IRSTI 68.29.01

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The application of remote sensing methods for monitoring agricultural lands in Akermen village, Zhambyl region of the Republic of Kazakhstan

Abstract. *The research purpose is to prove that the application of the remote sensing techniques is going to improve the crop yield quality. The research methodology is based on econometric and statistical analysis techniques. The research value is based on the fact that the remote sensing techniques may help to improve the food security which has strategic importance both on the national and global scales. The research findings demonstrate that at 5% significance level applying the remote sensing at all stages of the crop cultivation is significantly better than not applying the remote sensing at all. Moreover, applying the remote sensing under the supervision of the data analysts at all stages of the crop cultivation provides higher crop yield quality score than not using the remote sensing components at 95% confidence interval. Finally, the research results demonstrate that training staff plays crucial role for maintaining the efficiency of the crop yield output.*

Keywords: *remote sensing, agricultural lands, crop yield quality, Kazakhstan, agricultural output, Z-test, t-test, rejection region analysis, sample standard deviation.*

DOI: https://doi.org/10.32523/2789-4320-2022-4-123-133

Introduction

The research aim is to prove that the application of the remote sensing techniques is going to improve the crop yield quality. This research is unique because the case study is chosen to be Akermen village of Merki district in Zhambyl region. The research has significance as the food security plays the strategic importance not only on the national but in the global scale as well. The research objective is to apply the methods of analysis to prove that using remote sensing techniques is significantly better than not applying those techniques.

The most suitable philosophical stance for the research seems to be positivism because it allows to measure without which this research is impossible. Positivism is a position of epistemological philosophy [1].

It is worth mentioning that positivism consists of the following four different principles [2]:

- objectivism: scientific research should be free from any subjective assumptions and beliefs;
- phenomenalism: knowledge should be acknowledgeable by human senses;
- inductivism: new knowledge comes after gathering factual information;
- reductivism testable hypotheses can be created from a theory. The deductive approach may help us to taste various hypothesis. Each hypothesis test consists of the null and alternative hypothesis. Accepting or rejecting the null

hypothesis at the certain statistical significance level may help to make assumptions [3]:

- that are supported by statistical evidence;
- has reliability with the specific significance level.

On the other hand, using positivism may not be appealing for cases when applying scientific methods on researching the certain aspects of reality is complex and has limited number of techniques [4]. Therefore, positivism may not guarantee to describe how consumers feel about what some events mean to them [5]. For example, it is not always possible:

- to measure inter-relations;
- to take into account that some factor mutually impacts each other;
- to organise observations.
- to clearly define hypothesis.

Positivism can be linked with quantitative methods of research which allow to gather measurable data. Using the sample population in order to make assumptions related to the entire population is one of the commonly used methods in qualitative analysis [6, 7]. The online platform was used to interview employees in Akermen village of Merki district in Zhambyl region .

The choice for platform on the world web was given to Bristol Online Survey (BOS) tool due to the following reasons:

- allows interviewees answer survey questions any time convenient for them as long as they have access to internet;
- easy to use and navigate, as well as does not require knowledge of specific programming languages which makes the process of creating surveys more convenient;
- includes basic statistical analysis package which can calculate basic statistic indicators related to any question of a survey, such as median and mean;
- gives access 24-hour access to the current survey results.

Methodology

The remote sensing provides tools and techniques that can be used to obtain a wide variety of biophysical datasets that are useful for modelling agricultural land and water use [8].

The land cover data is available in image and vector formats, with individual vegetation types assigned to discrete classes. For example, each vegetation type in the image format is assigned the unique numeric value and in the vector format each polygon is going to have the specific information that describes the type of land cover in that polygon. This data is available with the wide range of thematic (classification scheme) and spatial (spatial resolution and degree) qualities [9].

The specific classification scheme is used for the specific land cover dataset which can be as simple as forest and non-forest classes or detailed as the species level map [10]. The significant point of thematic granularity is that the more classes are used, the lower the accuracy of each class is going to be. In other words, the classes in the forest and no-forest map are going to be more accurate than the individual classes in the species-level map.

