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SMART FARMING ADOPTION IN KIRIKKALE: A STUDY ON GRAIN PRODUCERS

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Abstract: In this study, the aim was to determine the awareness level, perceptions, adoption intentions, and barriers to adoption regarding smart agriculture practices among farmers engaged in maize and wheat cultivation in Kırıkkale province. In the research, frequency data from a 15-question questionnaire were used; univariate descriptive statistics (frequency-percentage), weighted means for Likert items, and multiple-response frequencies for multiple-response questions were reported. The findings show that a significant proportion of participants had heard of the concept of "smart agriculture," but awareness remained low for component technologies such as IoT. While technologies such as automatic irrigation and drones stand out as the most well-known and widely used applications, it was observed that the proportion of those actually using smart agriculture technology was limited. The main barriers to adoption are high cost and limited information, and the most critical policy topics for wider diffusion are training and awareness programmes and financial incentives. The results suggest that addressing digital infrastructure, advisory-training services, and shared machinery/technology parks together at the provincial scale may help disseminate smart agriculture.

Keywords: Smart agriculture, Precision agriculture, Digitalisation, Awareness, Technology adoption, Farmer survey

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1. Introduction

In the agricultural sector, climate variability, water scarcity, the contraction in labour supply, and rising input costs make it necessary to manage production processes in a more efficient, traceable, and sustainable manner. In this context, smart farming and Agriculture 4.0 approaches aim to enhance data-driven agricultural decision-making capacity through digital technologies such as sensor- and IoT-based monitoring, remote sensing, drone/UAV technologies, automation, and decision support systems. Review studies published in recent years emphasise that smart agriculture technologies are of strategic importance not only in terms of production efficiency but also in terms of resource-use efficiency, traceability, and environmental sustainability (Alotibi, 2025; Raj and Prahadeeswaran, 2025). Studies addressing the applicability of Agriculture 4.0 at the scale of Türkiye underline the potential of technological transformation while also drawing attention to structural limitations such as infrastructure, financing, and shortages in human resources/information (Ercan et al., 2019). Similarly, FAO's review of digital technologies in agriculture in Türkiye states that the digital transformation ecosystem is developing; however, adoption remains limited, especially among small- and medium-scale farms (FAO, 2025).

The technology adoption literature reveals that perceived usefulness, ease of use, risk perception, and expectations of economic return are decisive in farmers' decisions to use new technologies. Within this framework, approaches such as the Diffusion of Innovations Theory (Rogers, 2003) and the Technology Acceptance Model (Davis, 1989) suggest that farmer characteristics (age, education), farm scale, financial access, advisory services, and social networks play critical roles in adoption. More recent synthesis studies also support this framework, showing that farm scale, education level, access to capital, technical training, and perceived profitability are decisive variables in the adoption of precision and digital agriculture technologies (Kroupová et al., 2025; Pandeya et al., 2025). Similarly, international field studies conducted in recent years reveal that, although farmers' interest in smart agriculture technologies is high, adoption remains limited in many cases due to cost, lack of technical knowledge, and perceived uncertainty (Osrof et al., 2023). Similar findings have also been reported in field studies conducted in Türkiye. For example, a study focusing on precision agriculture awareness and use in the Çukurova Region showed that a significant proportion of participants had not heard the term "precision agriculture" before and that the need for training was high (Keskin and Sekerli, 2016). Another study conducted with farmers using GNSS-based automatic steering systems reported that although user satisfaction was high, the use of other precision agriculture technologies remained low; the main reasons were lack of information and investment cost (Keskin et al., 2018). A more recent nationwide study addressed the adoption of smart agriculture technologies in Türkiye through multivariate analyses and showed that financial access and information diffusion significantly increase the probability of adoption (Guldal et al., 2025).

Kırıkkale province is one of the important agricultural production areas of Central Anatolia, and maize and wheat production have a significant share in the provincial economy. In the province, digital technologies have high potential contributions in areas such as irrigation water management, input costs, and climate risks. However, evidence is limited at the local level regarding the extent to which farmers know the concept of smart agriculture, which technologies they recognise/use, and what the barriers to adoption are. Using survey findings conducted specifically in Kırıkkale, this study aims to reveal farmers' awareness and attitudes and, by comparing the findings with the national and international literature, to develop recommendations in terms of policy and extension.

2. Materials and Methods

The material of the study consists of frequency data obtained from a questionnaire form consisting of 15 questions applied to farmers engaged in maize and wheat cultivation in Kırıkkale province. The survey covered awareness of the concept of smart agriculture (Q1), level of awareness of smart agriculture practices (Q2), IoT awareness (Q3), heard-of/used status of various technologies (Q4), Agriculture 4.0 awareness (Q5), demand for information (Q6), recommended steps for wider diffusion (Q7), perceptions of productivity and sustainability (Q8–Q10), current use status (Q11), technologies used (Q12), reasons for non-use (Q13), intention to use in the future (Q14), and whether respondents had seen an example in the province (Q15).

