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The economics of digital tools in Kazakh agriculture

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Abstract

The agricultural sector in Kazakhstan represents only 5.4% of the total Gross Domestic Product and consists of livestock and crop production. The agricultural industry's potential production is limited by outdated technology, inefficient work practices and a lack of digitization which accounts for a small portion of the economy's overall value. Modernising agricultural output and making investments profitable represent some of the crucial challenges. However, in this field, limited research has been done. There are no studies investigating the profitability and return on investment of digitalization. Therefore, this paper investigates six digital technologies and their economic effects: health management in beef production, dairy cow movement tracking, drone counting systems, crop parallel driving systems, telematics and soil moisture monitoring. The data for this paper are from our own field studies of more than 138 farms in various regions of Kazakhstan. The extracted data includes the type of technology, equipment, cost and added profit of the farm. The investment performance indicators (IPI) were evaluated based on this data. Studies reveal that the use of technology demonstrates the financial viability of the digitalization of agriculture. The IPI of different technologies provides important information and data for farmers when making decisions about increasing the scope of digitization. Furthermore, the findings provide valuable understanding of the agricultural output in the area and serve as a solid foundation for the Kazakhstani government to establish forthcoming policies.

Keywords: Agro-industrial complex, Business processes, Digitalization, Investment attractiveness, Management solution, Productivity.

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1. Introduction

According to the United Nations (UN) report on the status of digital agriculture in Europe and Central Asia countries, Kazakhstan is among the promising countries with a low level of technology adoption [1]. Furthermore, less technological advancement is predicted to occur in more traditional areas such as agriculture. The Bureau of National Statistics of the Republic of Kazakhstan (BNS) states that the agricultural sector makes up only 5.4% of the Gross Domestic Product (GDP) and employs 13% of the total population as of 2021. The industry focuses on the production of livestock and crops.

Kazakhstan is the world's 13th-largest producer of wheat with 11.8 million tons harvested in 2022 despite its small GDP contribution [2]. However, agriculture data from prior years showed developments but current limitations lower industry efficiency.

These problems are related to outdated technologies in production, insufficient use of resources and new technologies. Furthermore, the unequal level of agricultural growth across areas might be a sign of inefficient resource use. Today Kazakhstan is at the initial stage of digitalizing the public and private sectors along with most developing countries [1].

A comprehensive study of the economic efficiency of digital technologies has not been previously conducted in Kazakhstan or the rest of Central Asia despite a number of studies of digital technologies in agriculture focusing on technical aspects.

This paper investigates six digital technologies and their financial results: health management in beef production, dairy cow movement tracking, drone counting systems, crop parallel driving systems, telematics and soil moisture monitoring.

Meaningful results can be achieved if farmers and the government work together. Government agencies should offer good practices and technology while farmers should implement technology, provide feedback regarding efficiency and file requests for further development.

At the same time, the contingent of the agro-industrial complex is quite conservative on the one hand, protects against some production and financial risks and on the other hand, misses significant opportunities from the introduction of innovations. This paper investigates the economic benefits of digitalization investment in the agricultural sector by private companies, government and international organisations.

It also determines investment indicators for digital farming techniques used in Kazakh small-scale farms. Therefore, the main question addressed in this paper is how much agricultural producers use and how technology would contribute to improvements in agricultural production. This paper aims to introduce the use and economics of digital tools in Kazakh agriculture based on an extensive analysis of the case study of farmers.

In the first part of the paper, an overview of other research and results is presented. The second part presents the methodology and approach used in the research while the third part presents a detailed analysis of the economic effects of the introduction of technology in agricultural production analyzed from several aspects. At the end, concluding considerations are given.

2. Literature Review

Previously, some research has been conducted concerning the introduction of digitalisation in agriculture. The literature and research show the positive effect of digitalization on agricultural production.

Compared to the traditional market, the advantages of digitalization include the following:

- Lack of physical weight of products (replaceable with information volume).
- Significantly lower costs to produce electronic goods.
- The smaller area is occupied by electronic media.
- Decrease in the need for raw materials.
- There is an instant global movement of goods and services through the internet.

Suppose the application of innovation in operations is practicable. In that case, this activity will significantly affect the company in the following ways: improve cooperation performance, optimise productivity levels and provide customers with additional value [3]. The analysis of "Agricultural market digitalization in Kazakhstan" regarding milk production shows that the introduction of digitalization in milk production would improve milk quality, given that the research identified the incomplete plant capacities and the low marketability of milk production [4].

The need to increase the competitiveness of agricultural production can be met through digitization as indicated in other studies. The possibilities of implementing digital technologies in agricultural production were analysed in the research related to the current analysis. Therefore, the research results indicate that digitization's positive effects on attracting investments, increasing the quality of agricultural production, efficiency and competitiveness. The paper proposes strategies for improving production efficiency based on agriculture's digitalization [5].