The spatial detail in the land cover dataset is usually the direct result of the type of remote sensing data on which the classification is based. For instance, when using lidar for high-resolution aerial photography the individual tree crowns are going to be seen which improves the ability to display species level information [11].

It is sometimes desirable to quantify various aspects of the patterns in the landscape using a variety of landscape metrics for use in the agricultural models once the land cover map is created [12]. These metrics provide the objective way to describe patterns that are described using subjective terms such as "highly fragmented," "small patches," and "heterogeneous terrain".

These metrics are easy to create by using software tools. There are two general indicators that can be used for sounding land for agricultural purposes: landscape composition and spatial configuration [13, 14].

Landscape composition may include:

- the proportional area of one type of coverage compared to the total area;
- diversity - the number of different types of patches of the landscape;
- the uniformity of the relative abundance of various types of patches of the landscape;

- diversity is a composite measure of the richness and uniformity of patches of the landscape.

The spatial configuration may include:

- the size and shape of the patches of the landscape;
- the ability to connect scraps of the landscape;
- scattered or folded scraps of landscape;
- setting relative to adjacent patches of the landscape.

It could be worth noting that care should be taken when using these metrics while landscape metrics could be important. Many of the metrics are very sensitive to the scale of the image and the scale of the area of interest, therefore, the comparison of time and space must be done with caution.

It is also worth noting that there are several characteristics of vegetation other than vegetation cover that can be measured using passive and active remote sensing: phenology; primary productivity; plant growth and health; vegetation structure [15].

The measurements of these type of characteristics are based on the fact that the reflection, transmission and energy dissipation in the dome are highly dependent on the structure of the vegetation and how the components of the vegetation (leaves, branches, trunks) interact with the energy spectrum used by a particular remote sensing instrument.

Land cover maps are usually created using the data from optical sensors and by combining radar and optical data. One area where radar sensors excel is when mapping wetlands and water under forests, such as in flooded forests or spring pools. Analysis of these types of localities can provide recommendations on the types of preparatory work required to convert these lands into agricultural areas.

Datasets can be created using manual or automated methods. The basic principle of the land cover classification is to translate pixel values into an image and then into meaningful land cover categories [15].

This is often done using automated procedures in which a computer algorithm is used to assign individual pixels or groups of pixels to one of the valid land cover categories.

The classification process can also be performed using the visual interpretation techniques, where the interpreter uses visual imagery such as tone, texture, shape, pattern and relationship to other objects to identify and group similar types of vegetation.

In general, the human brain is better at interpreting spatial characteristics in images, and automated algorithms are better suited for processing spectral (multiple bands of images) information.

There are dozens of classification methods in use, but there is no one perfect method for all types of needs. One of the limitations of classified land cover data is that the information is discrete rather than continuous. One workaround around this problem is to create a "solid field" dataset for selected vegetation species. In the continuous field dataset, each pixel value represents the percentage of that pixel covered by a particular type of land cover.

The datasets were created through using of drones for the remote sensing. The efficiency of the remote sensing techniques were proven by the case study of Akermen village of Merki district in Zhambyl oblast of the Republic of Kazakhstan.

Discussion

Akermen village of Merki district in Zhambyl region of the Republic of Kazakhstan mainly specialises in agricultural production. This village was facing the agricultural output issues because the crop yield in Akermen village was not competitive at the Republican level.

There were different cultivation technologies and scientific methods considered in order to increase the crop yield in this village. As a result, the remote sensing technology was tested in Akermen village because this technology did not put high constraints and pressure both in terms of the human resources and finances.

The grain was chosen as the test object due to its high demand in the global commodity market.

2000 hectares of agricultural lands in and around Akermen village were chosen in 2019

Table 1

Analysing groups NR and NS crop yield values for field A

Statistical factors	Group NR (remote sensing was never used)	Group RS (remote sensing was used at all stages of the crop cultivation)
n	3432	7575
Sample standard deviation	10.86	9.27
Sample mean	82.59	86.13

Note – calculations are made by the author

to specialise in grain production. These 2000 hectares after the initial screening through the application of the remote sensing were further divided into 4 smaller equally sized fields: A, B, C and D. Each field was further subdivided into 11007 plots of the land.