The data were compiled by the researcher in Excel in the form of option frequencies for each question and analysed with descriptive statistics in a manner similar to the SPSS approach. For single-choice questions, the frequency (n) and percentage distribution (%) of each category were calculated. For Likert-scale items (Q2 and Q9), the weighted mean ($\bar{x}$) and sample standard deviation (SD) were calculated. For questions with multiple responses (Q4, Q7, Q12, Q13), multiple-response frequencies were reported; since the totals of these tables may exceed 100, percentage values were given over the base n. In Q12, the base n was taken as the number of participants who stated that they used smart agriculture technology; in Q13, it was taken as the number of participants who stated that they did not use it.

From an ethical perspective, the study data were analysed at the level of anonymised aggregate frequencies. The research results do not contain any personal data that could be associated with participant identities. An important limitation of the study is the availability of aggregated frequencies instead of the raw individual dataset; therefore, relationships between variables (e.g. chi-square, correlation, or regression) could not be evaluated. Despite this limitation, the study provides a strong descriptive framework that makes basic trends and policy priorities visible at the provincial level.

3. Results

In this section, the findings obtained in line with the responses given to the questionnaire form applied within the scope of the research are presented systematically. Participants' awareness levels regarding smart agriculture practices, their technological knowledge and perceptions, their current usage status, and their future adoption tendencies were evaluated under separate subheadings. The obtained data were analysed in the form of frequency (n) and percentage (%) distributions for each question; for Likert-type questions, mean and standard deviation values were also calculated. Since the number of valid responses (n) could differ by question, each table was interpreted on the basis of the relevant valid sample size.

3.1. Participants' Level of Awareness of Smart Agriculture

In this subsection, participants' general awareness levels regarding the concept of smart agriculture and their level of knowledge of the basic components of digital agriculture were evaluated. In this context, whether they had previously heard the term "smart agriculture", their subjective level of awareness of smart agriculture practices, their knowledge of IoT (Internet of Things), their familiarity with the concept of Agriculture 4.0, and their demand for information on smart agriculture were considered together.

A total of 64.8% of the participants stated that they had previously heard the term "smart agriculture" (Table 1). This rate indicates that approximately two-thirds of the sample group is familiar with the subject at the conceptual level.

When the subjective level of awareness regarding smart agriculture practices was evaluated by a Likert scale, it was seen that the responses were concentrated mostly at low and moderate levels. The weighted mean for the level of awareness was calculated as 2.56 (Table 2).

The proportion of participants stating that they had knowledge of IoT was determined to be only 23.2% (Table 3). Similarly, the proportion of participants who stated that they had previously heard of the concept of Agriculture 4.0 remained at 19.7% (Table 4).

Table 1. Whether respondents had previously heard the term "smart agriculture" (Q1)

Option	n	%
Yes	92	64.8
No	50	35.2
Total	142	100.0

Note: The number of valid responses for Q1 is 142.

Table 2. Level of awareness of smart agriculture practices (Q2)

Level	n	%	Cumulative %
1 (Very low)	34	24.1	24.1
2 (Low)	35	24.8	48.9
3 (Moderate)	44	31.2	80.1
4 (High)	15	10.6	90.8
5 (Very high)	13	9.2	100.0
Total	141	100.0	100.0

Note: n=141. Weighted mean $\bar{x}$=2.56, SD=1.23.

Table 3. IoT awareness (Q3)

Option	n	%
Yes	33	23.2
No	109	76.8
Total	142	100.0

Note: n=142 for Q3.

Table 4. Whether respondents had heard of the Agriculture 4.0 project (Q5)

Option	n	%
Yes	28	19.7
No	114	80.3
Total	142	100.0

Note: n=142 for Q5.

These findings indicate that the general familiarity with the concept of smart agriculture is not reflected to the same extent in its technical digital components.

On the other hand, the fact that 83.8% of the participants stated that they would like to receive information on smart agriculture shows that the desire to learn about the topic is high. When the basic awareness indicators are evaluated together, it is understood that producers are not completely unfamiliar with the concept of smart agriculture; however, this awareness appears to remain mostly at the level of general discourse. This pattern is summarised in Figure 1.

3.2. Knowledge and Perceptions Regarding Smart Agriculture Technologies

In this subsection, participants' levels of knowledge of different smart agriculture technologies and their perceptions regarding these technologies were evaluated. In this context, which smart agriculture technologies producers had heard of or used, the priorities they regarded as necessary for the dissemination of smart agriculture, their views on the effects of smart agriculture practices on productivity and sustainability, and their evaluations of drone technology were considered together. These variables are important because they reveal not only producers' level of exposure to technology but also their perceptual and functional attitudes toward these technologies.