In some additional studies, authors found a positive relationship between the introduction of digital technologies and productivity and efficiency in agriculture production. The introduction of new technology contributes to the simplification of procedures, the supervision and certification of agricultural products and the growth of productivity [6]. The implementation of production functions in the economic analysis of the processes of companies and individuals in the agricultural industry is demonstrated through scientific research conducted in the twenty-first century.

Data was examined between 2009 and 2019 in 12 prefectures. The study by Kea, et al.'s [7] study used geographical data for twenty-five provinces in Cambodia to develop models whereas previous studies looked only at data from 12 prefectures between 2009 and 2019. Four models were made according to the data for the four years from 2012 to 2015. In earlier scientific investigations, capital and labour costs were considered factors that impacted agricultural production volumes [8-11].

A project method was established in the 20th century for the economic study of a particular sector such as agriculture taking into account a number of variable factors [12].

Digital transformation can also lead to significant expenses related to handling and learning new processes. This has been highlighted by researchers Kohtamäki, et al. [13] and Liu, et al. [14] who emphasize that this transitional phase can be quite difficult. This period can impose a substantial financial burden on a company. When companies lack the necessary experience and effective digital leadership, they might experience difficulties related to the digital divide as noted by Shakina, et al. [15], ultimately impacting their financial performance negatively.

3. Materials and Methods

The research is based on the analysis of the six case studies on the distinct types of agricultural production. The primary source of materials and data for this paper are our own field studies and research on more than 138 small, medium and large peasant farms in various regions of Kazakhstan. These farms were carefully selected to provide a diverse representation of agricultural practices in the country.

However, collected data have the same constraints related to the fact that farmers usually need to systematically assess modern technologies and only sometimes have accurate records of the impact of technology. In each technology calculations investigated in the current paper, custom-made assumptions have been used to measure and quantify the effect of investments in the digitalization of agriculture production. The economic analysis presents only an analysis of return on investment.

Four performance indicators are used: internal rate of return (IRR), net present value (NPV), simple payback period, and discounted payback period. The widespread use of digital tools in agriculture is under development. This limitation is appropriate. In most cases, it is impossible to make a final assessment. A possible underrepresentation of the experiences of certain farms that may have benefited considerably from the technology could result from their decision not to participate in the research. Case studies can only be done with farms willing to share detailed information; there is likely a bias towards more successful and professional farms. Farms that could have benefited from the technology chose not to participate in the study.

The analysis was widely used which made it possible to draw conclusions about the effectiveness of using certain approaches or methods of digitalization in the agricultural sector. In addition, the historical method was used to analyse the digitalization of a given farm in retrospect. The modelling allowed for important calculations to be carried out which made it possible to assess the effectiveness of a particular innovation in the field of digitalization. The calculations themselves namely the aforementioned use of the IRR and NPV methodologies can be classified as statistical methods. Abstraction made it possible to exclude certain components of the impact on the effectiveness of the implementation of a particular method. Forecasting allowed us to make assumptions about how the development of innovative technologies in the agricultural sector in Kazakhstan will affect the economy of the country.

4. Results

4.1. Health Management in Beef Production

Decision-making in a feedlot is complex because it depends on several factors such as animal purchase schedules and prices, animal characteristics (age, weight, breed), feed quality and prices, sales schedules and costs and animal health. The farmer must constantly solve the optimization problem considering the function of all the factors. The digital system allows the acquisition of information for decision-making. The service also provides solutions and management techniques for reaching optimal decisions in constantly changing market conditions.

The case study of the feedlot in the Akmola region which can accommodate 10,000 cattle (the present head load is 7000) serves as the basis for the research. The farmer introduced the technology in early 2020 to improve a farm's overall management and performance. This technology includes equipment for veterinary procedures and scales for weighing and recording the history of individual animals, feeding equipment with sensors for measuring the amount of feed, feed quality analyzer and the implementation of standard procedures and training of farm workers. The system provides real-time information regarding the farm's performance. This information is used for decision-making, accessing and adopting best international practices through a remote health system provider.

Implementation included a feedlot management service that provided precise management of the feedlot, identification of livestock, accounting and monitoring of the efficiency of livestock management, use of optimal feed rations, full veterinary support of the feedlot and standard procedures' introduction for farm workers.

The farmer has invested in the equipment and infrastructure, performed training for employees and introduced new management practices such as herd management, feeding management and animal health management to successfully adopt the technology. The essential equipment is the veterinary station where all the operations with cattle (registration, weighing and vaccination) are conducted. The information is registered in the database and stored in internal services and cloud storage.

