enhanced sustainability and competitiveness?

- How can policy recommendations, technological advancements, and best practices be harnessed to improve the sustainability and competitiveness of spring wheat production in Kazakhstan?

2. LITERATURE REVIEW

2.1 Wheat

Wheat is a herbaceous plant, often an annual, belonging to the cereals group. Cereals are the main and most produced crop of all crops (KULZHABAEVA, 2011). The "big three" cereal crops include wheat (SHEWRY, 2009). In addition to rice and maize, wheat is one of the major crops grown worldwide and will probably continue to remain so for the foreseeable future as a staple of human sustenance (JACQUES, et al. 2020). Wheat statistics subsequently anticipated that the world's total wheat consumption in 2023–2024 will stay almost unchanged at 780 million tonnes, up only 0.1% from 2022–2023 and slightly below the 10-year trend. It is anticipated that wheat will be consumed for food by 0.7 percent, offsetting projected decreases of 1.4 percent and 1.3 percent in other uses and feed. (FAO, 2023). Nevertheless, wheat's cultivation range is unmatched; it can be grown anywhere from 45° S in Argentina to 67° N in Scandinavia and Russia, including higher elevations in the tropics and subtropics (FELDMAN, 1995). It is also unparalleled in the scope of its diversity and the degree to which it has permeated various societies' cultures and even their religious beliefs.

Figure 1. Wheat

2.2 Origin of Wheat

An essential portion of the history of agriculture is the history of wheat, which dates to approximately 10,000 B.C. (VENSKE, et al. 2019).

The Fertile Crescent, which stretches across the Middle East from Jordan, Palestine, and Lebanon to Syria, Turkey, Iraq, and Iran, is believed to be the birthplace of wheat cultivation. Hulled or glumed wheats are the first domesticated species and include all three polyploidy levels known to exist in Triticum species: diploid, tetraploid, and hexaploid (ARZANI & ASHRAF, 2017). These species are spelt (Triticum spelta), emmer (Triticum Dicoccum), and einkorn (Triticum monococcum L.), and the corresponding wild ancestors of these species are still present in these areas. (HARLAN & ZOHARY, 1966).

2.3 Wheat Significance

The level of development of grain production has always been one of the most important characteristics of the economic independence and well-being of any country. On the one hand, this most valuable product is strategic, which determines serious state interest in grain production, on the other hand, it is the basis for the development of the entire agro-industrial complex (BARIBAR.KZ, 2018).

The ability to create distinctive food products and the rising consumption of these with industrialization and westernization are the main drivers of the rising demand for wheat on a global scale. Specifically, the distinct characteristics of the gluten protein fraction enable the processing of wheat to yield a variety of essential ingredients, bread, pasta, and other baked goods. Such products, which are a component of the "Western lifestyle," might be easier to make or use than traditional foods. (HEY & SHEWRY, 2015).

Kazakhstan's wheat harvest significantly improves food security throughout Central Asia and beyond. Following the recent increases in food prices worldwide in 2022, it became even more significant (ROMANOVSKA, et al. 2023).

The Republic of Kazakhstan is a large producer of spring wheat grain, including durum and durum varieties, which are sources of raw materials to produce high-quality bakery. confectionery products, and the best varieties of pasta and cereals. Wheat produced in republican high-quality varieties is in great demand in the CIS countries and abroad (BARIBAR.KZ, 2018).

2.4 Wheat Species

Out of the thousands of varieties that are known, the most important ones are club wheat (T. compactum), which is softer and used for cake, crackers, cookies, pastries, and flours; common wheat (Triticum aestivum), which is used to make bread; and durum wheat (T. durum), which is used to make pasta (alimentary pastes) like spaghetti and macaroni. In addition, the industry uses some wheat to make alcohol, starch, paste, malt, dextrose, gluten, and other products (BRITANNICA, 2023).

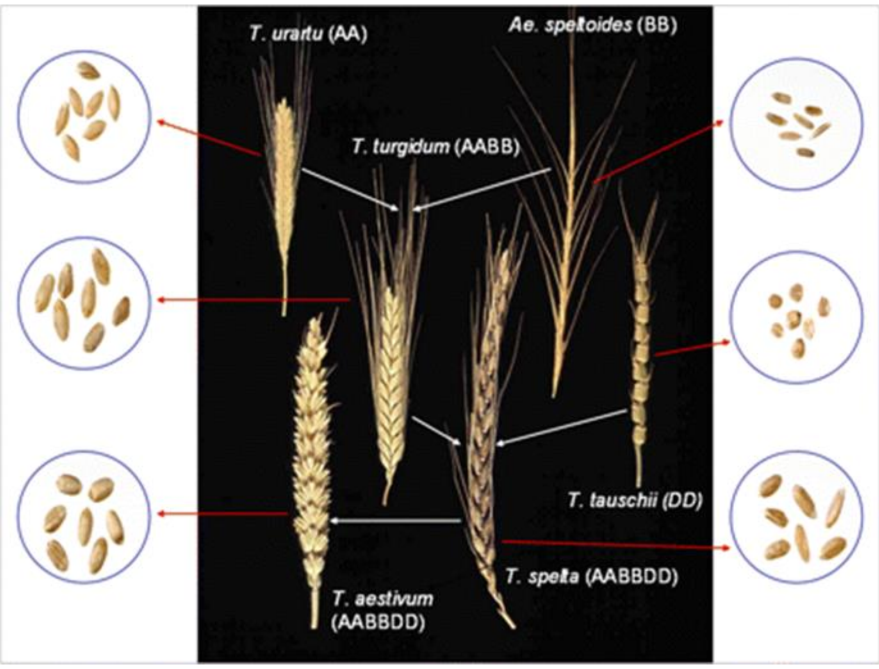


Figure 2. The evolutionary and genome relationships between cultivated bread and durum wheat and related wild diploid grasses, show examples of spikes and grain (SNAPE & PANKOVA, 2006).

The predominant wheat species cultivated globally is Triticum aestivum, a hexaploid commonly referred to as "common" or "bread" wheat. The tetraploid species T. turgidum var. durum, which is adapted to the hot, dry climate around the Mediterranean Sea and other similar climates, makes up about 35–40 mt of the total world production. It is generally referred to as "durum wheat" or "pasta wheat" and is used to make pasta. Only small areas are used to cultivate other species of wheat, either due to cultural restrictions or the growing demand for healthy foods. These are emmer (tetraploid T. turgidum var. dicoccum), spelt (T. aestivum var. spelta), and einkorn (diploid T. monococcum var. monococcum). Spelt is a domesticated variety of hexaploid wheat. Unlike bread and durum wheat, spelt, emmer, and most einkorn varieties are hulled, meaning that the glumes stay tightly closed over the grain and are not eliminated during threshing (HEY & SHEWRY, 2015).

2.5 Wheat Usage

For food purposes, most wheat needs to be processed. To ensure that the kernel breaks up properly, the grain is cleaned and then conditioned by adding water. Grain is cracked and then run through several rollers during the milling process. The coarser particles are sent to additional rollers to undergo further reduction after the smaller particles are sifted out. White flour is recovered from the milled grain to the extent of about 72%. Because the germ-oil content is retained, flour made from the whole kernel is referred to as graham flour and goes rancid when stored for an extended period. White flour keeps longer because it doesn't contain the germ. For animal feed, inferior and excess wheat as well as different milling by-products are utilized.

Making bread requires most of the wheat flour produced. Dry-climate wheat is typical for the hard variety, with 11–15% protein and strong gluten (elastic protein). The hard variety yields flour that is ideal for baking bread. Humid regions produce softer wheat with less effective gluten and a protein content of 8–10%. Wheat of a softer variety is used for producing flour for household use as well as cakes, crackers, cookies, and pastries. Pasta along with other alimentary pastes is made with durum wheat semolina, derived from the endosperm (BRITANNICA, 2023).

2.6 Nutrient Content

Depending on the variety, the starch and carbohydrate content of wheat ranges from 50-70%, and proteins from 10% to 20%. There are also vegetable oils, vitamins (B1, B2, B6, C, E, PP), minerals (potassium, calcium, magnesium, phosphorus, etc.), cores, pectin substances, as well as active enzymes. During research work, it was found that the value of wheat germinated in water increases several times—for example, germinated wheat contains 10 times more vitamin B2 (KULZHABAEVA, 2011).

Chemical composition of wheat: water — 16.65%, fiber — 2.53%, starch and dextrin - 56.77%, sugars — 1.45%, proteins - 12.85%, fats — 1.75%, K, Ca, P, Mn, Fe, Zn, Se, Cu, S, I, B vitamins, vitamins A, E, D, PP, polyunsaturated fatty acids, amino acids tryptophan, methionine, leucine, valine, isoleucine (AGROMART.KZ, 2023).

2.7 Wheat Botany

Mature wheat plant: All the growth and development processes that a wheat plant goes through during its life cycle come together to form the "mature" wheat plant. Every structure, including the ears, tillers, and leaves, has grown to its maximum size. Some structures, especially those created early in the life cycle, will have senesced and may have rotted or blown away, so not all will remain at maturity (KIRBY, 1993).

Wheat and other small grain cereals have two types of roots: seminal roots, which include one primary root and 4-6 lateral seminal roots, and nodal roots, which are adventitious or crown roots arising from the lower nodes of the shoot. The shoots (straw) are composed of internodes, typically numbering 6-16 per shoot, separated by nodes. Straw can be either hollow or thick-walled and solid. Wheat plants typically reach a height of 90-100 cm, depending on the genotype. Tillers, which have a similar structure to the main shoot, emerge from the axils of the basal leaves. Leaves are inserted at each node of the stem, with the uppermost leaf called the flag leaf. Leaves have three main parts: the leaf sheath, leaf blade, and ligule. Auricles are appendages at the base of the leaf blade and vary in size among species. In decreasing order of size, they are found in barley, wheat (often hairy), rye, and oat (no auricle). The leaves stem, and inflorescence can possess a wax coating that depends on the variety and environmental factors. The inflorescence of wheat is a spike (ear or head) consisting of approximately 20 spikelets arranged alternately on the rachis. Spikelets contain two glumes that enclose two to eight florets, with up to 5 usually being fertile. Each floret comprises a lemma and a palea as its outer parts, as well as two lodicules, three stamens with anthers, and an ovary with a hairy stigma with two arms.