When the smart agriculture technologies that participants had heard of or used were examined, it was observed that the highest proportion was in automatic irrigation systems (51.4%). This technology was followed by drone technology (45.1%), whereas sensors (25.4%), satellite imaging (19.0%), and artificial intelligence-assisted analyses (14.8%) were reported at lower rates (Table 6).

This distribution indicates that producers are more familiar with technologies that are more visible, practice-oriented, and directly associated with daily production processes. In particular, the fact that automatic irrigation systems rank first suggests that water management and irrigation efficiency occupy an important place in producer perception.

In contrast, the relatively lower awareness of data-based and more advanced digital applications such as artificial intelligence-assisted analyses and satellite imaging indicates that the more sophisticated components of smart agriculture have not yet become sufficiently visible in the field. This general tendency is presented more clearly in Figure 2.

When views on the dissemination of smart agriculture were evaluated, it was determined that participants most frequently selected "government support and incentives" (72.5%) and "training and awareness raising" (66.9%) (Table 7). In contrast, "making the technology more accessible" (39.4%) and "strengthening technological infrastructure" (37.3%) were indicated at lower, but still noteworthy, rates.

These findings show that farmers do not associate the dissemination of smart agriculture solely with the provision of technical equipment, but also evaluate it together with economic support mechanisms and information transfer processes. In particular, the high expectation of support and incentives suggests that smart agriculture technologies are perceived by producers as costly and investment-requiring practices. Similarly, the prominence of the option of training and awareness raising reveals that producers attach importance not only to access to technology but also to knowledge and competence regarding its use. This order of priorities is summarised in Figure 3.

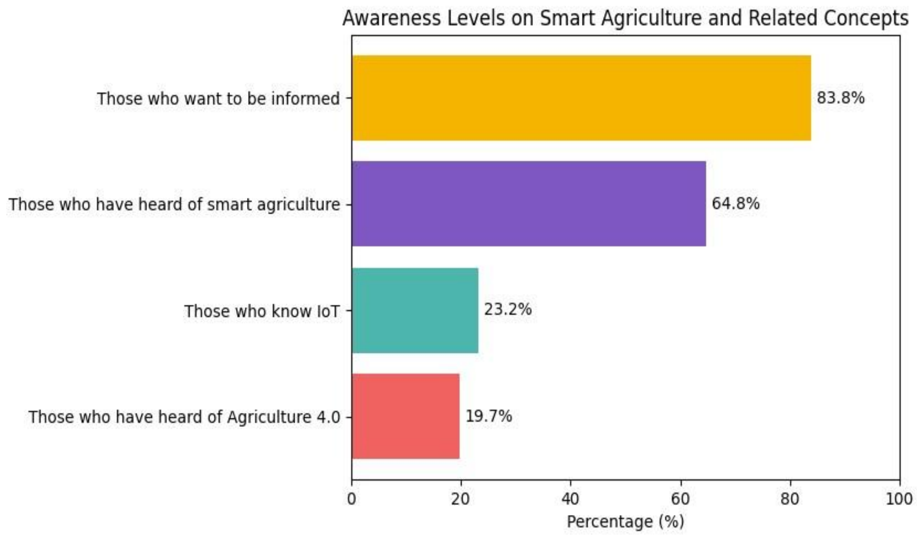

Figure 1. Basic awareness indicators of participants regarding smart agriculture.

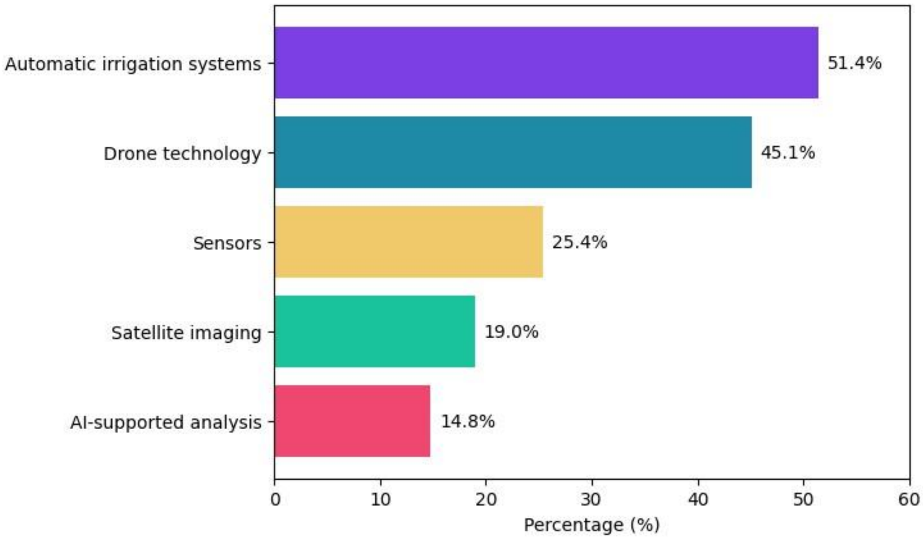

Figure 2. Smart agriculture technologies known by the participants.

