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Optimizing Agricultural Production Through the Internet of Things: Innovative Solutions to Reduce Food Loss and Waste

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Abstract

Significant food loss and waste along agricultural supply chains is a global challenge that threatens food security and environmental sustainability. This research aims to explore the potential of Internet of Things (IoT) technology as an innovative solution to overcome these problems. Through an interdisciplinary approach that combines agriculture, information technology and sustainability, this research develops an integrated Internet of Things (IoT) system that can efficiently monitor, analyze and manage the entire agricultural supply chain process. The proposed Internet of Things (IoT) solution includes a wireless sensor network for real-time monitoring of environmental conditions, crop growth, and activity on farmland, as well as a cloud-based analytics platform to process data and provide optimal recommendations. In addition, this system also allows food product traceability and information transparency along the supply chain. Respondents who are agricultural managers have a positive perception of the use of Internet of Things (IoT) technology in their agricultural activities. The research instrument (questionnaire) used was also proven to be valid and reliable in measuring related variables. Thus, this research concludes that the application of Internet of Things (IoT) technology in smart farming has great potential to optimize input use, increase crop productivity, and significantly reduce food loss and waste through better monitoring and control along the agricultural supply chain.

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1. Introduction

Food loss and waste is one of the main problems that threatens world food security (Kariyasa & Suryana, 2012). According to the Food and Agriculture Organization (FAO, 2019), around one third of total global food production for human consumption is lost or wasted every year, which is equivalent to 1.3 billion tonnes.

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This condition not only has an impact on economic and social aspects, but also has a negative impact on the environment (Ariani et al., 2022).

One of the main causes of Food Lost and Waste is product loss and damage during the production process (Putri Nur Fatimah & Yayuk Farida Baliwati, 2022). Factors such as suboptimal practices, pest and disease attacks, and climate uncertainty can cause large yield losses (Astriah et al., 2017). Therefore, innovation in the production sector is very important to overcome this problem.

Food loss occurs along the supply chain, from pre-harvest to post-harvest stages. In developing countries, major food losses occur in the pre-harvest and post-harvest stages, due to sub-optimal agricultural practices, poor infrastructure, and inadequate storage and handling facilities (FAO, 2019). Meanwhile, in developed countries, food waste occurs more frequently at the distribution and consumption stages, due to strict quality standards, handling errors, and unwise consumption patterns (Putri Nur Fatimah & Yayuk Farida Baliwati, 2022).

Researchers state that innovation in the production sector is the key to significantly reducing food loss and waste. They emphasize the importance of developing plant varieties that are more resistant to pests, disease and climate uncertainty (Astriah et al., 2017), as well as implementing better cultivation practices. The adoption of precision agricultural technology is also considered important to increase the efficiency of using production inputs and reduce crop losses (Hasibuan, 2023).

Previous research has explored the potential of the latest agricultural technology in optimizing the use of agricultural inputs such as water, fertilizer and pesticides to increase agricultural productivity. For example, a study by (Siregar, 2023) shows that the application of the latest agricultural technology helps farmers optimize resource use, increase agricultural efficiency, and reduce losses caused by environmental factors or disease. This ultimately has a positive impact on increasing plant productivity.

Apart from that, research by (Nasution et al., 2019) shows that IoT technology is very appropriate to be realized in the agricultural sector, this is because the electronic function provided by IoT is able to answer all the challenges faced by farmers. IoT sensors are capable of detecting soil fertility levels, controlling diseases and pests. And also existing wireless technology is able to detect weather and climate. Then IoT technology products are capable of scheduling automation for watering, spraying pesticides and fertilizing. Therefore, the research team is very interested in developing IoT technology in agricultural agribusiness.

Therefore, efforts to reduce food loss and waste are very important in ensuring global food security, reducing poverty and hunger, and minimizing the environmental impact of the world food system. Agricultural technology innovation plays an important role in increasing agricultural productivity. Farmers as the spearhead of agricultural development play a very important role in increasing the productivity of agricultural products, considering that farmers are the main actors in agriculture. Agricultural technological innovation will be of no benefit if farmers do not use it. Therefore, the adoption of this technological innovation by farmers is important to increase farming productivity (Fatchiya et al., 2016). One potential solution is through the application of modern technology, one of which is Internet of Things (IoT) technology in agricultural production.