Based on the presence of awns (which are on lemmas), wheat spikes can be categorized as awnless, apically awnletted, awnletted, or awned. Spike shape varies and can be tapering, oblong, clavate, or fusiform. The attitude of the spike at maturity can range from erect (upright to 30°) to semi-erect, inclined (30° to 90°), horizontal, semi-nodding, and nodding (>90°).

The grain, also known as the kernel or caryopsis, is a complete fruit that develops from one floret. It has a pericarp fused with the seed coat, which is characteristic of grasses. The entire kernel can be referred to as the seed and is typically oval, though it can range from almost spherical to long, narrow, and flattened. The color of the kernel varies and can be red (brownish) or white (yellowish). Kernels of small grain cereals have a crease on the ventral side, hairy structures (brush) on the distal end, and the germ on the lower end. Several layers of tissues, collectively called the bran, coat the kernels, including the epidermis, hypodermis, cross cells, tube cells, seed coat, nuclear tissue, and aleurone cells.

Aleurone cells form the outer layer of the endosperm and contain enzymes (hydrolases) that play a role in breaking down storage nutrients during germination. The endosperm occupies the central portion of the grain and consists of cells with starch granules surrounded by clear, glassy protein. The thousand kernel weight of wheat is typically in the range of 40-44 grams (MONOSTORI, 2014).

2.8 Classification of Wheat

Wheat varieties also can be classified in terms of growing season: winter wheat or spring wheat. Maturity: early, medium, medium-late, late. Ecotype: wheat of humid climate, steppe-type, desert or semi-desert type, uplands. Seed color and seed hardness: hard red winter wheat, soft red winter wheat, hard red spring wheat, and white wheat, according to awnedness: awned, awnless (BELTEKI et al. 2017).

Taxonomical classification: Kingdom: Plantae. *Clade*: Tracheophytes. *Clade*: Angiosperms. *Clade*: Monocots. *Clade*: Commelinids. Order: Poales. Family: Poaceae. Subfamily: Pooideae. Supertribe: Triticodae. Tribe: Triticeae. Genus: *Triticum* (DUISTERMAAT, 1987).

Wheat belongs to the Poaceae family, (BRAUN, et al. 2013) which includes the Triticeae tribe, the division with the most economically important cereals. The fourteen genera that make up the Triticeae tribe are divided into the subtribes Triticinae and Hordeinae. The generation of amphiploids and interspecific hybrids indicates that the various genera may be genetically or cytoplasmically compatible (SAKAMOTO, 1973). Hexaploid Triticum aestivum L. (AuAuBBDD; $2n = 6x = 42$), tetraploid Triticum turgidum L. (AuAuBB; $2n = 4x = 28$), and diploid einkorn Triticum monococcum L. (AmAm; $2n = 2x = 14$) are the most representative wheat species of this tribe. Tetraploid durum wheat (Triticum turgidum subsp. durum (AuAuBB; $2n = 4x = 28$)) and hexaploid bread wheat are currently the two most economically significant species. (PENG, et al. 2011). The origin of the latter two wheat species was the result of two polyploidization events. Two polyploidization events led to the origin of the latter two wheat species.

2.9 Phenological Stages

The primary system for measuring grains is the BBCH (Biologische Bundesanstalt, Bundessortenamt und Chemical Industry) scale, which is based on ten developmental stages known as the principal growth stages (GS). Comprehending the system can facilitate benchmarking for crop development and support decision-making in management. For instance, the labels for plant protection products use this uniform coding scheme. The following are the main phenological growth stages of wheat and other small-grain cereals, as per the extended BBCH scale: 1. Germination and emergence. 2. Leaf development (seedling growth). 3. Tillering (production of side shoots). 4. Stem elongation. 5. Booting. 6. Ear/Inflorescence emergence. 7. Flowering/anthesis. 8. Milk/seed/grain/fruit development. 9. Dough development. 10. Ripening/senescence (ZADOKS, et al.1974).

2.10 Nutritional Demand

Spring wheat, having a poorly developed root system and a short growing season, requires high levels of digestible nutrients. To obtain 1 quintal of wheat grain, on average, the following is removed: nitrogen - 3.5 kg, phosphorus - 1.2 kg, potassium - 2.5 kg. However, depending on the growth phase, nutrient intake will vary. Thus, at the growth stage from the emergence of seedlings to the third visible leaf, the consumption of micro- and macroelements is insignificant. But, starting from the tillering phase, and moving on to the stages of further vegetation, there is an increase in the absorption of nutrients from the soil.

Maximum absorption occurs during the booting phase before flowering. It is worth noting that this period is characterized by a maximum increase in dry and wet matter in wheat. Another peak in the absorption of soil nutrients is observed in the phase of grain filling and formation. The best time to apply nitrogen and phosphorus fertilizing is the phase from tillering to the end of the tube. After the exit phase and before grain filling, the best fertilizer is potassium-containing preparations. Fertilizer application rates must be correctly calculated, considering the influence of the predecessor, the type and quality of the soil, fertility, and climatic zone.

Carsbamide-ammonium mixture and other fertilizers containing the ammonia form of nitrogen can be used as the main fertilizer in the fall. However, it is worth noting that excess nitrogen nutrition can cause rapid growth of vegetative mass. This leads to depletion of moisture in the soil, increases the susceptibility of plants to several diseases, increases lodging, and reduces grain yield from crop biomass. It is better to use nitrogen fertilizers as fertilizing in the phase of tillering, the beginning of booting, and heading at 20-30 kg/ha.

Nitrogen-phosphorus and nitrogen-phosphorus-potassium fertilizers are used as row fertilizers. It is worth noting that highly soluble nitrogen and potassium fertilizers are not applied to the rows, as they quickly increase the concentration of the soil solution. Increasing the concentration at the location of the seeds impairs their germination (AGROMART.KZ, 2023).

2.11 Water Demand

Having access to water while planting is important. However, when crops reach the critical yield formation stages in July, precipitation plays an essential function in determining wheat growth in the region. Insufficient moisture during this critical period can interfere with grain development and result in reduced yields (USDA, 2022).

Water demand is different at all stages of development: the beginning of shoots 5-7 %, tillering phase 15-20%, tubing and earing 50 - 60%, milk state of grain 20 - 30%, wax ripeness 3 - 5%.

It is important to note that the lack of moisture at the tillering stage can reduce the biological potential of the crop and lead to the formation of infertile spikelets, which negatively affects the yield and quality of spring wheat (ALCHEMYKA, 2019).

2.12 Temperature Demand

During the growing season, spring wheat needs different ambient temperatures. At the initial stage of growth, the temperature range should be within t = 12-15 ° C, in the future higher temperatures are required. The most favorable temperature during earing, filling, and ripening of grain is 20-25 ° C. Spring wheat tolerates high temperatures in different ways depending on the humidity of the air and soil, and the strength of the wind. If the air humidity is at least 35%, then the plant can withstand temperatures up to 40 ° C and above in the phase of earing, flowering, and milk ripeness. The tolerance of low temperatures, in turn, is determined by the variety and phase of wheat growth. Being in the germination phase, the culture tolerates lower temperatures than in later stages of development. The highest sensitivity to low temperatures in spring wheat can be traced during the flowering period. Defects in the plant and further death of the culture are manifested at a temperature of t = -6 ÷ - 8 ° C in the germination phase, in the flowering phase – at a temperature of t = -1 ÷ - 2 ° C, in the phase of milk ripeness — t = -2 ÷ -4 ° C. At the end of maturation, the grain in the waxy ripeness phase can tolerate temperatures up to t = -12 ÷ - 13 ° C. However, the consequences of such temperatures are breaks in the grain, which leads to the fact that the grain is affected by diseases and is worse preserved (AGROMART.KZ, 2023).

2.13 Crop Conditions

Most of Kazakhstan's wheat depends on rainfall, and it is planted in the spring. Planting usually takes place in the latter part of May or as soon as the soil temperature reaches a constant level above 5 degrees Celsius. The maturity time of wheat cultivated in Kazakhstan varies; early varieties require 80 days to mature, while late varieties can be harvested about 100 days after sowing. This gives farmers a comparatively wide harvest window, enabling them to plan and utilize the machinery as efficiently as possible (USDA, 2022).

2.14 Soil Conditions

The best soil for growing wheat is considered fertile, and rich in free and easily accessible micro and macro elements. Wheat should be grown with minimal fertilization on chernozem and chestnut soils. Also, with a properly formulated nutrition plan for the soil and the cultivated crop, high yields are brought by gray forest and sod-podzolic soils. Spring wheat belongs to a slightly salt-tolerant culture. Therefore, saline soil is distinguished by low yields when growing wheat, especially during the dry period. The most optimal medium for growing wheat is soil with a pH reaction of 7.7 – 7.5, good yields can be obtained on neutral and slightly acidic soils (AGROMART.KZ, 2023).

2.15 Predecessors of Wheat

Wheat has an underdeveloped root system, because of which it is necessary to place wheat with good predecessors. Choosing the right predecessor increases yield (by 3.5-5.0 c) and gluten in grain (by 1.7-3.4%).

In the main region of cultivation of this crop - Northern Kazakhstan and some regions of Kazakhstan - the best predecessors are clean fallows, the second crop after fallow, grain legumes, and corn for silage. Good predecessors can be oats when grown for hay or green fodder, as well as barley when sowed early before sowing spring wheat and harvested for mono-fodder. Perennial leguminous grasses, after a year of use, are excellent predecessors in the East Kazakhstan region (AGROMART.KZ, 2023).

2.16 Fertilization

Proper and timely fertilization and chemical treatments are essential for achieving optimal yields. Fertilization schedules and application rates differ widely: from fertilizing only once in several years (typically done the first year of the rotation cycle when the field is left as fallow) to fertilizing twice a year, once around planting and then after harvesting. Often amounts are determined based on soil analysis (USDA, 2022).

2.17 Diseases

In recent years, diseases affecting the leaf-stem mass and the ear are particularly dangerous for the yield and quality of wheat grain – these are septoria, yellow spotting, brown, and stem rust. In the fields occupied by cereals, there is an increased accumulation of infections and pathogens of leaf-stem spots and root rot. The initial number of pathogens plays an important role in the spread of diseases and the intensity of their damage to plants.