Table 5. Demand for information on smart agriculture (Q6)

Option	n	%
Yes	119	83.8
No	23	16.2
Total	142	100.0

Note: n=142 for Q6.

Table 6. Heard-of/used smart agriculture technologies (Q4, multiple response)

Option	n	% (base n)
Drone technology	64	45.1
Sensors (soil/moisture/temperature, etc.)	36	25.4
Automatic irrigation systems	73	51.4
Artificial intelligence-assisted analyses	21	14.8
Drone technology	64	45.1

Table 7. Recommended steps for the dissemination of smart agriculture (Q7, multiple response)

Option	n	% (base n)
Training and awareness raising	95	66.9
Government support and incentives	103	72.5
Making technology more accessible	56	39.4
Strengthening technological infrastructure	53	37.3

Note: Base n=142. Since this is a multiple-response item, the percentage total may exceed 100.

When the perception dimension regarding smart agriculture technologies was examined, it was observed that the vast majority of participants believed that these technologies could make a positive contribution to agricultural productivity. Indeed, 87.1% of the participants stated that smart agriculture practices could increase productivity (Table 8). This very high rate shows that producers evaluate smart agriculture not only as a theoretical innovation but also as a practical tool that can improve production performance.

Evaluation of the use of drones in agriculture also stands out as one of the important indicators of technology perception. In this question evaluated on a Likert scale, the weighted mean was calculated as 3.13, and it was observed that responses were concentrated at moderate and moderately high levels (Table 9).

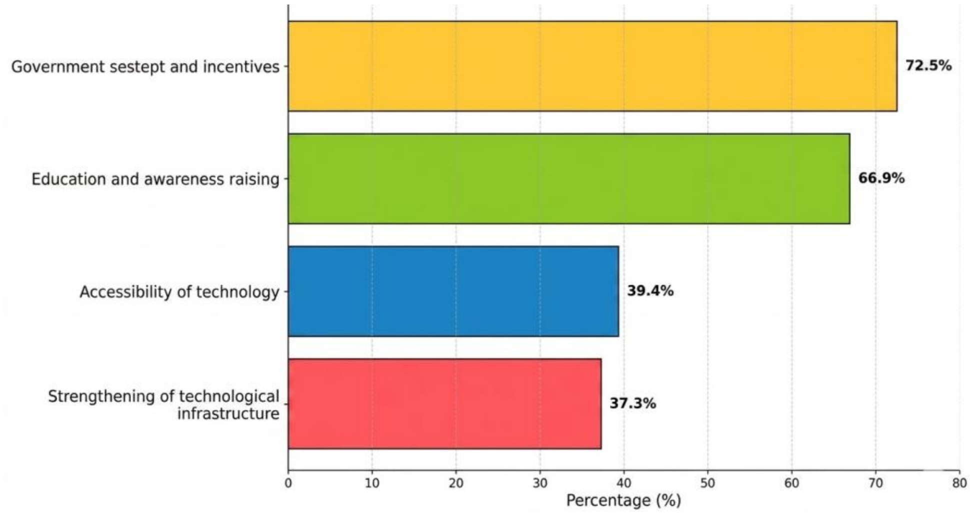

Figure 3. Elements regarded as priorities for the dissemination of smart agriculture.

Table 8. Belief that smart agriculture will increase productivity (Q8)

Option	n	%
Yes	128	87.1
No	7	4.8
Undecided	12	8.2
Total	147	100.0

Note: n=147 for Q8.

Table 9. Evaluation of drone use (Q9)

Level	n	%	Cumulative %
1 (Very low)	22	14.8	14.8
2 (Low)	27	18.1	32.9
3 (Moderate)	40	26.8	59.7
4 (High)	30	20.1	79.9
5 (Very high)	30	20.1	100.0
Total	149	100.0	100.0

Note: n=149. Weighted mean $\bar{x}$=3.13, SD=1.33.

This result shows that participants are not entirely distant from drone use; on the contrary, they display a certain degree of positive and curious attitude. It may be said that drone technology, whose visibility has increased in recent years especially in the context of agricultural spraying, monitoring, and precision applications, may have become more familiar to producers than other advanced digital technologies.

Similarly, the proportion of participants who think that smart agriculture practices support sustainable agriculture was found to be 68.9% (Table 10). However, the presence of an undecided group at the rate of 25.2% in this question is noteworthy.

This situation suggests that participants grasp the impact of smart agriculture on productivity more clearly, but may not have an equally clear opinion regarding broader effects such as sustainability, environmental benefits, and long-term resource management. Therefore, although producers' positive attitude toward technology is high, it is understood that this positive attitude should be supported, especially on the axis of sustainability, with more demonstration practices and information transfer.