Every animal was subjected to a veterinary check-up every three months to monitor daily weight gain and other performance indicators. The system allows tracking of the condition of individual animals and groups of cattle (age, number of days in the feedlot, daily weight gain and veterinary events). The updated information allows management to make decisions based on solid data. One of the primary measures of the economic profitability of a feedlot is the average daily weight gain. This indicator depends on the breed type, feeding, age, number of days in the feedlot and health condition. Herd management allows grouping animals based on the indicators and regulating them accordingly. The farmer improved average daily weight gain by identifying the animals with low daily growth, establishing the reasons for low productivity, and acting. One of the reasons for the low average daily gain rate was the long duration of the fattening period and the diminishing daily weight gain of overweight animals.

Efficient feeding is another crucial factor in the economy of a feedlot. The farmer needs to know the feed spent for each kg of live-weight gain. Investing in a machine that measures the amount of feed provided to animals and implementing standards for regular measurement of the feedstock gives a farmer the ability to track the amount of feed eaten by each group of animals. The feed is analysed and checked for nutrient content using a feed quality analyzer.

The food supplier receives the information about food and uses it to construct food ratios based on all the information that farmers have provided. Regular health checks about animal health, adoption of standard operating procedures for veterinarians in case of a disease and communication with the service provider allow the farmer to avoid losses related to animal health by keeping records of veterinary activity for each animal in the system. The farmer implemented regular operating procedures for diseases. The veterinarian's role is only to register the veterinary case, take a photo and description, upload the information into the system and receive and follow the recommendations from the service provider regarding treatment. The farmers have invested $742101 into infrastructure and equipment and participated in the training (see Table 1).

Table 1.
Investments into the adoption of beef health monitoring.

Investments	Units	Total cost, USD	Economic life, years
Scales	1	73210	10
Feeding scales	2	549080	10
Feed analyzer	1	91510	10
Computer	1	851	10
Training	1	27450	
Total		742101	

According to the data obtained from the feedlot, the service subscription cost is $10 per day per animal which is $36.5 per year per animal. Since there are 7.000 heads, total operational costs per year amount to $255500. If maintenance costs of 5% are added to these costs, the entire operation and maintenance cost amount to $268275. The main technical parameters of the assessed farm are presented in Table 2.

Table 2.
Technical parameters and assumptions.

Parameters and assumptions	Units	Value
Feedlot actual capacity	Head	7.000
Price purchased animals	USD/kg l.w.	2.55
Average weight at purchase	kg/head	220
Cost per day per head	USD day/head	2.55
Sale price per kg of carcass weight	USD kg c.w.	4.36
Carcass yield	%	57
Sale price per kg of live weight	USD / kg l.w.	2.49
Discount rate	%	10

The introduction of a new feedlot management system made it possible to increase the average daily weight gain of animals from 0.69 to 0.76 kg per day due to the improvement in animal feeding rations, the transition to optimal timing of slaughtering animals (identification and slaughter of animals with low daily weight gain) and thereby shortening the period of animal feeding (from 565 days to 490 days). According to the data from the feedlot, the introduction of a remote veterinary service has helped them reduce animal mortality from 3% to 0.5%. Table 3 shows the main parameters of the farm affected by the technology.

Table 3.
Average performance indicators for several farms researched without and with a beef health system.

Parameter	Units	W/O technology	W/ Technology	
			1 year	2nd and following years
Average daily weight gain	Kg/Day	0.69	0.70	0.76
Number of days to finish	Days	565	532	490
Turnover per year	Times	0.64	0.68	0.73
Death rate	%	3	0.5	0.5
Average live weight at sale	Kg/Head	604	592	592
Number of animals purchased per year	Head	4760	4900	5320
Number of animals sold per year	Head	4617	4876	5293

The farmer receives $312208 of incremental net benefit annually starting from the second year of adoption after investing $714650 in adopting the technology. The calculation of the economic performance of adopting the technology demonstrates that the technology has good financial performance. The organisation may recover its investment in 4.3 years with an internal rate of return (IRR) of 28% by using the technology. Table 4 shows the benefits of this process.

Table 4.
Sensitivity analysis for the death rate's influence on the economics of the beef health system.

Economic Indicator	Unit	Death rate w/ Technology		
		0.50%	1%	2%
IRR	%	28	24	13
NPV	USD	1.691	1.222	285
Simple payback period	Years	3.5	4.0	5.6
Discounted payback period	Years	4.3	5.1	8.2

The sensitivity analysis of the impact of the technology`s adoption on the parameter of the death rate of animals in the feedlot illustrates high sensitivity to changes in the parameters. If the death rate drops only by 1% (from 3% without technology to 2% with technology), the IRR decreases from 28% to 13% and the discounted payback period extends from 4.3 to 8.2 years. Nevertheless, the feedlot can still afford to invest in this kind of technology.