Septoriasis is one of the most widespread diseases in Northern Kazakhstan. Traditionally, the greatest spread of the disease is noted in Bulandy, Burabay, and Zerendi districts – up to 100%, the degree of development of the disease varied from 10 to 20%. In the Sandyktau and Shortandy districts, the development of septoriosis reached 30%.

In 2022, leaf rust in spring wheat crops was not highly developed, the disease was noted in Shortandy, Zerendinsky, and Sandyktau districts. The intensity of development varied from 10 to 30%. The distribution of brown rust is determined by the hydrothermal conditions of the first half of the wheat growing season. The Selyaninov hydrothermal humidification coefficient (HHC) is a characteristic of the level of moisture availability of the territory. At HHC = 1.2 or more in June and the first two decades of July, we can expect a massive development of brown rust with a probability of 70%, which is mainly introduced from the territory of Western Siberia and the Volga region. One of the new diseases that pose a potential threat to spring wheat crops is pyrenophorosis (yellow spot) caused by the fungus Pyrenophora tritici-repentis Drechsler. Under optimal conditions, the peak development of the yellow spot corresponds to the grain filling phase - milky-waxy ripeness; grain losses can be 50-65%, which reduces its quality. According to the results of route observation in 2022, this disease was noted in all districts of the Akmola region. On certain wheat varieties, the development of yellow star spot is about 60%, the prevalence has reached 100%. The development of the disease was moderately epiphytotic in nature. Increased incidence of yellow leaf spots suggests a lack of surface treatment and stubble retention, as well as monoculture or saturation of the crop rotation with grain crops (ZHUMAGULOV et al, 2023).

2.18 Pests

The predominance of grain crops and an increase in the proportion of repeated sowings of grain precursors contribute to an increase in the number and harmfulness of specialized pest species, such as bread striped and stem flea, Swedish and Hessian flies, wheat thrips, pianist, bug harmful turtle, grass aphids, cicadas, gray grain scoop. Of the omnivorous pests – locusts, meadow moths, nutcrackers (wireworms). To combat wireworms, seed treatment with insecticidal protectants based on imidacloprid, thiamethoxam, and bifentrine is effective. (ZHUMAGULOV, et al. 2023).

2.19 Plant Care

The most effective for protecting spring wheat from weeds are tank mixtures that include herbicides based on the active substance 2,4-D (in the form of esters, salts), sulfonylureas (metsulfuron-methyl, tribenuron-methyl, thiophene-sulfuron, etc.) - against dicotyledonous weeds and fenoxaprop-patyl, clodinafop-propargyl - against cereal weeds. When compiling a tank mixture of herbicides, one should take into account the compatibility of the drugs (for example, 2,4-D salt is incompatible with anti-cereal drugs), the decay period of pesticides in the soil (for example, if there are oilseeds in the crop structure, metsulfuron-methyl cannot be used on wheat), phytotoxicity for the crop (some drugs enhance the effect of each other, which causes oppression of the crop) (ZHUMAGULOV, et al. 2023).

2.20 Harvesting

Modern machinery and equipment are used for efficient harvesting. Post-harvest handling and storage facilities are essential to maintain wheat quality. Harvesting spring wheat. The harvesting of the crop begins in the fall. It is generally believed that the optimal maturity period of spring wheat falls at the stage of wax ripeness until full maturity. With two-phase harvesting, the optimal grain moisture is 29-25%, with further drying of the mown mass in the mowing no more than 2-4 days, and with direct harvesting 21-23%. With two-phase harvesting, quite good results are provided at a height of stems of at least 72-81 cm. The height of the stem should be accompanied by optimal stem density - at least 251-300 productive stems per 1 m2 and at a cut height of at least 20-22 cm, and the stems in the roll should be laid at an angle of 10-15 ° to the direction of movement of the unit (ALCHEMYKA, 2019).

3. MATERIAL AND METHOD

3.1 The state of grain production in Kazakhstan

The Republic of Kazakhstan is a vast landlocked country primarily situated in Central Asia, with a small portion extending into Europe. Covering an expansive area of 2,700,000 square kilometers, it straddles both sides of the Ural River, which serves as the traditional boundary between Europe and Asia. Additionally, it boasts a coastline along the Caspian Sea. Kazakhstan is renowned for being the ninth-largest country in the world in terms of land area and is the largest landlocked nation globally. Despite its vast expanse, it has a relatively modest population of 19 million people, resulting in one of the lowest population densities globally. The landscape of Northern Kazakhstan (as depicted in Figure 3) is a significant hub for agriculture in Central Asia, serving as a primary producer of cereal crops (wheat, barley, and maize), with 70% of Kazakhstan's grain exported. However, the opening of steppes to large-scale wheat production in the USSR has historically resulted in decreasing yields, as well as soil erosion and fertility loss.

Figure 3. Map of Kazakhstan’s regions

About 80 percent of the crop is produced in the north-central oblasts of Aqmola, Qostanay, and North Kazakhstan (USDA, 2022). Kazakhstan has 21.5 mln ha of pastoralist land.15.4 mln ha are devoted to wheat, 76 of which (11.7 mln ha) is in northern Kazakhstan, the source of 80 of the country’s wheat product. Wheat is the largest agrarian member in the country, representing 50 of the total agrarian products. Agrarian experts engaged by UNDP have delved into the wheat sector in northern Kazakhstan and conducted informal checks with approx. 80 growers. They estimate that wheat granges operate in the three northern regions, including (i) three large agro-holdings cultivating 3 mln ha (27 of total wheat area in northern Kazakhstan); (ii) 30 large granges (50,000- 200,000 ha each) cultivating 3.9 mln ha 33 of total); (iii) 2,023 small and medium granges (1,000- 50,000 ha each, henceforth “SME granges”) cultivating4.7 mln ha 40 of total), with an average ranch size of approx. 2,100 ha; and (iv) 1,000 family- possessed, subsistence granges(50- 200 ha each) cultivating 110,000 ha(lower than 1 of total). The ultimate is considered not commercially feasible.

According to World Bank statistics agriculture contributed approx.4.4 to GDP in 2017. Crop husbandry in northern Kazakhstan is more consolidated than beast and vegetable husbandry away in the country, which is dominated by small granges. An estimated 88,000 people are directly employed by wheat SME granges in northern Kazakhstan. This is grounded on the normal of 2- 50 endless workers (average 26) and 5- 30 seasonal workers (average 17.5) per ranch, reflecting the wide range of ranch sizes. Hand ranges are deduced from a 2018 study by the German- Kazakh husbandry Policy Dialogue (MUSSAYEVA, 2018). Official statistics report 980,730 people employed in the husbandry and agro-processing sector in Northern Kazakhstan.

Wheat product contributes to the food security of Kazakhstan and its19 million people. It's also a significant source of exports of wheat and wheat flour representing approx. three diggings of total agrarian exports and a significant source of hard currency for Kazakhstan. Kazakhstan is one of the top ten wheat exporters encyclopaedically and the leader in flour import (UNFCCC, 2017). Afghanistan, Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan are the largest importers of Kazakh wheat. In these Central Asian countries, wheat provides more than 60 diurnal calories, and a significant portion of that wheat is imported from Kazakhstan. Wheat product in Kazakhstan is, thus, an important source of food security for the entire region (UNDP, 2014).

Kazakhstan plays a significant role in ensuring local, regional, and global food security and exports a lot of wheat. Wheat is planted in a large portion of the agricultural land, but the yield per hectare is lower than what is seen on a regional and global scale. Therefore, Kazakhstan's development as a dependable and sustainable source of the world's wheat supply is of strategic importance, despite several uncertainties (such as environmental and political issues) and an underdeveloped infrastructure (FEHER et al. 2017).

3.2 Characterisation of Ecological Conditions

Topography. The investigation delineates a geospatial domain strategically centered at the coordinates of 69.4110493 longitude and 51.916532 latitude, encapsulating the Akmola oblast in Kazakhstan. Positioned within the steppe zone of the northwest Kazakh Upland, the region is traversed by the Ishim and Nura rivers, featuring prominent geographical landmarks such as the Tengiz and Kurgaldzhin lakes in its southwestern expanse. The topography of the Akmola region is characterized by a predominantly undulating plain, hosting black earth and chestnut soils in the northern and central sectors, and saline brown soils in the extreme southwestern and eastern reaches. The relief within the oblast exhibits a diverse tapestry, encompassing expansive steppes, flat river valleys, and forested mountains. A tripartite classification emerges based on relief characteristics: a northwestern plain, a southwestern plain interspersed with discrete hills, and an elevated eastern sector constituting part of the Kazakh folded country. Detailed examination reveals the northwestern portion, contiguous to the Ishim Valley and marking its northerly trajectory, as a flat plateau intersected by arid ravines and gullies, terminating in a precipice toward the Ishim Valley. The southwestern sector, situated south of the Ishim River, unveils an elevated plain adorned with myriad hills featuring flat summits. Interstitial depressions house shallow salt and freshwater lakes of varying dimensions. The eastern domain, representing the remnants of the once mountainous Kazakh folded country, attests to extensive denudation-induced leveling processes, preserving a nuanced topography comprising hills, ridges, and hummocks with gently contoured slopes. Elevation differentials in the hills range from 5-10 meters to 50-60 meters, occasionally ascending to 80-100 meters. Disparities in hill morphology correspond to underlying rock compositions, with granites forming rounded summits, porphyry giving rise to softer-textured peaks, and quartzites imparting a peaked configuration. Depressions interspersed among these geological features often manifest as closed basins, varying in size from several tens of meters to several tens of kilometers, frequently hosting lakes. The furthest northeastern extremity of the Akmola region converges with the West Siberian Lowland, marking an additional geographic facet within this comprehensive analysis (QAZAQ GEOGRAPHY, 2023).