In field A it was tested whether applying the remote sensing at all stages of the crop cultivation could be significantly different to not relying on the remote sensing at all. As a result, as shown by the table below the remote sensing was used at all stages of the crop cultivation in field A on its 7575 smaller plots of the land.

The following hypothesis test A could be formulated based on the data given by table above:

$$H_0: \bar{X}_{group\ NC} - \bar{X}_{group\ C} = 0 \quad (1)$$

$$H_1: \bar{X}_{group\ NC} - \bar{X}_{group\ C} \neq 0 \quad (2)$$

The samples are the same at 95% confidence interval when we cannot reject the null hypothesis (H_0). However, the samples are considered different at 5% significance level when we can reject the null hypothesis (H_1).

The Z-test is chosen to test the hypothesis because the sample size for groups NR and RS is bigger than 30. In addition, the alternative hypothesis (H_1) contains "≠0" and not "> or <". As a result, Z-test is going to be two-tailed.

Two tailed Z-test:

$$Z = \frac{(\bar{X}_{group\ NR} - \bar{X}_{group\ RS}) - (\mu_{group\ NR} - \mu_{group\ RS})}{\sqrt{\frac{s^2_{group\ NR}}{n_{group\ NR}} + \frac{s^2_{group\ RS}}{n_{group\ RS}}}} \quad (3)$$

$$Z = \frac{(86.13 - 82.59) - 0}{\sqrt{\frac{9.27^2}{7575} + \frac{10.86^2}{3432}}} \quad (4)$$

$$Z \approx 16.56 \quad (5)$$

We could assume the following because the mean of the crop yield for groups NR and RS was the same:

$$\mu_{group\ NR} - \mu_{group\ RS} = 0 \quad (6)$$

Z-test is two-tailed, the significance level *(a)* is 0.05. As a result, there are two critical values: $-Z_{0.025} = -1.96$ and $Z_{0.025} = 1.96$. Therefore, the rejection region analysis would look the following way:

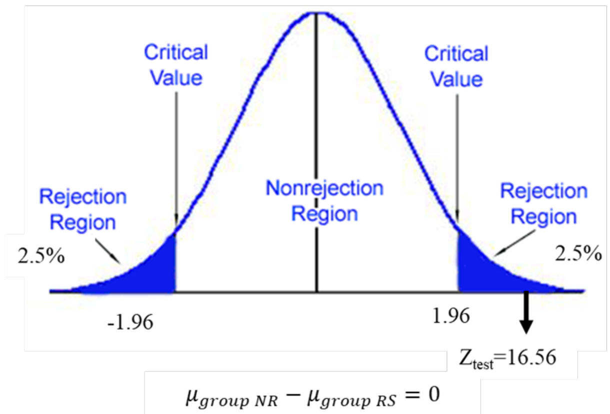

Figure 1 – The rejection region analysis for the hypothesis test A

Note – based on the calculations made by the author.

According to figure 1 Z-test value (16.56) lies within the rejection region. As a result, we can reject the null hypothesis (H_0) in favour of the alternative hypothesis (H_1) at 5% significance level.

Table 2

Analysing groups A and B for field B

	N	Sample mean	Sample standard deviation
Group A (remote sensing was used at all stages of the crop cultivation + data analyst team)	4083	88.91	7.58
Group B (no remote sensing)	6924	82.73	10.43

Note – calculations are made by the author

It also means that the difference between applying the remote sensing at all stages of the crop cultivation and never using the remote sensing is present in the crop quality score at 95% confidence interval. Therefore, at 5% significance level applying the remote sensing at all stages of the crop cultivation is significantly better than not applying the remote sensing at all.