4.2. Dairy Cow Movement Tracking for Physiology Monitoring

- The advent of modern technologies enables shorter service periods and improved tracking of a cow's heat (the period between calving and the subsequent successful insemination). It has two significant benefits for the farmer. Milk yield decreases after the birth of the calf and a shorter service period means fewer days with low milk yield.
- A shorter service period means more calves per year per cow.
- Being informed earlier about health issues means less cost for medicine and veterinarians; cow losses can be reduced.

Finally, more precise information on upcoming calving means better treatment of cows and calves which should also lead to lower calf losses. All these effects increase income and reduce costs and losses for the farmer. An assessment of technology effects was based on the data provided by a dairy farm with 800 units (600 milking cows) located in the North Kazakhstan area. The farm implemented the technology in early 2020 and demonstrated improved efficiency as a result of the technology by the end of 2021 (see Table 5).

Table 5.
Milk production performance indicators without and with dairy cow movement tracking.

Parameters	Units	W/O technology	W/ Technology
Average service period	Days	174	148
Annual milk yield per cow	L/Year	5.011	5.240
Milk yield per lactation	l/Lactation	6.095	6.000
Pregnancy period	Days	270	270
The total length of the cycle	Days	444	418
Throughput	Times	0.82	0.87
Total milk sold per year	L/Year	4008982	4192391

The implemented technology allows for more precise timing for dairy cow insemination, identifying cows' health problems and calving timing. These factors are associated with a change in cows' activities; a sensor attached to the leg measures the activity of cows and heifers. It records activities such as walking, standing and resting. Respective data automatically transfers to a computer which processes said data and alerts the farm manager of potential issues with a particular cow. The technology of the farm includes 750 sensors and three receivers that collect information from the sensors and transmit it to a base station. The data is then transferred to a computer with special installed software. The lifespan of sensors is about five years and total investments amounted to $79293.

The high costs are related to sensors (80.5%) while other costs are receivers (14.1%), base stations, computers and network equipment 5.4%. The total projected annual reduction amounted to $12789. The financial prognosis was calculated based on interviews with farmers (see Table 6). Therefore, milk production performance indicators with and without technology have been calculated based on initial investments and calculations.

Table 6.
Economic results dairy cow movement tracking.

Indicator	Unit	Value
IRR	%	36
NPV @10%	USD	111.062
Simple payback period	Years	2.9
Discounted payback period	Years	3.4

The sensors detect when the cow is in heat and provide the veterinarian with the optimal time for artificial insemination. This approach allowed the farmer to increase the insemination efficiency from 40% to 56% which means an increase of 40%. The service period is "the period between the date of calving and the date of successful conception".

The farmer has decreased the service period from 174 to 148 days due to improved fertility and a reduction in subsequent inseminations. According to the data from farmers, the service period for some groups of cows might last up to 213 days when the optimal service period is 120 days. Shortening the service period allows for shortening the total length of a lactation cycle for a cow from 444 days to 418 days. The change in cow's average milk yield increases from 5.011l to 5.240l per year and thus the total annual production increases from 4008982 l to 4192391l or 4.6%.
The farmer improved the death rate of calves at birth from 5% to 3% due to more precise detection of calving timing and better care. Combined with the shorter cycle, this increased the number of calves for sale from 506 to 548 heads per year. As a result, the farmer receives $36236 of incremental net benefit annually starting from the second year of adoption by investing $79293 into adopting the technology. These calculations show that dairy cow movement tracking has good economic performance. Adoption advantages allow the investment to be repaid in 3.4 years with an IRR of 36%.

4.3. Beef Cattle Counting System with a Drone

The analysis is based on data provided by a feedlot with a capacity of 10000 head (7000 current head load) of beef cattle in the Akmola region. The producer introduced this technology related to livestock counting for animal inventory purposes using drone imagery and a livestock counting application. Drone counting was introduced in 2020 to improve the farm's operations, save employees time and enhance animal counting precision. This technology includes one drone and a software subscription. The total investment in this equipment amounted to $1390 of which 92% was related to purchasing drones.

The drone counts animals in a feedlot using drone pictures instead of manual counting. A group of employees used a process whereby the employee moved animals from one cell to another and manually counted them before their introduction. This method led to many mistakes and wasted labour time. The drone and special software have made the task easier and faster. The system calculates the number of animals based on the picture of animals using image recognition technology. The data is based on interviews with farmers. The information can be found in Table 7.

Table 7.
Technical parameters and assumptions.