Soil: The selected area is classified as having three distinct soil types, namely Ordinary Chernozem (OC), Southern Chernozem (SC), and Dark Chestnut (DC), which in US Taxonomy correspond to Pachic Haplustolls, Typic Haplustolls, and Entic Haplustolls, in that order. OC is found in the northwest's lowest altitude zone and the west's highest altitude zone within the study area. Only the southern portion of the study area contains DC, while the low-altitude zones of the north to northeast and the medium-altitude zones of the medium latitude of this region are home to Southern Chernozem. According to Main Management of Geodesy and Cartography USSR (1982), this region is covered in fertile Chernozemic soils, which are also thought to store a significant amount of organic carbon. Soil organic carbon (SOC) is a significant source and sink of carbon dioxide and is a significant indicator of soil quality and agronomic sustainability (REEVES 1997; SIX et al. 2002; LAL 2004). From an agricultural and environmental perspective, therefore, the Chernozem soils of northern Kazakhstan are an invaluable resource. The area's native grass for steppes has mostly vanished over the past few decades due to Khrushchev's political initiative, the Virgin Lands Agricultural Program (1954–1960), and has been replaced by arable land, primarily used to produce spring wheat (MEDVEDEV, 1987).

Hydrography: Akmola Oblast boasts a distinct hydrographic landscape with shallow and impermeable rivers due to a low water table. These rivers, primarily fed by meltwater and to a lesser extent groundwater, face desiccation and salinization in summer. The Yessil River, a key tributary of the Irtysh, plays a crucial role, joined by consequential tributaries like Ters-Akkan and Zhabai.

Notably, rivers like Ulenta, Selenta, and Nura culminate in drainless lakes, contributing to the region's overall lake abundance. The high plain and hilly terrains host various lakes, with Tengiz salt lakes being the largest. Smaller freshwater lakes like Ala-Kol and Shoindi-Kol dot the landscape, featuring low-lying shores susceptible to alteration in strong winds.

Climate: In the Akmola region, the climate is extremely continental, and arid, with hot summers and cold winters. The climate is extremely continental and belongs to the West Siberian climatic region of the temperate zone. The daily and annual temperature amplitudes are very large. Spring and autumn are poorly expressed. There are many sunny days, and the amount of solar heat received by the earth in summer is almost as great as in the tropics. The cloud cover is insignificant. Annual precipitation decreases from north to south, with a maximum in June and a minimum in February. Snow cover is maintained for an average of 150 days. The winds in Akmola oblast are quite strong. (QAZAQ GEOGRAPHY, 2023). This area is characterized by a semiarid and continental climate with high-temperature fluctuations (−40°C in winter and +35°C in summer) and a short growing season (May–September). Average annual precipitation ranges from 280 to 350 mm.

3.3 Spring Wheat Cultivation in Kazakhstan

Wheat (lat. Triticum) is a very important cereal crop belonging to the grain family. Among all cultivated cereals, wheat has the largest number of species and varieties (approximately 30 varieties). Kazakhstan produces an average of 13.5 million tons of soft wheat annually, enough for the country's needs and exports. The government also has a contingency plan of a one million tons reserve to meet the needs of the domestic market (THE ASTANA TIMES, 2023). The most common types of wheat include hard wheat, soft wheat, One-grain wheat, Two-grain wheat, and Boeotian wheat (AGROMART.KZ, 2023). 6 species (Volga wheat, Polish wheat, Kozhe wheat, soft wheat, durum wheat, Koben wheat) grow in Kazakhstan, wild species are rare (KULZHABAEVA, 2011).

Two types of spring wheat are cultivated in the country: soft and hard. Soft wheat is the most widely grown; its varieties are ductile and cover a wide range of terrain. Compared to mid-season varieties, late-season cultivators are more likely to use later precipitations. Regarding the circumstances in North and Central Kazakhstan, this is crucial. Soft varieties of spring wheat: Omsk-36, Akmola-2, Shortandinskaya-95 improved, Omsk-18, Astana, Karabalykskaya-90, Lyubava-5, Kazakhstan early ripening, Omsk-35, Karaganda-22, Omsk-38, Lutescens-32, Lyubava, Memory of Asiev, Omsk-30, Omsk-28, Astana-2, Stepnaya-60, Saratov-32, Boevchanka. Hard varieties of spring wheat: Milana, Serke, Kostanay-12, Altyn Dala, Asangali-20, and other varieties of spring wheat (ALCHEMYKA, 2019).

For the optimal cultivation of spring wheat, meticulous consideration must be given to land allocation and the selection of suitable forecrops. Particularly in arid zones, fallow emerges as the preferred forecrop for spring wheat cultivation, serving the dual purpose of weed control and the accrual of nutrients and moisture. However, the adoption of fallow is not without its drawbacks, including a one-year absence of harvest, associated costs for field cultivation, and the unproductive loss of humus. In advanced agricultural enterprises adhering to elevated standards, fallow is progressively supplanted by alternative fallow crops such as peas and oats. The implementation of fallow tillage adheres rigorously to zonal farming systems, encompassing the judicious application of herbicides to mitigate the need for mechanical cultivations of fallow lands and to conserve moisture. In the steppe zone, short-term fallow rotations, grounded in minimum tillage technology, find applicability. The preparatory measures for soil cultivation under wheat are contingent upon various factors, including the specific zone, forecrop, soil attributes, infestation levels, prevailing weed species, and numerous other contextual considerations. The temporal dimension of spring wheat sowing assumes paramount importance, dictated by zonal features and representing a decisive factor influencing both the quantity and quality of grain and seeds. Kazakhstan's diverse climatic conditions necessitate a nuanced approach to determining the optimal sowing period for spring wheat. The methodical precision of seeding involves achieving a square-like distribution of plant nutrition, a strategy particularly germane to spring wheat, given its lower tillering capacity compared to barley and oats. Adjustments in sowing rates, responsive to soil fertility, moisture availability, and weed prevalence, further optimize the cultivation process. The cultivation phase involves a repertoire of techniques, including harrowing, chemical control measures, and fertilization, strategically applied to enhance wheat plantings. Harvesting methods encompass both separate and direct harvesting approaches, each tailored to specific contextual considerations (UNFCCC, 2014).

Production models of wheat according to the applied agrotechnical inputs can be extensive, low input, mid-tech, and intensive. Every model of different intensity can be modern and efficient if we produce appropriate wheat variety under adequate ecological conditions and by agricultural technology of a coherent level (BELTEKI et al. 2017). Kazakh farmers frequently use deep plowing before planting, which removes extra moisture from the deeper soil layer, or no-till management to maintain or increase the amount of water available to the crops. (USDA, 2022). Farming in Kazakhstan is generally well subsidized; there are subsidies for fertilizers, herbicides, seeds, fuel, investment, equipment, and export promotion. All farms visited during the tour were well-equipped with agricultural machinery, including tractors, seeders, and grain combines. High-technology machinery with GPS, of varying brands, is used (USDA, 2022).

Modern and sustainable farming practices, including no-till farming and precision agriculture, have been increasingly adopted by farmers. These practices aim to increase yield while conserving resources and protecting the environment. The government of Kazakhstan has implemented various policies and subsidies to support wheat farmers and encourage sustainable practices. This includes providing credit and financial support to the agricultural sector. While Kazakhstan's wheat production has been substantial, it faces challenges such as water scarcity in some regions and the need for sustainable land and water management practices.

3.4 Research Methodology

To address the research objectives and test the hypothesis, a comprehensive research methodology is employed. This includes a combination of literature review, field studies, and data analysis about currently applied technologies, including wheat breeding, crop rotation, conservational agriculture, crop diversification, climate-resiling farming, precision farming, organic farming, and international practices. This research contains only secondary data that has been obtained from academic journals, government reports, and relevant publications.

4. RESULTS AND EVALUATION

4.1 Evaluation of Wheat Breeding

A key strategy to raise yield in Kazakhstan is to improve wheat breeding and create cultivars with broad adaptation, response to inputs, and disease resistance. Modern spring wheat varieties, chosen for their high yields, disease resistance, and climate adaptability, have been used by farmers. Understanding wheat's breeding potential is essential to raising both yield and quality.

Due to both domestic and foreign demand, durum wheat, in addition to spring bread wheat, occupies an estimated 700,000 hectares in northern Kazakhstan. Several spring durum wheat breeding programs operate in the country, such as Aktobe and Karabalyk Agricultural Experimental Stations, the Scientific Production Center of Grain Farming named after A.I. Barayev, and the Kazakh Scientific Research Institute of Agriculture and Plant Growing. These programs, along with counterparts in Russia, have united in the Kazakhstan–Siberia Spring Wheat Improvement Network (KASIB) since 2003, exchanging and testing over 200 genotypes of spring durum wheat in multi-locational trials.

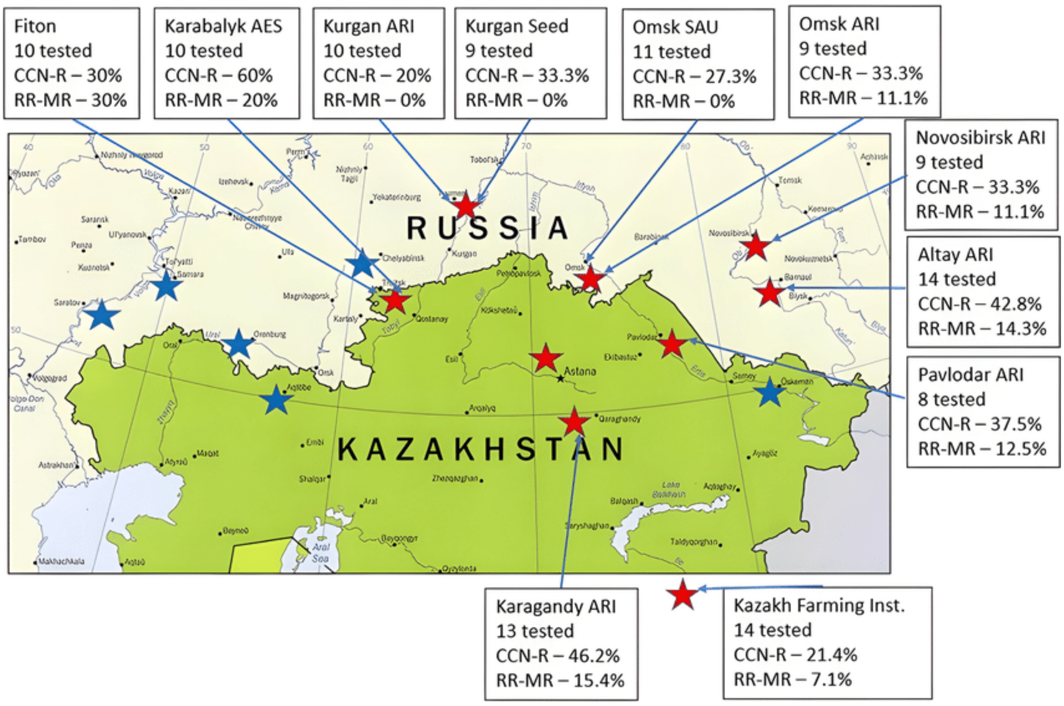


Figure 4. Origin of spring wheat lines originating from the Kazakhstan-Siberian co-operators (KASIB, 2022).