When this subsection is evaluated in general, it is seen that participants' perceptions of smart agriculture technologies are mostly positive, but that levels of knowledge and familiarity differ according to technology type. While producers are more familiar with more concrete and application-oriented technologies, their levels of knowledge regarding more advanced digital and data-based solutions remain relatively limited.

Table 10. Perception that smart agriculture supports sustainability (Q10)

Option	n	%
Yes	93	68.9
No	8	5.9
Undecided	34	25.2
Total	135	100.0

Note: n=135 for Q10.

3.3. Factors Limiting the Use and Adoption of Smart Agriculture Technologies

The generally positive knowledge and perceptions of participants regarding smart agriculture technologies make it necessary to evaluate the actual level of use of these technologies in the field as well. In this subsection, producers' use of smart agriculture technologies in their own farms, the main applications they use, and the main barriers to use are discussed. Thus, it is aimed to reveal more clearly the relationship between awareness and positive attitudes and actual use.

When participants' use of any smart agriculture technology in their own farms was examined, it was observed that the rate of use remained limited within the overall sample. Indeed, only 20.6% of the participants stated that they used any smart agriculture technology in their own farms (Table 11). In contrast, a large segment of 79.4% stated that they did not use any smart agriculture technology. This finding indicates that the levels of awareness and positive perceptions identified in the previous subsections are not reflected to the same extent in actual practice in the field.

Table 11. Use of smart agriculture technology on the farm (Q11)

Option	n	%
Yes	29	20.6
No	112	79.4
Total	141	100.0

Note: n=141 for Q11.

However, examining which applications are preferred by producers who state that they use smart agriculture technologies is important in terms of understanding the current pattern of use in more detail. For this reason, the main smart agriculture technologies preferred by the user group were also evaluated.

When Table 12 is examined, it is seen that the most common application among participants who stated that they use smart agriculture technology is automatic irrigation systems (62.1%). This is followed by drones (37.9%), sensors (27.6%), and other applications (24.1%). This distribution shows that producers tend to prefer technologies that can be integrated directly into the production process, provide tangible benefits, and are more understandable in terms of application. In particular, the fact that automatic irrigation systems also stand out here reveals that this technology occupies a remarkable position at both the awareness and usage levels. In addition to the current pattern of use, understanding why smart agriculture technologies are not adopted on a wider scale is also important. For this reason, the reasons why non-user participants remain outside use were also evaluated separately. These findings are important in terms of revealing the main limiting factors behind the gap between awareness and practice.

Table 12. Smart agriculture technologies used (Q12, multiple response)

Option	n	% (base n)
Sensors	8	27.6
Drones	11	37.9
Automatic irrigation systems	18	62.1
Other	7	24.1

Note: Base n=29. Since this is a multiple-response item, the percentage total may exceed 100. Base n refers to those who said "Yes" in Q11.

When Table 13 is examined, it is seen that the dominant barrier among participants who do not use smart agriculture technologies is high cost (61.6%). This is followed by lack of information (31.2%) and problems of access to technology (19.6%). In addition, 28.6% of the participants marked "other" reasons. In contrast, the relatively lower rate of the option "not needing it" (6.2%) suggests that most farmers do not see these technologies as completely unnecessary, but experience various limitations in moving to implementation. This finding indicates that economic- and information-based barriers may be decisive in the adoption of smart agriculture. The main barriers to use are visually summarised in Figure 4.

When this subsection is evaluated in general, it is understood that awareness and positive perceptions regarding smart agriculture technologies are not sufficient on their own for use. Although a significant proportion of producers view the technology as potentially useful, they have difficulty putting these technologies into actual practice due to factors such as cost, lack of information, and access problems.

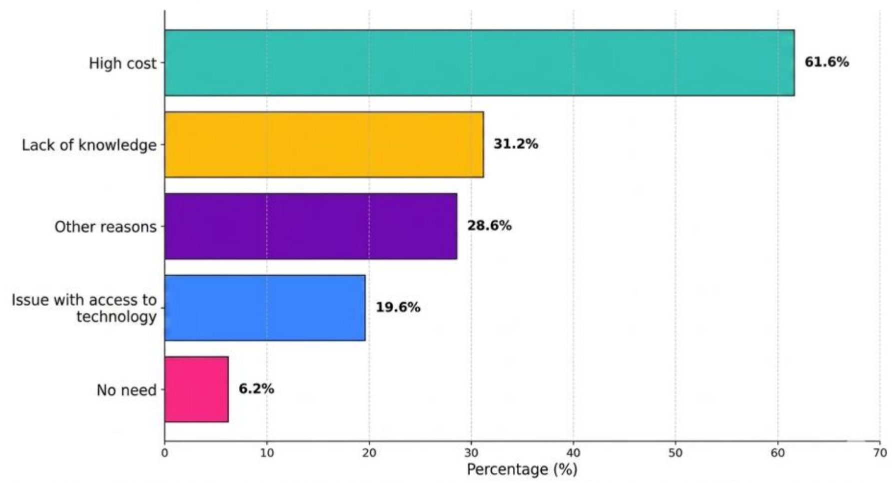

Figure 4. Main barriers limiting the use of smart agriculture technologies.