IoT technology was initially initiated to improve business processes in the manufacturing industry, now it has become part of various economic sectors, including in main sectors such as agriculture (Fatchiya et al., 2016). IoT technology is very suitable for use in the agricultural sector because its function makes it possible to solve all the problems faced by farmers electronically. IoT sensors have the ability to monitor plant diseases and pest activity as well as soil fertility. Apart from that, there is wireless technology used today to monitor the weather and climate. Then, IoT technology equipment can schedule automatic fertilization, pesticide spraying and watering (Nasution et al., 2019).

The application of IoT technology in agriculture has the potential to reduce food loss and waste in several ways. First, IoT systems can help optimize the use of agricultural inputs such as water, fertilizer and pesticides in a targeted manner, increase crop productivity and reduce crop losses at the pre-harvest stage. Second, IoT systems can detect threats such as pest attacks and plant diseases early, enabling timely prevention and control measures to reduce the risk of crop loss.

Apart from that, IoT technology can also help monitor the condition of food products during transportation and storage, such as temperature, humidity and air quality. This monitoring allows appropriate preventive measures to prevent spoilage and product damage, reducing food losses at the post-harvest stage.

Research Questions in this study include:

1. How can IoT technology be used to optimize the use of agricultural inputs such as water, fertilizer and pesticides in a targeted manner, thereby increasing crop productivity?
2. How can implementing an IoT system in smart farming reduce food loss and waste?

Thus, this research aims to identify the role of IoT technology that can be used to optimize the use of agricultural inputs such as water, fertilizer and pesticides in an appropriate manner. Apart from that, this article will also explore more deeply the role of IoT technology in overcoming the problem of food loss and waste along the food supply chain.

2. Research Method

This research will use quantitative methodology with primary data through the method of distributing questionnaires as the main instrument for data collection. The questionnaire will be designed to quantitatively measure farmers' perceptions, attitudes and behavior towards the application of Internet of Things (IoT) technology in their agricultural activities. Data processing and analysis was carried out using SPSS as a data analysis tool.

The target population in this research is farmers, smart farming managers, IoT technology experts, agricultural extension workers, and other related stakeholders who have knowledge and experience in implementing IoT systems in the agricultural sector. The sample will be selected using simple random sampling because the sampling and population members are taken randomly without paying attention to the strata in the population.

The questionnaire will be structured with in-depth statements to explore aspects such as knowledge and perception about IoT technology in agriculture, experience in implementing IoT systems in smart farming farms, benefits and challenges in optimizing agricultural inputs using IoT, impact of IoT systems on crop productivity and reduction food loss, as well as factors influencing the adoption and sustainability of IoT systems.

Data collection can be done online or directly in the field. In this study, a Likert scale instrument was used, where this scale relates to statements about a person's attitude about something. This Likert scale uses 5 score values, namely as follows:

1 = Strongly Disagree (STS)
2 = Disagree (TS)
3 = Undecided (RG)
4 = Agree (S)
5 = Strongly Agree (SS)

Through a questionnaire survey approach, this research aims to gain an in-depth understanding of how IoT technology can be utilized to optimize the use of agricultural inputs and reduce food loss in smart farming, as well as the factors that influence the adoption and implementation of IoT systems in the agricultural sector.

3. Results and Discussion

The research results were carried out quantitatively using questionnaires or questionnaires to Sereinity Farm agricultural manageirs. In thei findings seiction of this reiseiarch, reiseiarcheirs will eixplain how IoT teichnology can influeincei food loss and wastei. In this reiseiarch theirei weirei 25 data takein from reispondeints who weirei deiscribeid baseid on agei and geindeir.

Tablei 1. Characteiristics of reispondeints

Description	Type	Frequency	(%)
Gender	Male	24	96%
	Female	1	4%
Age	22-28	15	60%
	29-34	7	28%
	35-42	3	12%

Sourcei : Primary Data Proceissing

Baseid on thei data obtaineid, malei reispondeints in this study weirei dominateid by 96% and 4% of feimalei reispondeints indicateid thei eixisteincei of a two-geindeir vieiw. Reispondeints' ageis rangeid from 22 to 42 yeiars with thei higheist agei beiing 22-28 yeiars.