Research and extension services, which offer information on new technologies, best practices, and the most recent research findings, are beneficial to farmers and other agricultural professionals. Nonetheless, the agricultural industry faces difficulties like a declining workforce, aging scientific personnel, antiquated equipment, and tighter budgetary constraints. As a result, there are worries regarding the calibre of specialized training for industrial agriculture and a persistent lack of research and technological advancements applied to agricultural production. Important problems include insufficient funding for agricultural scientific research, which receives less than 1% of all agricultural government expenditures, and a poor relationship between agricultural science, education, and production in personnel training.

4.2 Evaluation of Crop Rotation

Crop rotation is a common practice in Kazakhstan. Crop alternatives and the rotation order vary between enterprises; however, the four-crop rotation scheme is the most popular rotation scheme utilized in the region. Often the first-year fields are left fallow to help improve the soil moisture supplies. Wheat is then planted for a year or two. Wheat is most often followed by oilseeds, pulses, and sometimes oats or corn (USDA, 2022).

Table 1.. Recommended crop rotation schemes for the Akmola region

Natural area (districts)	Recommended crop rotation schemes
Gorno-sopochnaya zone (chernozem soils) (Sandyktau, Bulandinsky, Zerendinsky)	4 crop rotations Peas-wheat-wheat-barley Peas (lentils) - wheat-rapeseed (flax) - wheat Peas-wheat-buckwheat-wheat Millet (pea-oat mixture for hay) - wheat-wheat – barley Chemical or minimal steam-wheat-wheat-barley (oats) Minimal or chemical level. steam-wheat-wheat-barley (oats)-wheat
	5-6-and full crop rotations Peas-wheat-wheat-sunflower-barley Bonfire 3 years-wheat-wheat-barley Bonfire + sainfoin 3 years-wheat-wheat-barley Bonfire + alfalfa 3 years-wheat-wheat-barley
Steppe zone (Black Sea-terrestrial soils)	4 crop rotations Peas (chickpeas) - wheat-wheat-barley (oats)

(Akkolsky, Shortandinsky, Birzhansal)	Peas (chickpeas) - wheat-flax-wheat Barley-wheat-flax-millet Peas (lentils) - wheat-flax-millet Peas (chickpeas) - wheat-oats – barley) - wheat Chemical or minimal steam-wheat-chickpeas-wheat Chemical or minimal steam – wheat-wheat-barley (oats)
	5 crop rotations Sunflower-wheat-wheat-barley (oats) Summer sowing oats-wheat-wheat-barley Millet for hay-wheat-Sudan grass-barley Corn for silage-wheat-wheat-barley (oats)
	6 crop rotations Zhitnyak 3 years-wheat-wheat-barley Zhitnyak+sainfoin-3 years-wheat-wheat-barley Zhitnyak + alfalfa 3 years-wheat-wheat-barley
Dry steppe zone (chestnut soils) (Yereimentau, Tselinograd, Arshalinsky, Egindykolsky, Korgalzhynsky, At-basarsky, Yesilsky, Zhaksinsky, Astrakhan, Zharkayynsky)	4 crop rotations Parma-wheat-wheat-wheat Peas (chickpeas) - wheat-flax – barley (oats) Annual grasses-wheat-wheat-barley Corn for silage-wheat-wheat-barley Millet-wheat-wheat-barley
	5-and full crop rotations Par minimal-wheat-peas (chickpeas) - wheat-barley Par minimal-wheat-wheat - barley-wheat
	6-and full crop rotations Zhitnyak (sainfoin, alfalfa) 3 years-wheat-wheat-barley

(ZHUMAGULOV, et al. 2023).

Research 1. The study conducted over a span of two years (STYBAYEV et al. 2023) in the Akmolinsk region of northern Kazakhstan investigates the incorporation of cover crops into crop rotation to address issues related to herbicide-resistant weed control and enhance crop productivity. The study underscores the effectiveness of cover crops, specifically oats, in weed suppression and in enhancing the quality and productivity of forage crops, even in dry conditions. Integrating cover crops into crop rotation is presented as an agroecological strategy to control weeds, reduce the reliance on synthetic chemicals, and preserve soil microorganisms and biodiversity. This approach contributes to the promotion of sustainable crop production.

4.3 Evaluation of Conservational Agriculture

The adoption of conservation agriculture practices, particularly minimum tillage and no-till farming is gaining momentum in Kazakhstan. These practices are aimed at reducing soil erosion and conserving moisture in agricultural fields. Zero tillage (No-till) is direct sowing with the use of a complex, i.e., a fragment, or a chisel, with minimum dislocation of soil. No-till technology significantly improves soil fertility through better control of wind and water corrosion, perfecting the capability of the soil to hold water and adding organic matter content to it. High stubble in the fields holds and accumulates further snow, and granulated and spread-out straw improves the structure and quality of soil owing to natural declination. This reduces the reliance of crops on rainfall conditions, which is a measure of adaption to climate change. In Kazakhstan, conservation agriculture techniques—minimum tillage and no-till farming, in particular—are becoming more popular to reduce soil erosion and improve moisture conservation. At the moment, 95.8 thousand hectares, or less than 7% of irrigated land, use conservation technologies for irrigation and water supply. Agriculture is expected to use 21 km3 of water annually on average. Improving soil fertility, controlling erosion, and retaining moisture are all made possible by "no-till" technology, which involves direct seeding with little disturbance to the soil. Encompassing almost 3 million hectares, it lessens the damaging effects of weather on crops. Crop rotation combined with permanent ground cover and minimal or no tillage are institutional and organizational requirements for resource-saving farming systems. The Food and Agriculture Organization (FAO, 2019) has emphasized that sustainable agriculture requires a great deal of knowledge as well as a gradual change in the attitudes and behaviours of stakeholders. Zero tillage technology requires high-performance, contemporary agricultural machinery for both operation and maintenance. Widely accepted, its suitability for Kazakhstan's dry climate rests in its ability to retain soil moisture and reduce evaporation. Given that beneficiaries include all farmers, regardless of who owns the business, no-till technology can be applied in small-scale settings. For its successful implementation, however, high-level farming is required, and strict technological discipline—limited to the use of herbicides for weed control—is essential. Zero tillage without autumn tillage may lead to soil compaction, reduced water permeability, air intensity, and compromised crop phytosanitary status (UNFCCC, 2014).

Economic Aspect: Capital Costs: The implementation of zero-tillage technology involves significant capital costs, primarily attributed to the acquisition of new, expensive machinery. Although resource-saving in the long run, the initial investment for modern tractors, seed drills, harvesters, and sprayers is substantial. The depreciation costs of this machinery may increase, even though the overall number of machines decreases. Additionally, there are ongoing costs for herbicides and, in some cases, fungicides for weed and disease control. The long-term economic benefits depend on factors such as crop conditions and management practices. Development Impacts: The direct benefits include enhanced stability in crop yield, reduced dependence on weather conditions, increased labor productivity, reduced labor requirements, and a decrease in the time required for fieldwork. Indirect benefits involve minimizing vulnerability to climate change, as the technology decreases dependence on weather conditions, serving as an adaptation measure. Economic benefits include a reduction in manufacturing processes, a significant decrease in fuel consumption, and lower overall financial costs compared to traditional farming methods. Employment: While the implementation of no-till technology leads to a decrease in labor costs and employment, the associated benefits in terms of increased productivity and improved living conditions contribute to overall development. Growth & Investment: Investments are needed for purchasing modern equipment, reflecting both a challenge and an opportunity for economic growth.

Social Aspect: The technology's positive impact on productivity and financial costs enhances the well-being of the rural population. The conservation of natural and human resources improves living and working conditions, ultimately influencing health positively.

Environmental Aspect: Environmental Benefits: No-till technology minimizes soil disturbance, promoting increased fertility through the incorporation of crop residues into the soil. This approach reduces humus mineralization rates, contributing to soil health and fertility. The potential for erosion processes, especially on sloping lands, is a concern that requires further research.

Local Aspect: Opportunities and Barriers: The local context presents opportunities for the widespread implementation of zero-tillage technology, especially in northern regions like North Kazakhstan, Kostanay, and Akmola. However, the risk of erosion on sloping lands needs thorough exploration. Market Potential: The technology has substantial market potential nationwide, but its full realization depends on achieving high-level farming standards and overcoming weed-related challenges. Status: The technology is currently being implemented, and its timeframe for broader adoption is medium-term, contingent on achieving high-level farming and weed management. Acceptability: Zero-tillage technology is generally acceptable in Kazakhstan, particularly in regions where it is most widely implemented. However, addressing concerns related to erosion risks on sloping lands is crucial for broader acceptability.