On the other hand, it is not clear at this moment whether data analysis may enhance effects of the remote sensing on the crop yield. Therefore, as shown by the figure below in field B the entire team of data analysts were hired to supervise the remote sensing on 4083 smaller plots of the land.

The table above demonstrates that the sample mean for the crop yield for field B (82.73) without any remote sensing is quite close (around 0,17% difference) to the same value for field A (82.59).

Table 2 demonstrates that hiring data analysts to supervise the remote sensing for field B increased the sample mean for the crop yield by 3,2% compared with the same value for field A (where the remote sensing was not supervised by the data analysts).

The data defined by the table above could help us to formulate the hypothesis test B:

$$H_0: \bar{X}_{group\ A} - \bar{X}_{group\ B} = 0 \qquad (7)$$

$$H_1: \bar{X}_{group\ A} - \bar{X}_{group\ B} > 0 \qquad (8)$$

The samples are the same at 95% confidence interval when we cannot reject the null hypothesis (H_0). However, the samples are considered different at 5% significance level when we can reject the null hypothesis (H_1).

The Z-test is chosen to test the hypothesis because the sample size for groups A and B is bigger than 30. In addition, the alternative hypothesis (H_1) contains "<" and not "≠". As a result, Z-test is going to be upper-tailed (one-tailed).

Upper-tailed Z-test:

$$Z = \frac{(\bar{X}_{group\ A} - \bar{X}_{group\ B}) - (\mu_{group\ A} - \mu_{group\ B})}{\sqrt{\frac{s^2{}_{group\ A}}{n_{group\ A}} + \frac{s^2{}_{group\ B}}{n_{group\ B}}}} \qquad (9)$$

$$Z = \frac{(88.91 - 82.73) - 0}{\sqrt{\frac{7.58^2}{4083} + \frac{10.43^2}{6924}}} \qquad (10)$$

$$Z \approx 35.81 \qquad (11)$$

We could assume the following because the mean of the crop yield for groups B and A was the same:

$$\mu_{group\ A} - \mu_{group\ B} = 0 \qquad (12)$$

Z-test is one-tailed (upper-tailed), the significance level *(a)* is 0.05. As a result, there is one critical value: $Z_{0.05} = 1.645$. Therefore, the rejection region analysis would look the following way:

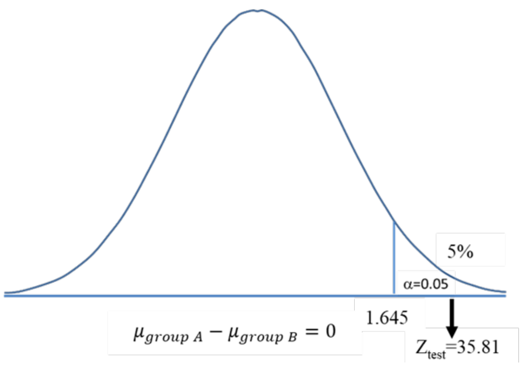

Figure 2 – The rejection region analysis for the hypothesis test B

Note – based on the calculations made by the author

According to figure 2 Z-test value (35.81) lies within the rejection region. As a result, we can reject the null hypothesis (H_0) in favour of the alternative hypothesis (H_1) at 5% significance level.

It also means that applying the remote sensing under the supervision of the data analysts at all stages of the crop cultivation provides higher crop yield quality score than not using the remote sensing components at 95% confidence interval.

On the other hand, it is not clear yet whether training staff may boost the crop yield value even further. Therefore, field C was chosen for the next experiment with the remote sensing techniques.

It is worth noting that field C consists of the eroded and degraded lands. Moreover, field C has the lowest soil fertility among other fields considered in this research.

On the other hand, fields A, B and D have similar soil fertility level and located adjacent from each other. However, field C is located on the outskirts of Akermen village (in Merki district of Zhambyl region) away from other fields. The table below gives more information about field C.

The table above demonstrates that the sample mean for the crop yield for field C without remote sensing for field C (79.01) is noticeably less than the same value for field A (82.59) and field B (82.73).

The main reason for that is the qualitative difference of the soil fertility for field C compared to other fields due to the plots of land being significantly eroded and degraded.