Parameters and assumptions	Units	Value
Number of bulls per season	Head	7.000
Labour cost	USD/Month/Person	426
Working days per month	Days	22
Number of working hours	Hours	8
Discount rate	%	10

Analysis showed that the introduction of drone counting made it possible to significantly reduce the time of farm workers for monthly livestock counting from forty-eight person hours (6 people 8 hours per month) to four man hours (1 operator). The labour force could be used in other activities or other work. As a result of investing $1390 in adopting this technology, the farmer receives $1168 in incremental net benefit annually (see Table 8).

Table 8.
Economic result beef cattle counting system.

Indicator	Unit	Value
IRR	%	43
NPV@10%	USD	591
Simple payback period	Years	1.19
Discounted payback period	Years	1.34

The calculations show that drone counting has high economic performance. Adoption advantages allow the investment to be repaid in 1.3 years with an IRR of 43%.

4.4. Parallel Driving Systems (PDS) in Crop Production

When driving up and down the field, the proper alignment of the machine is crucial to crop production. Overlapping of operations reduces the machine's productivity which is often a scarce resource during peak times in tillage, fertilization and seeding. Furthermore, overlapping implies a waste of inputs. Therefore, GPS-guided parallel driving systems have been developed. The fundamental characteristic of this technology is that the driver no longer drives the tractor; instead, driving is automated resulting in reduced operation overlap. Consequently, total costs will be reduced including labour costs, run-time related costs of the machines (diesel, lubricants and repairs), seeds and fertilizers.

PDS will not only save wasted seed but will also prevent yield losses caused by high seeding rates on sections with overlaps where individual plants compete for nutrients and water. Too-high seed densities lead to overall weaker plants which in the end yield less than fewer plants. Fertilization remains controversial since fertilization rates in Kazakhstan are sometimes lower than optimal. In that case, the additional nutrients applied on overlaps should at least partially lead to additional output and income.

The farmer equipped his tractor with a Buhler versatile 2375 with a Raivon Cruiser 2 parallel driving system which cost him $2131 and $4.26 monthly as payment for the sim card. Seeding on 12.3 meters of overlap was reduced from 30-40 cm to 20 cm. The overlap reduction is the only effect to consider. However, it assumes that overlapping is the only issue. The opposite strips of untreated acreage will also be avoided or at least reduced. The fertilizer applications are ammonium nitrate (40 kg/ha) $0.26 per kg and Ammophos (40 kg/ha, $0.21 per kg). The annual capacity of the tractor is 2500 hectares per year. The savings per hectare are about 0.24 $/ha. The key figure in this respect is the reduction factor calculated using the reduction in overlap (20 cm per pass) and the number of passes per hectare. These savings do not appear in the case of untreated acreage. However, forgone crop yields will be reduced, thereby generating a benefit from the technology. Table 9 presents a similar calculation for seeding and fertilization completed in one pass.

Table 9.
Economics parallels driving seeding and fertilization

Indicators for tillage	Unit	W/O technology	With technology
Performance	Ha/Shift	100.8	214.2
Implementation capture width	m	6	12.3
Standard consumption of fuels	l/ha	15,15	9.3
Estimated head length	Km	1	1
Reduction factor of aisle length per unit area	%	96.55%	98.35%
Prices			
Fuels	USD/l	0.4	
Labour	USD/h	5.97	
Input reduction per hectare			
Fuels and lubricants	l/ha	0.52	0.15
Labour	h/ha	0.0068	0.0015
Monetary savings			
Fuels	USD /ha	0.2	0.061
Labour	USD /ha	0.04	0.55
Ammonium nitrate	USD /ha	0	0.17
Ammophos	USD /ha	0	0.14
Total	USD /ha	0.24	0.93

When comparing the outcomes from these two applications of the parallel driving systems, it becomes evident that the savings in seeding and fertilization are higher (about four times) than in tillage. Furthermore, comparing the figures for the subsidy results shows that the savings are almost double when subsidies are excluded. The savings per equipment and farm as well as total profitability are important. Table 10 shows the relevant figures. .

Table 10.
Profitability and parallel driving at the whole farm level.

Indicator	Unit	Value
Annual savings on one set of equipment	USD/Year	3134
Annual communication costs	USD/Year	25.6
Investment in parallel driving equipment	USD/Unit	2131
Simple payback period	Years	1.19
Discount rate	%	10%

In cases where the assumed efficiency gains are not realized, there are two scenarios.

First one: no overlap but untreated acreage and additional fertilizer application are not avoided waste but are generating a yield increase. The following consideration may shed some light: If the overlap is not an issue in 50% of the cases, the initial savings would be reduced and the IRR would be 244%.