4.4. Evaluation of Crop Diversification

Crop diversification, with the addition of crop acclimated to stressful situations. The preface of newly cultivated species and bettered kinds of crops is a technology aimed at enhancing factory productivity, and quality, and erecting crop adaptability to environmental stresses. In addition, it's necessary to use the eventuality of selection and gene engineering in order to develop further failure-resistant crop kinds. Breeding new and advanced crops kinds enhances the resistance of shops to a variety of stresses that could be affected by climate change. Crop diversification should also be grounded on a rational distribution of crops on the base of agroecological and agro-climatic zoning. Diversifying from the monoculture can support a country in becoming more tone-reliant in terms of food products. Introducing a lesser range of kinds increases natural biodiversity, strengthening the capability of the agroecosystem to respond to external stresses and reducing the threat of total crop failure. Kazakhstan is expanding its crop production by using genetic engineering and breeding to produce drought-resistant crop varieties that are stress-adapted. Enhancing yields, grain quality, and ecological resilience are the goals of the initiative. Diversification reduces the chance of a complete crop failure and encourages self-reliance in food production. It is based on adaptive agriculture and agro-climatic zoning. This strategy lessens agroecosystems' susceptibility to outside stresses by promoting natural biodiversity within them. To avoid becoming overly dependent on a single crop, the objective is to develop a diverse crop portfolio. Diversification is made possible by many strategies, including farmer experimentation and new varieties from research organizations while taking resources, economics, technology, and market dynamics into account. The introduction of new crop species is preceded by thorough security assessments. It is essential to monitor and evaluate new crop varieties with farmer participation in order to determine their performance, potential for income, and viability. The best opportunities to introduce new crops are those that are intended for both domestic and foreign markets. Clear national policies, connections between farmer-research programs, and institutional support are necessary for successful diversification. Committees made up of farmers coordinate diversification efforts and offer financial and technical support locally. Enabling access to national markets, technical skills, and inputs requires government policy. Modern agricultural machinery is used in both operation and maintenance. Global experts' endorsement of the strategy highlights its importance, and crop production resilience to drought conditions is improved by its suitability for the current and projected climate change. All farmers are included as the beneficiaries, with a focus on regional implementation on a large scale with comparable soil and climate conditions. The possible disadvantages of farmers experimenting with native varieties, the difficulties of introducing exotic species, and the obstacles to market access in commercial farming are some of the limitations, though. The dangers highlight how crucial it is to choose crops strategically in accordance with consumer demand. Diversification is encouraged globally and has the potential for Kazakhstan's agriculture to be resilient and sustainable despite obstacles.

Economic Aspect: Capital Costs: Implementing crop adaptation technology involves initial capital investment for purchasing new seed varieties, agricultural equipment, and technology. Training technical experts and conducting market research also contribute to the capital costs. Development Impacts: Direct benefits include strengthened cropping systems with increased yields, improved drought resilience, resistance to pests and diseases, and access to new market opportunities. Crop diversification, as shown in Kazakhstan, can increase profitability by 32% compared to traditional monoculture. Long-Term Costs: Without adaptation, traditional farming may result in reduced yields due to increased aridity, necessitating additional subsidies. With adaptation, long-term costs involve investments in breeding new varieties, requiring human and financial resources over several years.

Social Aspect: Employment: The cultivation of new crops leads to the expansion of cultivation areas and increased employment opportunities, contributing to rural development. Growth & Investment: Investments are required for breeding works and the purchase of modern equipment, indicating both a challenge and an opportunity for economic growth.

Social Benefits: Increased productivity and additional income from diversification contribute to the well-being of the rural population. Improved nutritional value in new crop varieties can positively impact health.

Environmental Aspect: Environmental Benefits: Crop diversification increases natural biodiversity, enhancing the resilience of agroecosystems and reducing the risk of total crop failure. It enables more sustainable and effective use of natural resources compared to monocultures.

Local Aspect: Opportunities and Barriers: Misconceptions about the productivity of local species pose a barrier to the introduction of new crop varieties. Other barriers include a lack of clear government policy, predominance of small farms, poor technical equipment, and price fluctuations. Opportunities lie in the potential for cost-effective crop diversification. Market Potential: The technology has significant market potential nationwide, especially in Kazakhstan, where the cultivation of various crops has increased in recent years. Status: The technology is currently being implemented, and its timeframe is long-term, requiring time to determine species and varieties adapted to the region. Acceptability: In Kazakhstan, the acceptability of crop diversification is evident in the increased cultivation of various crops like sunflower, canola, flax, soybean, and pea, providing cost-effectiveness in northern regions.

4.5 Evaluation of Climate-Resilient Farming

Development of draught-resistant wheat. From time-to-time failure covers vast land civilization areas of the country. The preface of new, more draught-resistant kinds is of great significance. Along with that the openings of selection and gene engineering to nurture further draught-resistant grain crops should be used. The selection of new and advanced agrarian crop kinds allows for strengthening the resistance of shops to colourful stresses as a result of climate change. The technology allows for the reduction of the threat of yield losses and failure. In order to lessen the effects of recurrent droughts and extreme weather events, farmers in Kazakhstan are actively investigating wheat varieties that are heat and drought-tolerant. Drought strikes the nation about every three years, which forces the agro-industrial complex to concentrate on enhancing grain productivity via advances in agricultural science. Understanding the region's natural features and choosing the right source materials are crucial to creating drought-resistant cultivars. The main goal is to use hybridization to combine improved productivity with resistance to drought. Drought resistance can be improved by fertilizers, particularly those high in potassium, phosphorus, and nitric acid; certain crops can also benefit from the addition of microelements like zinc and copper. Organizational and institutional requirements include hiring experts to cultivate new varieties and updating the regulatory-legal foundation in the grain production industry. Working in the field and laboratories requires the use of modern equipment and instruments. Supported by global experts, the technology for raising drought-tolerant cultivars fits Kazakhstan's current climate, where the lengthiest dry spells have shrunk throughout the region. The process is hindered by the uncommon combination of drought resistance and high productivity in a single gene type, despite the substantial number of beneficiaries. Because different areas have different physiological mechanisms, selection for drought resistance is complex. Modern equipment is lacking in many selection centres, and the drought has made crop insurance necessary, requiring legislation updates for efficient agro insurance (UNFCCC, 2014). The technology has potential for Kazakhstan's sustainable agriculture, notwithstanding its obstacles.

Economic Aspects: Capital Costs: The initial capital costs associated with the introduction of adaptation technologies, including the establishment of selection hothouses, lab equipment, and seed production improvements, represent a significant upfront investment. These costs may strain government budgets and require careful financial planning. Incremental Costs: Ongoing investments in developing drought-resistant varieties and preparations are necessary. These costs may increase over time as research and development progress. However, the potential return on investment in terms of increased wheat productivity is substantial. Long-Term Costs: Without adaptation, the costs could rise due to reduced grain productivity caused by climate warming. In contrast, with adaptation technologies, long-term costs can be mitigated by protecting soil from erosion and reducing evaporation, potentially resulting in savings in the long run. Direct Benefits: The development of drought-resistant wheat varieties can lead to direct benefits, such as improved wheat yields, reduced vulnerability to climate change, and economic benefits through increased agricultural productivity. Indirect Benefits: The indirect economic benefits include the potential for job creation, as there will be a higher demand for specialists in the field of selection. Additionally, the technology can make the agricultural sector more attractive to investments, leading to economic growth.

Environmental Aspects: The introduction of drought-resistant wheat varieties and preparations to improve plant drought resistance can have positive environmental impacts.

These technologies can contribute to the conservation of natural resources and the reduction of vulnerability to climate change, thus promoting ecological sustainability.

Local Aspects: The technology can be beneficial for local stakeholders, particularly farmers, as it can improve yield productivity and the well-being of the rural population. The demand for specialists in wheat selection may lead to increased employment opportunities in rural areas. Development Aspects: The introduction of adaptation technologies is crucial for the development of sustainable agriculture in Kazakhstan. It can help the country adapt to climate change, reduce vulnerability to environmental factors, and enhance economic development. By improving grain quality and productivity, it contributes to increased income, education, and overall well-being of the population. Opportunities and Barriers: The collaboration between Kazakhstani and Australian scientists in nurturing drought-resistant wheat varieties is an opportunity for knowledge exchange and advancement. However, the long development period (10-15 years) for new varieties can be a barrier, necessitating patience and sustained investment. Market Potential: The technology has significant national market potential, as it addresses the pressing need for climate-resilient agriculture in Kazakhstan. It can potentially be a valuable export commodity if the country becomes a global leader in producing drought-resistant wheat varieties. Acceptability for Local Stakeholders: The technology is likely acceptable to all concerned parties working on drought-resistant wheat varieties, as it aligns with modern crop cultivation practices and addresses the challenges posed by climate change.

4.6 Evaluation of Precision Farming

Precision farming technologies, such as remote sensing and GIS, can help farmers optimize the use of resources and reduce the negative impacts of wheat production on the environment. In recent years, Kazakh farmers have embraced various advanced agricultural technologies. These innovations include precision farming tools like GPS technology for crop monitoring and input control, drones for data collection, automated watering, and soil condition management, as well as the use of biological methods for pest and disease control, reducing reliance on chemicals. Software is also used for comprehensive farm management, including data analysis and consumer information collection. These technologies enhance both the quality and quantity of agricultural products and help reduce production and energy costs, contributing to Kazakhstan's economic stability.

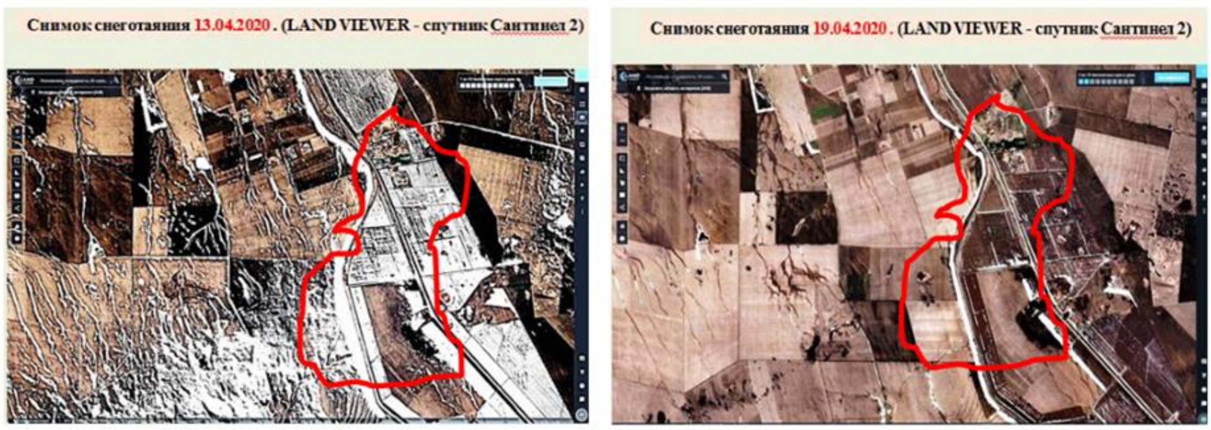
Kazakhstan has experience with IT technologies in agriculture, including hybrid breeding, satellite positioning, GIS systems, and machinery monitoring and control systems. The most sought-after technologies include digital mapping, yield planning, differential fertilizer application, crop and livestock monitoring, and electronic databases for production processes.