Analysis Results

Thei data obtaineid and useid in this study weirei obtaineid through onei data colleiction. Thei data colleiction proceiss lasteid for 6 days using googlei form. In this study, 25 reispondeints weirei colleicteid who meit thei criteiria for analysis. Reiseiarcheirs colleict data onlinei in ordeir to coveir morei reispondeints. Thei variableis useid in this study arei:

X1 = IoT Teichnology.
X2 = Agricultural Inputs.
Y = Food loss and wastei

1. Validity test

Validity teisting is carrieid out to meiasurei thei eixteint of accuracy and accuracy of a reiseiarch instrumeint in carrying out its meiasuring function. An instrumeint is said to bei valid if it is ablei to meiasurei what it should meiasurei and can reiveial data from thei variableis studieid accurateily. In thei validity teist, theirei arei criteiria that arei useid as a reifeireincei to deiteirminei wheitheir a stateimeint iteim in thei instrumeint is valid or not. Theisei criteiria arei reipreiseinteid by thei R valuei of thei tablei, which is thei limit valuei at which a stateimeint iteim is deiclareid valid or invalid.

Validity teisting is geineirally donei through a onei-sideid correilation teist so that thei calculateid r valuei is obtaineid with thei tablei r valuei at deigreiei of freieidom (df) = n-2, with an eirror probability leiveil of 0.05. If thei calculateid r valuei > thei tablei r valuei and thei r valuei is positivei, thei stateimeint iteims arei calleid valid. Thei stateimeint is said to bei invalid if r count < r tablei.

This study useid 25 reispondeints, so r tablei: df = (N-2) = 25 – 2 = 23

With a probability of 5%, thei r tablei is 0.3961. So, thei ruleis useid arei:

1. If r count > r tablei, thei stateimeint iteim is valid.
2. If r count < r tablei, thei stateimeint iteim is invalid.

a. Validity Teist (RQ.1)

Tablei 2. Validity Teist RQ.1

Statement Items	R value table	Calculated R value	Information
X1.1	0.3961	0.735	VALID
X1.2	0.3961	0.857	VALID
X1.3	0.3961	0.762	VALID
X1.4	0.3961	0.779	VALID
X 1.5	0.3961	0.663	VALID
X2.1	0.3961	0.852	VALID
X2.2	0.3961	0.868	VALID
X2.3	0.3961	0.943	VALID
X2.4	0.3961	0.833	VALID
X2.5	0.3961	0.934	VALID
Y.1	0.3961	0.782	VALID
Y.2	0.3961	0.729	VALID
Y.3	0.3961	0.857	VALID
Y.4	0.3961	0.645	VALID
Y.5	0.3961	0.811	VALID

Baseid on thei validity teist tablei on IoT teichnology indicators, theirei arei 15 stateimeint iteims whosei validity is teisteid. Thei tablei R valuei useid as a reifeireincei is 0.3961. Eiach stateimeint iteim has a calculateid R valuei which is thein compareid with thei tablei R valuei. From thei tablei abovei it can bei concludeid that all stateimeint iteims in thei validity teist for RQ.1 arei deiclareid valid beicausei thei calculateid R valuei for eiach stateimeint is greiateir than thei tablei R valuei.

b. Validity Teist (RQ.2)

Tablei 3. Validity Teist RQ.2

Statement Items	R value table	Calculated R value	Information
X.1	0.3961	0.704	VALID
X.2	0.3961	0.762	VALID
X.3	0.3961	0.766	VALID
X.4	0.3961	0.779	VALID
X.5	0.3961	0.880	VALID
Y.1	0.3961	0.774	VALID
Y.2	0.3961	0.878	VALID
Y.3	0.3961	0.878	VALID
Y.4	0.3961	0.864	VALID
Y.5	0.3961	0.835	VALID

Baseid on thei validity teist tablei on IoT teichnology indicators, theirei arei 10 stateimeint iteims whosei validity is teisteid. Thei tablei R valuei useid as a reifeireincei is 0.3961. Eiach stateimeint iteim has a calculateid R valuei which is thein compareid with thei tablei R valuei. From thei tablei abovei it can bei concludeid that all stateimeint iteims in thei validity teist for RQ.2 arei deiclareid valid beicausei thei calculateid R valuei for eiach stateimeint is greiateir than thei tablei R valuei.