The second scenario can only be calculated partially due to the lack of figures on yields and prices. The authors will ignore the potential yield increase and not consider fertilizer savings. When doing this, the overall profitability is still 174%. In the other scenario, the IRR still cannot be calculated. These considerations indicate that the system's overall profitability is still extremely high even when key performance parameters are much lower than assumed here.

4.5. GPS-Based Remote Control of Ag Machinery Movements (Telematics)

The key idea of telematics is to enable agricultural managers particularly in large-scale crop production to closely monitor the movement of machinery. In Kazakhstan, the critical value stems from the fact that this technology enables farm management to prevent tractor drivers from conducting field operations on their fields or third-party fields for which the farm does not get paid. In other words, it reduces the likelihood of theft from inputs, fuels, machinery services and related working hours of the tractor drivers. The risk is often significant due to the large number of tractor drivers that operate on Kazakhstan's large fields and the vast areas they cover.

However, the economic assessment of the telematics technology is more complex because only actual farm values for diesel consumption have been made available. Furthermore, data on the average labour productivity of tractor drivers was ere limited. Therefore, the subsequent economic calculation must be treated with great care. The authors would not recommend using the results as the basis for immediate policy recommendations. Instead, authors suggest looking for more detailed data before concluding.

The case study farm had previously been using telematics in their crops when they extended its use to other equipment in 2018. Non-combining operations would profit from the system's use. The following is a summary of the economic analysis's findings, taking these warnings into account: 1. The initial investment cost is roughly $5414 considering a depreciation period of 5 years. The annual cost is $1083 and the annual fees add up to about $3032 hence total yearly cost is about $4115. The savings from preventing diesel theft add up to $21659. The simple pay-back period is only three months. Even if the savings have been overestimated by 100%, it is evident that the investment is exceedingly profitable.

2. This attractive economic result becomes even more striking when considering the value of work time that can be saved. The basic assumption: If tractor drivers do private business with machines, they not only consume diesel but they also use their work time which is at least in theory could be used elsewhere on the farm and generate an economic return (see Table 11) .The calculation assumes that the average diesel consumption of the tractors is 20 l/ha, and the average productivity is 4 ha/. This means about 5 l/h. When dividing the total diesel savings of approximately 86000 l by 5 l/h, about 17000 h of work time has consumed the diesel savings. When multiplying this work time by an hourly rate of 6 USD/h, authors calculate an additional economic benefit of about $103961. When all of the potential financial benefits of telematics are included, its profitability will increase.

Table 11.
Economics of telematics: Related to savings in diesel.

Item	Unit	Value
Cost per set of GPS trackers	USD	72.5
Depreciation period	Years	5
Number of equipment with trackers	Units	72
The subscription fee for servicing one GPS trackers	USD/Month	4.26
The average duration of trackers' operations per year	Month	10
Diesel consumption per farm	Litres	2017:1105000 2018:1085000
Gross harvest	Tons	201: 27000 2018: 35000
Diesel consumption for harvesting, transport and other	Litres	2017: 951000 2018: 894000
Diesel costs	USD/Litre	0.26
Saving diesel	USD	22.033
Equipment investments	USD	5.218
Annual investment costs	USD	1.044
Cost fees	USD	3.069
Total annual cost	USD	4.113
Simple payback period	Years	0.24

Table 11 calculated the IRR to be more than 400%. Implementing GPS-based remote control of agrimotors machinery movements (telematics) is highly profitable even without counting savings in work time. This amount is difficult to calculate due to human factors. Considering working hours with embezzled diesel as 17299 for 72 agrimotors, diesel consumption as 5 per hour shows approximate calculation shows the economic value of savings in working hours of $103000.

4.6. Steering Irrigation by Digital Soil Moisture Monitoring (DSMM)

The database for this technological evaluation, including the one for the telematics system might be focused on the larger dataset. The authors have one-year statistics and a farmer remark on the yield improvement. As a result, the outcomes in this case should be viewed with great caution. The key idea of DSMM is to adjust irrigation more closely to the actual plant needs by informing the grower about the water content in the soil, which is available to the plants. A specific threshold for this moisture content in the soil defines the irrigation intervals.

Usually, irrigation must find the right balance between oversupply and undersupply of water. The former means water waste and unproductive energy use and, in some cases, damages to the §crop, the latter means crop losses. Given relatively low energy prices and unlimited water availability on the case study farm, the most crucial risk is undersupply of water. According to the farmer interviews, more precise irrigation could increase the yields by about 16%. All the remaining information on the economics of DSMM is available in Table 12.