Table 13. Reasons for not using smart agriculture technology (Q13, multiple response)

Option	n	% (base n)
High cost	69	61.6
Lack of information	35	31.2
Problem of access to technology	22	19.6
No need	7	6.2
Other	32	28.6

Note: Base n=112. Since this is a multiple-response item, the percentage total may exceed 100. Base n refers to those who said "No" in Q11.

3.4. Future Usage Tendencies and Adoption Status

The low current level of use and the presence of various barriers to use do not mean that farmers are completely closed to these technologies. For this reason, participants' tendencies toward future use of smart agriculture technologies and their general adoption profiles regarding these technologies were also evaluated separately. In this subsection, intention to use in the future and the existence of visible application examples at the local level were considered together.

As seen in Table 14, a significant proportion of participants stated that they considered using smart agriculture technologies in the future. Indeed, the proportion of those responding "yes" was found to be 75.0%. In contrast, the proportion of those saying "no" remained only 4.2%, while 20.8% stated that they were undecided. This result shows that, although the current level of use is low, the potential tendency toward adoption of technology is high. Therefore, the difference between current use and future intention to use suggests that the level of adoption may increase when appropriate support mechanisms, training activities, and accessible application examples are provided.

In the adoption of smart agriculture technologies, not only individual knowledge and intention but also application examples observed in the surrounding environment can be effective. For this reason, whether participants had seen a farm using smart agriculture systems in their province was also evaluated. This variable is important in that it reflects the local visibility of the technology and its potential to serve as an example.

Table 14. Intention to use smart agriculture (Q14)

Option	n	%
Yes	108	75.0
No	6	4.2
Undecided	30	20.8
Total	144	100.0

Note: n=144 for Q14.

When Table 15 is examined, it is understood that a relatively limited proportion of the participants stated that they had seen a farm using smart agriculture systems at the provincial level. This situation suggests that the visibility of smart agriculture practices at the local level is not yet sufficiently high. The scarcity of observable local application examples may cause trust in the technology and willingness to implement it to remain limited. Therefore, increasing demonstration areas, pilot farm applications, and regional examples may be an important support element for the dissemination of smart agriculture technologies.

Table 15. Whether respondents had seen a farm using smart agriculture in the province (Q15)

Option	n	%
Yes	40	27.8
No	104	72.2
Total	144	100.0

Note: n=144 for Q15.

When the findings obtained are evaluated in general, it is seen that participants' levels of awareness and interest regarding smart agriculture practices are relatively high, but that this awareness is not reflected to the same extent in technical knowledge and actual use.

Table 16. Comparative summary of the study findings with the literature

Theme	This study (Kırıkkale)	Typical finding in the literature	Example source
Awareness	64.8% had heard the term smart agriculture; IoT awareness 23.2%	Concept awareness is increasing, but knowledge of enabling technology is limited	Keskin and Sekerli (2016); FAO (2025)
Use	Actual use 20.6%; automatic irrigation is the most common	Use is generally low; water/automation are the "first adopted" applications	Guldal et al. (2025); Yildirim et al. (2025)
Barriers	High cost 61.6%; lack of information 31.3%	Cost and lack of information/service are the main barriers	Ercan et al. (2019); Keskin et al. (2018)
Policy priority	Incentives and training are the most selected steps	An integrated approach of incentives + extension + infrastructure is recommended	Agriculture and Forestry Council (2024); Trendov et al. (2019)

Note: Table 16 was prepared in order to provide a summary comparison between the descriptive findings of this study and the tendencies frequently reported in the literature.

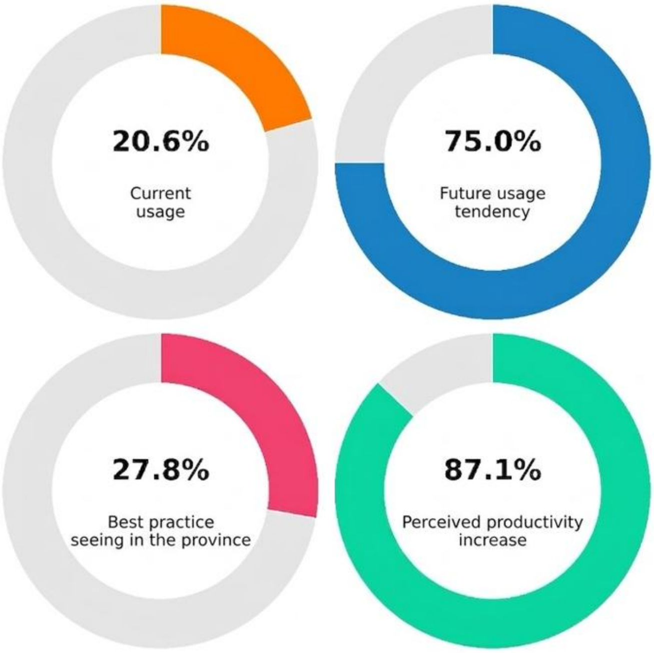

Figure 5. Participants' smart agriculture adoption profile.