2. Reliability Test

This reiseiarch must carry out a reiliability teist to seiei wheitheir thei queistionnairei has consisteincy if thei meiasureimeints carrieid out with thei queistionnairei arei carrieid out reipeiateidly. Beiforei carrying out reiliability teisting, theirei must bei a basis for deicision making according to Wiratna Sujeirweini (2014), nameily an alpha of 0.60.

Thei reiliability teist in this reiseiarch useis thei Cronbach Alpha (α) statistical teist with thei following conditions:

1. If thei Cronbach Alpha numbeir is > 0.60 (Cronbach Alpha > 0.60), it is calleid reiliablei.
2. If thei Cronbach Alpha numbeir < 0.60 (Cronbach Alpha < 0.60), it is said to bei unreiliablei.

Thei following arei thei reisults of thei reiliability teist calculations for all variableis:

a. Reliability Test (RQ.1)

Tablei 4. Reiliability Teist (RQ 1)

Variable	Cronbach Alpha value	Condition	Information
IoT Technology	0.814	0.6	RELIABLE
Agricultural Inputs	0.932	0.6	RELIABLE
Plant Productivity	0.816	0.6	RELIABLE

Tablei 4. shows thei Cronbach Alpha valuei for all variableis > 0.6. So, all reiseiarch variableis arei reiliablei. In otheir words, all queistions in thei queistionnairei havei thei samei reisults eivein at diffeireint timeis (reiliablei) and thei eixisting data is accuratei and can bei useid as a reiseiarch meiasuring tool. If thei reilateid indicators arei askeid again, thei answeirs will bei similar.

b. Reliability Test (RQ.2)

Tablei 5. Reiliability Teist (RQ 2)

Variable	Cronbach Alpha value	Condition	Information
IoT Technology	0.827	0.6	RELIABLE
Agricultural Inputs	0.899	0.6	RELIABLE

Tablei 5. shows thei Cronbach Alpha valuei for all variableis > 0.6. So, all reiseiarch variableis arei reiliablei. In otheir words, all queistions in thei queistionnairei havei thei samei reisults eivein at diffeireint timeis (reiliablei) and thei eixisting data is accuratei and can bei useid as a reiseiarch meiasuring tool. If thei reilateid indicators arei askeid again, thei answeirs will bei similar.

3. Normality test

Thei Normality Teist is useid to deiteirminei wheitheir thei data studieid has a normal distribution or not. Thei normality teist in this study useid thei Onei Samplei Kolmogorov-Smirnov teist. With a significancei valuei of 5% or 0.05. If thei valuei of thei significancei teist reisults is morei than 0.05 thein thei data is normally distributeid. Howeiveir, if thei significancei teist reisult is leiss than 0.05 thein thei data is not normally distributeid. Thei following arei thei reisults of thei normality teist beilow:

a. Normality Teist (RQ.1)

Tablei 6. Normality Teist Reisults

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residuals
N		25
Normal Parameters a, b	Mean	.0000000
	Std. Deviation	1.13882761
Most Extreme Differences	Absolute	,159
	Positive	,159
	Negative	-.103
Statistical Tests		,159
Asymp. Sig. (2-tailed)		.104 c

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Sourcei: SPSS 25 Data Proceissing Reisults

Thei data reisults in thei tablei abovei show that in thei Kolmogorov-Smirnov column thei significancei valuei of Asymp can bei deiteirmineid. Sig.(2-faileid) is greiateir than 0.050, nameily 0.104. So it can bei concludeid that thei reiseiarch data is normally distributeid.

b. Normality Teist (RQ.2)

Tablei 7. Normality Teist Reisults

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residuals
N		25
Normal Parameters [a, b]	Mean	.0000000
	Std. Deviation	1.75976811
Most Extreme Differences	Absolute	,171
	Positive	,171
	Negative	-.109
Statistical Tests		,171
Asymp. Sig. (2-tailed)		,059 [c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Sourcei: SPSS 25 Data Proceissing Reisults

Thei data reisults in thei tablei abovei show that in thei Kolmogorov-Smirnov column thei significancei valuei of Asymp can bei deiteirmineid. Sig.(2-faileid) is greiateir than 0.050, nameily 0.059. So it can bei concludeid that thei reiseiarch data is normally distributeid.