The crop yield value for the remote sensing at all stages of the crop cultivation under the supervision of the data analyst team for field C (89.48) with the staff training being higher than the same value for field B without staff training (88.91). Therefore, staff training could become the necessary step for the application of the remote sensing techniques.

The table above demonstrates that for group RS the staff training was provided before the start of the agricultural season and mini training seminars were held throughout the crop cultivation period.

On the other hand, no extra training at all was provided for group NR. In order to test the efficiency of combining the staff training and the remote sensing the hypothesis test C is formulated:

$$H_0: \bar{X}_{group\ RS} - \bar{X}_{group\ NR} = 0 \qquad (13)$$

$$H_1: \bar{X}_{group\ RS} - \bar{X}_{group\ NR} > 0 \qquad (14)$$

The samples are the same at 95% confidence interval when we cannot reject the null hypothesis (H_0). However, the samples are considered different at 5% significance level when we can reject the null hypothesis (H_1).

The Z-test is chosen to test the hypothesis because the sample size for groups A and B is bigger than 30. In addition, the alternative hypothesis (H_1) contains "<" and not "≠". As a result, Z-test is going to be upper-tailed (one-tailed).

Upper-tailed Z-test:

$$Z = \frac{(\bar{X}_{group\ RS} - \bar{X}_{group\ NR}) - (\mu_{group\ RS} - \mu_{group\ NR})}{\sqrt{\frac{s^2{}_{group\ RS}}{n_{group\ RS}} + \frac{s^2{}_{group\ NR}}{n_{group\ NR}}}} \qquad (15)$$

Table 3

Analysing groups RS and NR

	N	Sample standard deviation	Sample mean
Group RS (remote sensing at all stages of the crop cultivation under the supervision of the data analyst team + staff training)	6321	5.29	89.48
Group NR (no remote sensing + no staff training)	4686	11.44	79.01

Note – calculations are made by the author

$$Z = \frac{(89.48-79.01)-0}{\sqrt{\frac{5.29^2}{6321}+\frac{11.44^2}{4686}}} \quad (16)$$

$$Z \approx 58.206 \quad (17)$$

We could assume the following because the mean of the crop yield for groups RS and NR was the same:

$$\mu_{group\ RS} - \mu_{group\ NR} = 0 \quad (18)$$

Z-test is one-tailed (upper-tailed), the significance level *(a)* is 0.05. As a result, there is one critical value: $Z_{0.05}$ = 1.645. Therefore, the rejection region analysis would look the following way:

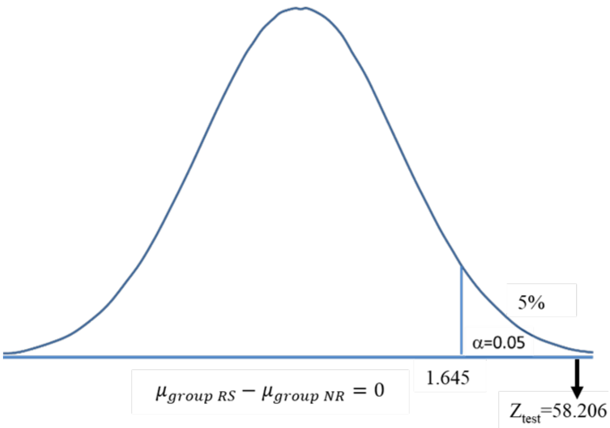

Figure 3 – The rejection region analysis for the hypothesis test A3

Note – based on the calculations made by the author

According to figure 3 Z-test value (58.206) lies within the rejection region. As a result, we can reject the null hypothesis (H_0) in favour of the alternative hypothesis (H_1) at 5% significance level.

We can sum up the analysis to state that the staff training for the remote sensing at all stages of the crop cultivation under the supervision of the data analyst team provides higher crop yield at 95% confidence interval compared to the absence of the remote sensing combined with not providing extra training to the employees in Akermen village.