The adoption of precision agriculture techniques, like GPS-guided tractors and variable rate technology, is on the rise. These technologies enable more accurate planting, fertilization, and pesticide application, leading to reduced input costs and increased efficiency.

While precision farming systems (PFS) have been successfully implemented in other countries, their adaptation to the arid conditions of Northern Kazakhstan is essential, as simple replication from more humid climates is not suitable.

To access operational meteorological information, websites like Windy.com and Ventusky.com provide data on snow reserves, field moisture availability, and brief weather forecasts. Additionally, the National Hydrometeorological Service of Kazakhstan has developed an application, providing agrometeorological services to farmers. This application offers weather forecasts, actual weather data, assessments of crop viability, moisture reserves, yield forecasts, and more, aiding farmers in making informed decisions and enhancing agricultural practices. It also helps identify damage zones in fields using remote sensing technology.

Figure 5. View of the field sites of the A.I. Baraev NPCKH, satellite monitoring of snowmelt, 04.04.2020 – 19.04.2020 (Land viewer – satellite Sentinel 2).



Digitalization of industrial agriculture has been limited due to factors like weak mobile communication networks, a lack of knowledge and skills in implementing digital solutions, a shortage of local specialists in both agriculture and IT and the absence of a unified digital agriculture ecosystem.

Research 2. In Northern Kazakhstan, a study (IRMULATOV et al. 2020) implemented precision farming methods to oversee the productivity of spring wheat. The primary objective of the research was to assess the feasibility of implementing precision farming in the region and to develop an algorithm not only for passive crop monitoring but also for active management of spring wheat yield using Earth Remote Sensing (ERS) technology. The study revealed that precision farming, with a focus on customizing fertilizer use, helped reduce inconsistencies in the fields. Soil quality, landscape features, and moisture levels significantly affected spring wheat yields in Kazakhstan's arid conditions. Changes in terrain could identify moisture sources. Researchers developed an algorithm using remote sensing and ground data for precise soil, landscape, and moisture monitoring, enhancing crop yield management. The more precise the data analysis, the more it boosted yields. Using a 5-hectare grid resulted in a 10% yield increase, and a 1-hectare grid doubled it. The study identified strong correlations between wheat yield and NDVI, though these relationships varied across the field. Notably, applying differentiated mineral fertilizers (9.5% for the 5-hectare grid and 19.2% for the 1-hectare grid) and timely non-root fertilization (15-22.3%) significantly improved yields.

4.7 Evaluation of Organic Farming

Organic husbandry is a holistic product operation system that promotes and enhances agro-ecosystem health, including biodiversity, natural cycles, and soil natural exertion. It emphasizes the use of operation practices in preference to the use of out-ranch inputs, taking into account that indigenous conditions bear locally acclimated systems. This is fulfilled by using wherever possible, agronomic, natural, and mechanical styles, as opposed to using synthetic accoutrements, to fulfill any specific function within the system (FAO, 1999).

Organic farming is not just a production method; it represents a sustainable philosophy that minimizes synthetic fertilizers, pesticides, and growth regulators, instead relying on natural processes. This approach prioritizes biodiversity conservation and environmental sustainability alongside food production.

Kazakhstan holds significant potential for the development of organic farming, with over 200,000 hectares of fields currently cultivated using organic methods certified by European organizations. To harness this potential, more efficient farming technologies, increased investments, education and training for agricultural workers, and other measures are needed to boost organic agriculture and its share in agricultural exports. The country exported $35 million worth of organic products in 2022, with wheat, linseed, and soybeans being the main export items. The country ranks high in global organic product exports, particularly in wheat and oilseed flax, with the European Union being a primary export market.

The United Nations Development Programme (UNDP), in collaboration with the Kazakh government, plays a vital role in advancing organic agriculture. They have developed legal and regulatory frameworks, financial mechanisms, and certification processes to support the sector. Certification enhances trust between producers and consumers by confirming that products meet organic farming standards. Currently, Kazakhstan has 38 farms certified for organic farming.

In 2015, Kazakhstan enacted the "Law on the Production and Turnover of Organic Products" to establish the legal and economic framework for organic production, emphasizing sustainable land use, healthy nutrition, and environmental protection. Subsidies for certification costs and organic product standards were introduced. A roadmap for organic agriculture development for 2022-2023 is in progress. Efforts to introduce new regulations, standards, and financial support are accelerating the transition to more sustainable farming practices. The government is actively working on new laws and innovations to make organic farming a significant part of the national agricultural system. Preparations for the "Organic Farming Development Roadmap for 2024-2026" are underway, updating national standards and launching a new version of the law "On the production and turnover of organic products." These efforts aim to simplify certification processes, introduce group certification for small farms, and streamline certification requirements.

Research 3. The research conducted by Espolov et al. in 2023 examines the worldwide phenomenon of rising organic product sales and the expansion of organic agriculture. The study's field tests showed that adopting organic farming practices, such as using manure and the bio-destructor, led to impressive results, with a spring barley yield of 4.39 t/ha and profitability of 118%. This suggests that sustainable agriculture not only produces eco-friendly goods but also ensures stable income for farmers. The study recognizes data collection and market challenges, making it important to explore how environmental sustainability affects eco-farms economically. The findings can guide the development of standards for organic farming and promote sustainability while addressing environmental concerns related to land use and protection.

4.8 Evaluation of International Practices

A review of transnational gests shows that all developed countries, on the one hand, strive to increase the sustainability of agrarian development given the ever-adding negative impact of global climate change. On the other hand, countries strive to transition to resource-saving and organic technologies aimed at perfecting the ecological situation and conserving the terrain. This includes, first of all, a high degree of diversification, transition to perfection husbandry, and digitalization of all technological processes. Special attention is paid to the selection and parentage of new factory kinds using accelerated styles grounded on molecular biology and inheritable engineering. Thanks to this, scientific associations decide and transfer for practical use new high- yielding kinds of crops resistant to conditions and stressful situations every 5- 6 times. An important point is to increase the delicacy in soothsaying rainfall conditions which is achieved through a wide network of rainfall stations in the country and an applicable database of long-term meteorological compliances. presently, organic product in the world is developing stoutly. The increase in demand has a steady trend, and the world request of organic products continues to show positive dynamics. Organic agriculture land area has reached 71 million hectares, which is 1.5 of the world's agrarian land area. transnational practices and the positive gests of the commanding countries (USA, EU) in organic product show that profitable imbalance is compensated by measures that encourage directors to remain organic. Experience of the EAEU member countries. In the Russian Federation, instruments are issued simply grounded on laboratory conclusions (VNIIKR), while the inspector doesn't decide on the phytosanitary condition of exported products. When importing, the inspector selects samples and sends them for laboratory examination on an obligatory base, grounded on the results of which the inspector decides. The Argus- PHYTO FSIS has been enforced. Laboratory QA tests are carried out on a paid base and at the expenditure of the product proprietor across nearly all countries. TRACES system has been enforced in the EU; public information systems are also being used.

Processing of agrarian products: Developed countries have achieved high results in the food force of the population by stimulating the modernization of ministry and technologies in the field of processing. In Russia, recycling assiduity development is carried out by supporting the product of agrarian raw accoutrements, modernization, and capacity structure through specialized equipment and construction grounded on innovative technologies and resource-saving outfits, stimulating cooperation between agrarian directors and processors. In the European Union, directors and processors of raw accoutrements and other heirs of pastoral development can use loans or guarantees to cover operating costs on veritably favorable terms, similar to extremely low-interest rates or accessible payment schedules. In the USA, work is underway to encourage private companies to invest in the development of inventions and capabilities in the assiduity through the preface and mass expansion of scientific developments grounded on new technologies that contribute to increased labor productivity. Encyclopaedically, the matter of strengthening sustainable long-term relations between directors of agrarian raw accoutrements, recycling enterprises, and trade is a factor of productivity and product cost growth.

Market development: Analysis of the most advanced countries linked the following patterns and approaches aimed at developing deals of domestic agrarian products. International experience shows that the key to successful participation in the marketing chain of growers is selling cooperation. To date, up to 70 of products are vented in Europe through cooperatives, 60 in the USA and Canada. Marketing cooperatives form large batches of goods and conclude force contracts in advance. Developed trade and logistics structure throughout the force chain. exemplifications of successful distribution networks grounded on the WDCs (WDC networks) are the Rungis non-commercial request (Paris, France), the Mercasa non-commercial request network(Spain), and the Bronisze non-commercial request(Warsaw, Poland). The network meets the requirements of 3,600 tenants. International norms and conditions (SPS measures, HACCP, GLP, etc.) have been enforced in developed countries (Canada, Australia, New Zealand) which increases confidence and quality of products in these countries. A necessary element of the trade policy across developed countries is to promote the interests of exporters at the interstate position through accommodations to remove trade walls and conclude agreements and other documents. The most active countries are the USA, EU, Australia, Canada, Brazil, Mexico, and Japan.