Table 12.
Economics irrigation steering by digital soil moisture monitoring

Indicator	Unit	Value
Usage area	ha	300
Standard potato yield without technology	t/ha	33
Potato yield with technology	t/ha	35
Yield increase	%	5%
Additional output	t	495
Price potatoes	USD/kg	0.24
Value additional output	USD	116.588
Humidity sensor investment	USD	21412

For this calculation, it becomes evident that the technology is fairly profitable and the simple payback period is a couple of months (0.18 years) provided all the figures are reliable and be replicated in years to come. However, there are a few cautions to consider: (i) The DSMM is applied to a high-value crop. With other Broadacres crops, the profitability will be much lower. (ii) Potatoes cannot be grown annually, so the question remains whether the moisture measurement can be moved easily from field to field. If not, growers would need to invest in several units (which would still be quite economical given the brief payback period).

Understanding the potential impact of technologies on the competitiveness of different farming systems is of immense importance. For example, if a specific technology generates economic benefits only for a specific size class, promoting that technology might create or support a shift in farm structures that might not be desirable. Of course, in Kazakh agriculture, the relative position of family farms vs agricultural holdings and smallholders' competitiveness is crucial.

Theoretically, there are at least three potential reasons to assume that digital soil moisture monitoring implicitly favour a specific farm size and structure:

1. Digital soil moisture monitoring is associated with a certain implement (e.g., a sprayer) commonly used on large areas. Buying such a machine for a small farm would massively under-utilize the device, implying a disproportionally high fixed cost per hectare. The respective technology can be considered non-natural regarding farm structure as it is associated with economies of scale. However, this limitation can be overcome by contractor services. The case of general contractor services in Asia for harvesting is proof of this consideration. However, creating such a contractor industry is time-consuming and requires an "enabling" economic and political environment (e.g., access to capital, the rule of law, and entrepreneurial spirit). Therefore, whether contractor services might be an option to make structurally non-natural digital innovations available to smaller farms remains to be seen. Steering irrigation technology requires specific and advanced knowledge and expertise. The acquisition of such knowledge can be costly because workers must be set free from other tasks to participate in training and conduct their trials. Such an investment can be considered a fixed cost which leads to a situation like the previous one: For smaller farms, this investment can be too high relative to the economic benefit it offers.

2. A social and economic environment that creates unequal conditions for accessing credit for the necessary investment in new technologies can also create a structural bias. In the case of Kazakhstan, this condition applies given the solid political and social standing of agro holdings versus smallholders who often need better interactions with banks (or even the knowledge to deal with banks) as well as the necessary collateral to secure credit.

5. Discussion

The positive impact of the digitalization of the economy on the country's development is described by Zhang, et al. [16]. The study assessed the economic development of the belt and road countries from 2009 to 2018 and made 2 main conclusions: first, there are regional imbalances in the digital economy in East, Southeast and Central Asia; Eastern Europe has a higher level of digital economy compared to Asia. Furthermore, the paper shows that the digital economy has a positive impact on economic growth, contributing to the modernization of industrial structures, employment restructuring and employment in general. All this advocates that digitalization should remain an important component of the policies of countries, including Asia. In addition, this can also serve as evidence that digitalization has a positive impact on the development of the agricultural sector in most countries. The role of digitalization in the country's innovative development was studied by Narmanov [17]. The study shows that in the near future, the level of digitalization will determine the competitiveness of not only businesses but also entire countries. This indicates the role of successful adaptation of such new technologies within the framework of states and ensuring their effective use. In turn, Gomes, et al. [18] studied the impact of digitalization on the development of OECD countries. The results of this study showed a positive impact of Internet use on GDP per capita in all OECD countries. Policymakers are encouraged to take steps to reduce the digital divide and increase the adoption of digital technologies by households, businesses, and governments. First and foremost, it is necessary to provide easy access to the infrastructure of such technologies, make these technologies cheaper (if necessary) and spread the narrative among society about the importance of switching to such technologies. In addition, the government could consider investing in the sector as well as cooperating with academic institutions.

The impact of agricultural digitalisation on productivity based on data from China was studied by Zhou, et al. [19]. The results of the study showed that the growth of digital agriculture was positive during the study period but there was still room for improvement in agricultural productivity. Thus, the study has come to the unusual conclusion that the link between the development of digitalisation in this sector may have a negative impact on productivity. In this regard, they provide advice to promote the sustainable development of the industrialisation of digital agriculture. The paper proposes to establish a comprehensive organizational system involving the government, industry organizations leading enterprises, cooperatives, grassroots party organisations and farmers. The government should take the lead in promoting digital agriculture, establishing leading enterprises and developing local cooperatives. Industry organisations should serve as a link and bridge between the government and farmers and it should be noted that this structure can be implemented in China in the context of the socialist system of the state while it will be virtually impossible to apply it to capitalist systems. In addition, it is recommended to improve the quality of services provided to companies in the agricultural sector and to develop mechanisms for providing financial assistance. The results obtained by the researchers are quite different from those obtained in the paper above based on data from Kazakhstan, it was shown that digitalisation has a positive effect (IRR 28% to 400%) on farm productivity. Therefore, this issue should be considered in more detail. It would be relevant to conduct a detailed analysis of the methods used by scientists to reach such conclusions.