In order to check whether the training improves the output of the individual worker sixteen employees were chosen for the next test. These employees were involved in using the remote sensing techniques in Akermen village of Merki district last agricultural year.

This year employees in Akermen village had received training before the start of the agricultural year.

Therefore, the following hypothesis test D was formulated:

$$H_0: \mu_{Quality\ Score\ Before\ Training} = \mu_{Quality\ Score\ After\ Training} \quad (19)$$

$$H_1: \mu_{Quality\ Score\ Before\ Training} \neq \mu_{Quality\ Score\ After\ Training} \quad (20)$$

The hypothesis test portrays a null hypothesis:

1. H_0 states that the crop yield means are equal and thus cannot reject the null hypothesis.

2. H_1 states that the crop yield means are not equal and thereby rejects the null hypothesis. If the test rejects the null hypothesis, this shows that there is a significant difference between the quality scores of the two groups.

Therefore, in order to calculate the statistic of a paired t-test, we need the sample mean of the differences $\bar{X}_{diff}$, the sample standard deviation of the differences s and the sample size n. As a result, we then use the following formula to calculate the value of t:

$$t = \frac{\bar{X}_{diff}}{\left(\frac{s_{diff}}{\sqrt{n}}\right)} \quad (21)$$

As a result, we calculated the standard deviation of the differences by using the excel formula =STDEV.S(), giving us the, to the third decimal rounded, number 5.298.

The mean of the differences was calculated by adding all the differences together and dividing by n (number of employees, which is 16), which gave us the value -5.154. As a result, by having calculated these variables, we can use these to calculate the test statistic:

$$t = \frac{-5.154}{\left(\frac{5.298}{\sqrt{16}}\right)} \quad (22)$$

$$t \approx -3{,}89 \quad (23)$$

Having our test statistic, we now need to find the critical value to compare to t. use a two-tailed t-test with a significance level (a) of 0.05 and a n-1 degrees of freedom. Now we can use the t-distribution table to find the critical value corresponding to these variables.

It is worth noting that the critical value is 2.131. As t (-3,89) is less than our critical value we can reject the null hypothesis, proving that there is a significant difference between the crop quality scores before and after training.

Results

The hypothesis tests A, B and C proved that the remote sensing could provide significantly higher crop yield at 95% confidence interval. However, the most interesting discovery was the perception of the remote sensing among employees.

The majority of staff who were involved with the application of the remote sensing techniques had higher expectations and more complaints about the crop yield quality.

As a result, the test of independence whether the application of the remote sensing differs from not relying on it may be formulated based on the chi-square test analysis. Therefore, hypothesis test E:

H0: no difference between applying the remote sensing and using it in terms of the received employee complaints about the crop yield quality.

H1: difference between applying the remote sensing and using it in terms of the received employee complaints about the crop yield quality.

The chi-square test of independence analysis is shown by the figure below.

The figure above demonstrates that the chi-squared value is 240.62. There are 3 degrees of freedom because:

$$(\text{rows-1})\times(\text{columns-1})=(4-1)\times(2-1)=3 \qquad (24)$$

Therefore, the critical chi-squared value is 7.81.

Let's consider 95% confidence interval. The value for chi square test probability (0.00000) is less than the significance level (0.05). As a result, we reject at 95% confidence interval the null hypothesis. Moreover, the perception of using the remote sensing among employees creates different staff complaints about crop yield quality at 5% significance level. Therefore, more research is needed to understand the perception of the remote sensing techniques among employees of the agricultural sector in the Republic of Kazakhstan.