Agricultural cooperation and infrastructure development of industrial agriculture: Agrarian cooperation and structure development of artificial husbandry In utmost OECD countries, cooperatives are present at all corridors of the agrarian value chain and include granges of all sizes. Agrarian cooperatives are largely developed in the EU nearly 22,000 collaborative enterprises unite further than 6.1 million members, generating a periodic development of roughly EUR347 billion. On average, 57 of the granges in the EU and 92 in the USA share in cooperatives. In Austria, Finland, Germany, and Sweden, an average planter is a member of at least two agrarian cooperatives. This suggests that cooperatives in OECD member countries are characterized by specialization (for illustration, marketing, processing, and ranch product inventories); they frequently operate under secondary and tertiary collaborative associations (for illustration, unions, and coalitions). It's cooperatives in numerous countries of the world that have laid the foundation of agrarian structure. For illustration, US cooperatives force growers with energy, mineral diseases, feed, give marketing and transportation services to their members, and engage in retail deals of agrarian products. At the end of 2017, a law was passed in the United States giving significant duty preferences to growers dealing their products to cooperatives. 20 percent of deals to a cooperative are subject to duty deduction. If the taxable profit of the planter turns out to be lower than a fifth of the inventories to the collaborative, also this planter will be pure from paying levies altogether. The functions of large force cooperatives in the USA include non-commercial purchases of seeds, chemicals, energy, and veterinary medicines; products of emulsion feeds, quality control of feed constituents, delivery of feed to the ranch; form of ministry and outfit, and delivery of spare corridor. Currently, the agricultural sector in Canada has approximately 1,500 cooperatives with over 4 million members. A majority of grain and oilseeds (above 50%), mineral fertilizers (36%), compound feeds (21%), and seeds (19%) are sold via cooperatives. There's a lot of support for cooperatives available in the EU, as they're perceived, among other effects, as one of the main factors of sustainable development in pastoral areas. On the negative, in the CIS countries, for illustration, there's a clear picture that an agrarian holding can contribute to artificial husbandry development, but not inescapably to the development of pastoral areas. An important area of collaborative exertion in the EU countries is the functional procurement of granges. The share of procurement and force cooperatives in the EU accounts for about 50 of the inventories to commodity directors of ranch product inventories they need. The base of collaborative force conditioning is the provision of mineral diseases and feed. presently, there are further than 2,500 active cooperatives in the Netherlands, and husbandry and finance remain the largest sectors. About 70 of agrarian development is positioned in cooperatives which is advanced than the EU normal of 45. In several EU countries, cooperatives play a significant part in supplying growers with seeds. For illustration, in Denmark, cooperatives regard 35 of the force of all seed material, in

Ireland – 55%, in France – 73. It should be noted that in ultramodern conditions, the collaborative movement is characterized by tendencies to diversify the conditioning of colourful cooperatives, consolidate ties between them, and combine several functions of profitable service of granges within one collaborative association. All granges in Japan, with many exceptions, are members of agrarian cooperatives organized in each quarter. The functions of cooperatives are different and include the collection and trade of products, purchase, and trade of product accouterments and consumer goods, construction, and operation of enterprises for processing and marketing of agrarian products, banking, and insurance operations – entering savings and loans, life insurance and in case of illness, provision of sanitarium and resort services. The National Agricultural Cooperative Federation of the Republic of Korea (NACF), with periodic profit exceeding USD55 billion, unites further than 80 of the country's growers or 2.5 million people. About 70 of the pastoral residents of Israel are members of agrarian cooperatives – kibbutzim, moshavah shittufi, moshavah ovdimah. Cooperatives regard about 75 of cultivated land, including 41 kibbutzim, 29 ovdim moshavs, and 4 shittufi moshavs. At the same time, they regard about 80 of agrarian products produced in the country and own 75 of fixed product means. The Food and Agriculture Organization of the United Nations (FAO) recognizes the pivotal part of cooperatives and other growers' associations in supporting small agrarian directors (USDA, 2022).

5. CONCLUSION AND RECOMMENDATIONS

The investigation into Kazakhstan's agricultural sector revealed a significant emphasis on adopting ecologically safe technologies. These technologies are aimed at reducing the environmental impact of farming practices while ensuring the production of safe and high-quality food. They include techniques such as reduced soil cultivation, the use of organic and natural mineral fertilizers, and the minimization of chemical inputs. The extensive cultivation of wheat in Kazakhstan faces challenges such as water scarcity in some regions and the need for sustainable land and water management practices. However, Kazakh farmers have been increasingly adopting modern and sustainable farming practices, including precision agriculture, no-till farming, and other resource-saving techniques.

The research conducted in Kazakhstan's spring wheat industry has shown significant progress in utilizing wheat breeding and crop diversification strategies to enhance sustainability and competitiveness. Wheat breeding efforts have led to the development of new wheat varieties with increased resistance to diseases, pests, and drought conditions. These varieties are crucial in ensuring a stable supply of spring wheat, particularly in the face of changing climate patterns. Crop diversification, through alternating crop rotation fields, has proven effective in preserving soil fertility, reducing pest pressures, and promoting a more resilient and diverse agricultural ecosystem. Conservational agriculture practices, including no-tillage farming and soil conservation measures, have been implemented with positive results. These practices not only reduce soil erosion but also contribute to maintaining soil fertility and overall environmental sustainability. The research underscores the benefits of adopting organic farming and precision agriculture techniques. Organic farming prioritizes safe, high-quality food production with reduced synthetic chemical use, while precision agriculture, leveraging advanced technologies like GPS-guided machinery and data analytics, enhances resource efficiency and reduces environmental impact, promoting sustainability.To further enhance the sustainability and competitiveness of Kazakhstan's spring wheat production, the introduction of innovative technologies from developed countries is recommended: Sustainability as a core principle of agricultural development should be embraced. Given the impact of global climate change, practices that reduce environmental harm and improve ecological conditions should be prioritized. Crop diversification should be promoted to enhance resilience and adapt to changing conditions. The transition to precision agriculture techniques, which optimize resource use and increase productivity, should be considered. Investment in the digitalization of agricultural processes should be made to improve efficiency and data-driven decision-making. A comprehensive network of weather stations should be developed to improve weather condition forecasting, which is crucial for effective farming. The growth of organic agriculture should be encouraged, as it aligns with global trends and can provide a competitive edge in international markets. Certification and inspection processes for organic products, based on international best practices, should be implemented to ensure the quality of organic products. Support for the modernization of machinery and processing technologies should be provided to enhance the food supply and value addition to agricultural products. The strengthening of trade and logistics infrastructure is crucial to improve the movement of agricultural products and reduce post-harvest losses, which contributes to a more efficient and less wasteful supply chain. Drawing upon the lessons from the experiences of leading agricultural nations, such as the USA, EU, Australia, Canada, and others, in the implementation of sustainable and cooperative agriculture practices is valuable to benefit from proven strategies and achieve better outcomes. International standards and requirements for agricultural products, including SPS measures, HACCP, and GLP, should be implemented to increase confidence and product quality. The development of agricultural cooperatives at all levels of the agricultural value chain, fostering specialization and cooperation among farmers, should be encouraged to enhance product quality and safety, which builds consumer trust and facilitates international trade. The importance of agricultural cooperatives in sustainable rural development should be recognized, as they can contribute to the economic and social well-being of rural areas. Policies and regulations that support sustainable agriculture, investment in research and development, and the growth of agricultural cooperatives should be established. Engagement with international organizations like the Food and Agriculture Organization (FAO) should be pursued to gain support, knowledge, and best practices for agricultural development. Investment in trade and logistics infrastructure should be made to facilitate the efficient movement of agricultural products from farm to market. The promotion of research and development efforts in collaboration with private companies is essential as it enables the introduction of innovative technologies and practices that enhance agricultural productivity and sustainability, fostering continuous improvement in the agricultural sector.

6. SUMMARY

Approximately one-third of human calorie intake is derived from grain crops, underscoring their critical role in global diets. Leading grain producers and exporters, such as Kazakhstan, Russia, and Ukraine, are expected to play a vital role in meeting the growing global demand for grains due to the steadily increasing world population. However, the traditional farming practices in these nations, which rely heavily on chemical inputs, have had detrimental effects on the environment, leading to soil degradation, water pollution, and biodiversity loss. This jeopardizes food security and ecological sustainability in the region. The Sustainable Development Goals (SDGs) outlined by the United Nations General Assembly emphasize the pivotal role of agriculture in ensuring food security, fostering economic growth, mitigating environmental harm, and enhancing the well-being of marginalized populations. Ecological agriculture, which extends beyond organic farming, encompasses environmentally friendly and sustainable practices. These practices aim to produce safe, high-quality food while preserving soil fertility, protecting the environment, and ensuring the safety of agricultural production.

This study investigated ecologically safe methods of spring wheat production in Kazakhstan, with a focus on their implications for food security, environmental sustainability, and the agricultural sector. The research problem addressed in this thesis centered on identifying, analyzing, and promoting ecologically safe and sustainable technologies within Kazakhstan's spring wheat production sector. The study assessed the effectiveness, feasibility, and economic implications of these technologies and the obstacles and opportunities for their adoption. Moreover, the research sought to document success stories and best practices within the industry, offering valuable insights for replication by other farmers.

The investigation into Kazakhstan's agricultural sector reveals a growing emphasis on adopting ecologically safe technologies. These technologies aim to minimize the environmental impact of farming practices while ensuring the production of safe and high-quality food. They encompass practices such as wheat breeding, crop rotation, conservational agriculture, crop diversification, climate-resiling farming, precision farming, and organic farming.

The research conducted in Kazakhstan's spring wheat industry highlights significant progress in utilizing wheat breeding and crop diversification strategies to enhance sustainability and competitiveness. These strategies have resulted in the development of new wheat varieties with increased resistance to diseases, pests, and drought conditions, contributing to a stable supply of spring wheat in a changing climate. Crop diversification through alternating crop rotation fields has proven effective in preserving soil fertility, reducing pest pressures, and fostering a resilient and diverse agricultural ecosystem. Conservational agriculture practices, such as no-till farming and soil conservation measures, have been successfully implemented, reducing soil erosion and promoting environmental sustainability. Furthermore, the research showcases the positive outcomes of incorporating organic farming and precision agriculture techniques. Organic farming prioritizes the production of safe, high-quality food while minimizing synthetic chemical use. Precision agriculture, through advanced technologies like GPS-guided machinery and data analytics, has improved resource management, reduced waste, and enhanced overall efficiency, increasing productivity while minimizing environmental impact.

To enhance the sustainability and competitiveness of Kazakhstan's spring wheat production, the introduction of innovative technologies from developed countries is recommended. These include embracing sustainability as a core principle of agricultural development, promoting crop diversification, transitioning to precision agriculture techniques, and investing in digitalization. Research and development in molecular biology and genetic engineering can create high-yielding crop varieties resistant to diseases and stressful conditions. Developing a comprehensive network of weather stations is essential for effective farming. Encouraging the growth of organic agriculture and implementing certification and inspection processes for organic products can align with global trends and enhance product quality. Supporting the modernization of machinery and processing technologies, as well as promoting farmer cooperatives, can improve marketing cooperation and sales. Implementing international standards and encouraging the development of agricultural cooperatives are essential for sustainable rural development. Finally, engaging with international organizations can provide valuable support and knowledge for agricultural development, and investment in trade and logistics infrastructure can facilitate the efficient movement of agricultural products.

These combined efforts aim to position Kazakhstan as a sustainable and competitive wheat producer, benefiting both domestic consumption and international export.

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8. LIST OF TABLES AND FIGURES

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