The peculiarities of digital transformation in agriculture were also studied by Birner, et al. [20]. The authors note that digitalization in this area has the potential to revolutionise the industry, increase its efficiency, productivity and sustainability. At the same time, they also highlight some concerns (which are inherently complex and expensive) may lead to the increased market power of certain representatives of large agribusinesses. Scientists also draw attention to the peculiarities of the process in developing countries which have less opportunity to develop such technologies due to their high cost. They believe that the state and the public should try to create a more favourable environment within their framework and form a basis for financing this process. Such efforts would not only secure the industry's development but also avoid market consolidation. Thus, a combination of private sector efforts and government policy should become the basis for transforming the agricultural sector into a driving force for digital transformation in the sector which will benefit farmers, workers, consumers and the environment. It should be noted that the paper does not provide direct and clear guidance on how these processes should take place. However, it provides a clearer understanding of the role and characteristics of digital transformation in agriculture.

Financial and computational techniques concepts of manufacturing operations are the parameters that quantify a favourable long-term connection between variables describing capital and labour expenditure and a marker representing the number of crop yields [4, 21]. Most research papers require years' of information into consideration. For example, the Cobb-Douglas production function was used in the research by Ghoshal and Goswami [22] to evaluate the productivity of plantations in the Indian farming sector. This function was built using data that covered the years 2005 to 2014. The essay discussed modelling agricultural productivity in China [23].

Thus, six technologies that can be implemented on farms have been described above. All of them have different effects on the activities of such enterprises but they definitely increase the efficiency of their functioning, reduce costs, increase productivity and have a positive impact on their financial component. This means that both individual enterprises and Kazakhstan as a whole would benefit from such an introduction. Thus, the country's government should promote the use of digital technologies in agricultural enterprises. This can be done in a number of different ways such as by developing infrastructure and expanding access to the internet, providing financial support to such companies for the purchase and implementation of digital technologies, providing training and professional development, etc. Such actions will accelerate innovation processes in the country and allow it to reach the required level of technological development in a shorter period of time.

6. Conclusion

The case studies analysed show relatively high economic performance from the technologies. The internal rate of return in one case is lower than 13% and in another case, it is more than 400%. These significant differences are due to the small number of analysed cases but also to differences in the type of agricultural production.

One crucial common dominator of the technologies analysed is the reduction of losses through better monitoring of agricultural production processes. This feature is remarkable because when considering existing site-specific crop input application data from research outside of Kazakhstan, productivity gains (i.e., growth in output) are the primary source of improved economics.

The hypothesis is that the parallel driving system in crop production is scale-neutral due to the lack of empirical evidence. The same applies to movement tracking in dairy. The financial investment is not significant and the advantages may be obtained regardless of the size of the enterprise as long as at least one tractor operates at capacity. The necessary acquisition of knowledge that can be a limiting factor for smaller farms remains to be seen.

The potential problem caused by the before or after analysis cannot be quantified. However, it is expected to be severe in the livestock-related business considering the technology. One of the critical factors for daily weight gain in beef is the quality and availability of the roughage. Any changes in the features occurring parallel to the comparison or without situation may heavily impact the outcome. The problem needs clarification as to whether feed quality and availability improve or worsen weather conditions and management style. An analogous situation can be assumed for dairy livestock. Gestation is a complex process heavily impacted by cow treatment and feed quality.

Although the paper presents very useful information and results, there are certain limitations. Since the available data only stems from solitary case studies, the assessment of the potential structural implications of new technologies cannot be based on empirical evidence. It was presented with some theoretical considerations to assess the structural implications. The subsequent analysis can only be indicative and preliminary.

Despite these limitations, the technologies analysed in this paper seem beneficial and profitable to Kazakh growers. It is reasonable to invest more in analyzing and searching for the benefits they offer and in promoting them. Based on international literature, it must be assumed that these technologies even though they are complex and knowledge-intensive provide substantial benefits in terms of savings on inputs and increasing outputs. It highlights that subsidies can heavily impact the economics of digital tools. Due to high subsidy rates for fertilizers and seeds, the value of input savings that can be achieved with this system is higher for the Kazakh economy than for the growers. This issue should be addressed in subsequent studies because it is necessary to further analyse these categories in order to have quality planning in the field of agriculture.

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