Observed				**Chi squared**		
	Remote sensing	No remote sensing	Row totals		Remote sensing	No remote sensing
No complaints	1304	6271	7575	No complaints	6.83	1.55
Minor complaints	585	1441	2026	Minor complaints	117.69	26.73
Significant complaints	135	799	934	Significant complaints	8.29	1.88
Serious compalints	13	459	472	Serious compalints	63.28	14.37
Column Totals	2037	8970	11007			
				Chi-squared	240.62	
Expected				Degrees of freedom	3	
	Remote sensing	No remote sensing	Row totals	Criticial chi-squared	7.81	
No complaints	1401.86	6173.14	7575	Chi-sq test probability	0.00000	
Minor complaints	374.94	1651.06	2026			
Significant complaints	172.85	761.15	934			
Serious compalints	87.35	384.65	472			
Column Totals	2037	8970	11007			

Figure 4 – The chi-square test of independence between applying not applying the remote sensing on plots of the land in field D in terms of the received employee complaints about the crop yield quality

Note – based on the calculations made by the author

Conclusion

In conclusion, the case study of Akermen village in Merki district of Zhambyl region proves that applying the remote sensing is correlated with increase in the crop yield quality. Moreover, assigning the data analyst team to coordinate agricultural workers may improve the yield quality output even further. Finally, training and educating employees plays the vital role in achieving higher crop yield.

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Қазақстан Республикасы Жамбыл облысы Ақермен ауылындағы ауыл шаруашылығы жерлерін бақылау үшін қашықтан зондау әдістерін қолдану

Аңдатпа. Зерттеудің мақсаты – қашықтан зондтау әдістерін қолдану ауыл шаруашылығы дақылдарының өнімділігін арттыруға ықпал ететінін дәлелдеу. Зерттеу әдістемесі эконометриялық және статистикалық талдау әдістеріне негізделген. Зерттеу құндылығы қашықтан зондтау әдістері ұлттық және жаһандық ауқымда стратегиялық маңызы бар азық-түлік қауіпсіздігін жақсартуға көмектесетініне негізделген.Зерттеу нәтижелері –зерттеу нәтиелері мен қорытындысы. Зерттеу нәтижелері 5% маңыздылық деңгейінде қашықтан зондтауды ауыл шаруашылығы дақылдарын өсірудің барлық кезеңдерінде қолдану қашықтан зондтауды мүлде қолданбағаннан әлдеқайда жақсы екенін көрсетеді. Сонымен қатар, қашықтан зондтауды дақылдарды өсірудің барлық кезеңдерінде деректер талдаушыларының қадағалауымен қолдану 95% сенімділік интервалында қашықтан зондтау құрамдастарын пайдаланбағанға қараганда дақыл өнімділігі сапасының жоғары көрсеткішін қамтамасыз етеді. Соңында, зерттеу нәтижелері егін өнімділігінің тиімділігін сақтау үшін кадрларды оқыту шешуші рөл атқаратынын көрсетеді.

Түйін сөздер: қашықтықтан зондтау, ауылшаруашылық алқаптары, дақылдардың өнім сапасы, Қазақстан, Z-тесті, t-тесті, ауытқу аймағын талдау, үлгі стандартты ауытқу.

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Применение методов дистанционного зондирования для мониторинга сельскохозяйственных земель в селе Акермен Жамбылской области Республики Казахстан

Аннотация. Цель исследования – доказать, что применение методов дистанционного зондирования позволит улучшить качество урожая сельскохозяйственных культур. Методология исследования основана на эконометрических и статистических методах анализа. Ценность исследования основана на том факте, что методы дистанционного зондирования могут способствовать повышению продовольственной безопасности, имеющей стратегическое значение как в национальном, так и в глобальном масштабах. Результаты исследования показывают, что при уровне значимости 5% применение дистанционного зондирования на всех этапах возделывания сельскохозяйственных культур значительно лучше, чем его полное отсутствие. Более того, применение дистанционного зондирования под наблюдением аналитиков данных на всех этапах выращивания сельскохозяйственных культур обеспечивает более высокую оценку качества урожая, чем неиспользование компонентов дистанционного зондирования при доверительном интервале 95%. Наконец, результаты исследований показывают, что обучение персонала играет решающую роль в поддержании эффективности производства урожая.

Ключевые слова: дистанционное зондирование, сельскохозяйственные угодья, качество урожая, Казахстан, сельскохозяйственная продукция, Z-тест, t-тест, анализ области отклонения, выборочное стандартное отклонение.

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