A significant proportion of participants stated that they had previously heard the term smart agriculture and expressed openness to using these technologies in the future. However, the limited current use rate and the scarcity of visible examples at the provincial level suggest that the adoption process is still at an early stage. The general pattern of the study can be summarised as limited actual use despite high interest and positive attitudes. This general adoption profile is presented visually in Figure 5.

4. Discussion

The level of awareness and adoption of smart agriculture among maize and wheat producers in Kırıkkale province is in parallel with the general tendencies reported in different regions of Türkiye. Although the proportion of those who had heard the term "smart agriculture" in this study is relatively high (approximately two-thirds), IoT awareness is markedly low. This result suggests that the core components of the technology ecosystem (sensors, data collection, connected systems) are not sufficiently known by farmers at the conceptual level; in contrast, more visible and tangible applications in the field (drones, automatic irrigation) are remembered more easily. Findings drawing attention to the low awareness of the term and concept of precision agriculture in the Çukurova case (Keskin and Sekerli, 2016) show that the difference between "concept awareness" and "application awareness" is important in the dissemination of smart agriculture.

The fact that the level of awareness in Q2 ($\bar{x}$=2.56) remained in the low-to-moderate band supports the notion that, despite increasing awareness, in-depth knowledge and experience are limited. Similarly, Keskin et al. (2018) reported that, although the satisfaction of farmers using GNSS-based automatic steering was high, the use of other precision agriculture technologies was very low and that the greatest reason was lack of information. In this study as well, lack of information stood out as an important barrier in Q13. Therefore, it is considered that extension-training activities should not be limited only to technology promotion, but should be supported with practical content on topics such as use scenarios, maintenance/calibration, data interpretation, and economic return.

The low rate of use (20.6%) is consistent with nationwide studies showing that smart agriculture technologies in Türkiye are still at an early adoption stage. In their study conducted with 325 farmers in Türkiye, (Guldal et al., 2025) emphasised that smart agriculture users had higher financial access and information levels and that small land scale and the absence of credit use limited adoption. In the Kırıkkale case, the fact that high cost ranked first among the reasons for non-use (61.6%) shows that access to finance and investment risk are decisive. This finding is also consistent with the heading of 'investment costs and the need for incentives', which comes to the fore in SWOT-based evaluations regarding the applicability of Agriculture 4.0 in Türkiye (Ercan et al., 2019).

The fact that automatic irrigation systems ranked first both among the heard-of/used technologies and among the technologies actually used in multiple-response questions suggests that the need for water management and irrigation efficiency in Kırıkkale may influence technological preferences. Considering the climate conditions and the limited water resources in Central Anatolia, irrigation automation and sensor-based water management can be expected to offer direct economic returns to farmers (water and energy savings, yield increase). This is consistent with the application areas of 'resource efficiency and decision support' emphasised in FAO's digital agriculture report (FAO, 2025).

The findings of Q7 showed that the two most critical priorities for wider diffusion are "government support and incentives" and "training and awareness raising". This result is consistent with the structural barriers stated in the digital agriculture working document of the IVth Agriculture and Forestry Council (digital infrastructure deficiencies in rural areas, the need for digital literacy and training, and the development of supportive policy mechanisms). Although the Council document states that awareness has increased after 2020, it emphasises the need for policy in the areas of infrastructure and capacity development for wider diffusion. In addition, within the scope of programmes supporting climate-smart agriculture investments such as TUCSAP, the dissemination of grants and technology investments and the development of common-use models through shared technology parks and cooperatives/producer organisations may be important leverage points.

The high intention to adopt (75%) but low rate of having seen an example in the province (27.8%) indicates that the dimension of 'observability' (Rogers, 2003) needs to be strengthened at the local level. Demonstration farms, field days, and making local success stories visible may contribute to reducing perceived risk and reinforcing positive attitudes toward technology. This approach is also consistent, from the perspective of the Technology Acceptance Model, with accelerating adoption through concretising perceived usefulness and experiencing ease of use (Davis, 1989).

4.1. Comparative Evaluation with the Literature and Examples From Türkiye

Recent studies on smart agriculture and digitalisation in agriculture in Türkiye show that adoption at the farmer level is a multidimensional problem. For example, national-scale studies report that technology users are more advantaged in terms of indicators such as credit use, agricultural insurance, and machinery park, and that channels of access to information (extension service, fairs, cooperative networks) accelerate adoption (Guldal et al., 2025). These findings are consistent with the prominence of cost and lack of information in Kırıkkale; in other words, financial access and information diffusion also appear decisive at the local scale.

Secondary data analyses on the state of digital transformation in Türkiye (TÜİK ICT indicators, agricultural outlook field studies, etc.) also discuss that there is heterogeneity in digital literacy and technology use in rural areas and that a significant proportion of agricultural enterprises cannot access digital tools regularly (Özoğul, 2025). This provides a background explaining why the option of strengthening infrastructure in Q7 was marked at noteworthy rates. In addition, the digital transformation working document of the IVth Agriculture and Forestry Council emphasises that areas such as rural internet access, digital device use, and the development of legislation/incentive mechanisms are prerequisites for wider diffusion.

When concrete application examples are considered, automatic irrigation systems and sensor-based water management stand out as the "entry technology" of digital agriculture in many regions of Türkiye. In this study as well, the fact that automatic irrigation ranked first among actual users (62.1%) confirms the same tendency. Current studies addressing irrigation management applications based on climate and soil data show that digital applications are critical in terms of water efficiency; however, diffusion can be limited by information, service, and investment costs (Yildirim et al., 2025).

4.2. International Context and Policy Implications

In the international literature, the digital transformation of agriculture is associated with targets such as increased productivity, emission reduction, and climate resilience. FAO's global evaluations regarding digital agriculture transformation emphasise that the digital divide (differences in infrastructure and skills) slows adoption especially among small producers and that it is important for public policies to be designed according to the principle of inclusiveness (Trendov et al., 2019). The difference between the high intention to adopt and the low actual use in Kırıkkale can be interpreted as a local reflection of this digital divide. In this context, not only providing technology but also reducing investment risk, developing service capacity, and disseminating farmer-oriented decision support services appear critical.

4.3. Summary Comparison of Findings with the Literature

Finally, because the study is based on aggregated data, differences among subgroups (e.g. farm scale, education level, irrigation type) could not be analysed. In future studies, carrying out multivariate analyses (logistic regression, multiple correspondence analysis, structural equation modelling) on the raw dataset may reveal the determinants of technology adoption more strongly. In addition, quantitatively demonstrating the economic effects of smart agriculture through cost-benefit analyses and return on investment (ROI) calculations will support evidence-based decision-making in policy design.

5. Conclusion

Although awareness of smart agriculture among maize and wheat producers in Kırıkkale province is increasing, the level of knowledge remains limited in terms of enabling technologies (IoT, sensor/data management). Although the actual use rate is low, the intention to adopt is high. The most important barriers to adoption are high investment cost and lack of information. Within this framework, the following recommendations have been developed:

Applied training programmes at the provincial level (sensor installation, data reading/interpretation, automation settings, maintenance-calibration) should be disseminated; certified modules should be developed through university–provincial directorate–private sector cooperation.

Grant/incentive programmes, low-interest credit packages, and insurance/guarantee mechanisms (risk sharing) should be designed specifically for smart agriculture investments in order to increase financial access.

Shared technology parks through cooperatives and producer unions (drone service, sensor rental, sharing of automation equipment) should be established; the scale disadvantage of small enterprises should be reduced.

The visibility of technologies should be increased in Kırıkkale through model/demonstration farms and field days; local success stories should be systematically shared through extension channels.

Digital infrastructure (internet access, data communication quality) and the technical service ecosystem should be strengthened; especially in rural areas, access to maintenance-repair and spare parts should be improved.

5.1. Proposed Road Map for Kırıkkale

In order to disseminate smart agriculture at the local scale, recommendations can be transformed into a short-, medium-, and long-term road map. In the short term (0–12 months), the priority should be practical training that will increase awareness, demonstration fields, and the establishment of pilot automation/sensor applications. In the medium term (1–3 years), it should be aimed to develop cooperative/producer union-based shared technology parks, drone service provider networks, and maintenance-service capacity. In the long term (3+ years), the gradual dissemination of more advanced digital services such as data-based production management, provincial agricultural data infrastructure, and decision support services (weather, irrigation, disease forecasting) can be planned. Within this framework, strengthening the local R&D and implementation ecosystem through university–public–private sector cooperation will accelerate the adaptation of technologies to the field.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	M.C.P.	G.A.K.G.	D.G.K.	B.D.
C	30	40	20	10
D	50	20	10	20
S	20	60	10	10
DCP	50	30	10	10
DAI	40	20	30	10
L	30	30	20	20
W	20	30	20	30
CR	20	30	30	20
SR	10	30	20	40
PM	20	60	10	10
FA	20	40	20	20

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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