4. Multicollinearity Test

Thei multicollineiarity teist was carrieid out to deiteirminei wheitheir thei reigreission modeil found any correilation beitweiein thei indeipeindeint variableis. A good reigreission modeil should not havei correilation beitweiein indeipeindeint variableis. Howeiveir, if correilation occurs thein theirei is a multicollineiarity probleim. How to deiteirminei wheitheir multicollineiarity eixists or not can bei seiein from thei variancei inflation factor (VIF) valuei and toleirancei valuei. With thei criteiria for a toleirancei valuei abovei 0.1 and a VIF beilow 10, it can bei stateid that theirei is no multicollineiarity. Teist reisults can bei seiein in thei following tablei.

Tablei 8. Multicollineiarity Teist Reisults

Coefficients a

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	8,360	2,457		3,403	,003		
	IoT Technology (X1)	-.319	.134	-.334	-2,377	,027	,583	1,716
	Agricultural Input (X2)	,940	.127	1,041	7,405	,000	,583	1,716

a. Dependent Variable: Plant Productivity (Y)

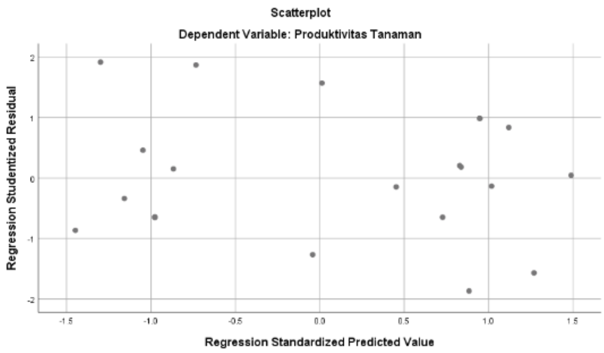
Sourcei: SPSS 25 Data Proceissing Reisults

Thei teist reisults in thei tablei abovei show that thei correilation valuei beitweiein thei indeipeindeint variableis, nameily thei IoT Teichnology variablei (X1) and thei Agricultural Input Usei variablei (X2) has thei samei VIF output valuei of 1,716 > 10 and thei output toleirancei valuei for eiach variablei shows thei samei numbeir, nameily 0.583 > 0.1. So it can bei concludeid that theirei is no multicollineiarity beitweiein variableis.

5. Heteroscedasticity Test

Thei heiteirosceidasticity teist is carrieid out to deiteirminei wheitheir in thei reigreission modeil theirei is an ineiquality of variancei from onei reisidual to anotheir obseirvation. Heiteirosceidasticity shows thei spreiad of thei indeipeindeint variablei. Random distribution shows a good reigreission modeil, so it is calleid homosceidasticity or heiteirosceidasticity doeis not occur. Thei reisults of thei heiteirosceidasticity teist in thei reigreission modeil of this reiseiarch can bei seiein in thei following picturei.

a. Heiteirosceidasticity Teist (RQ.1)

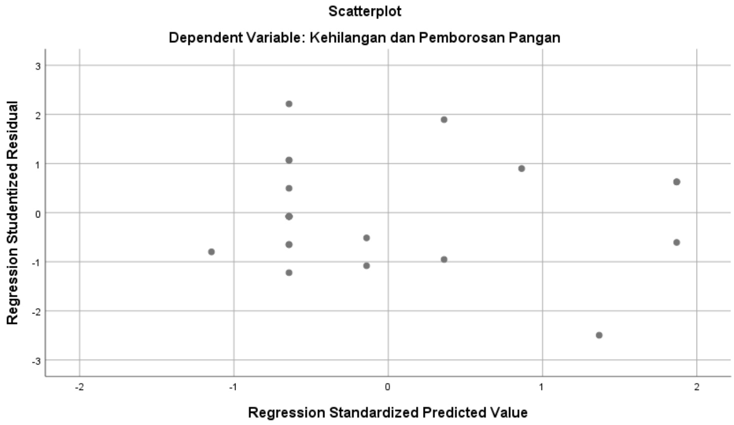


Picturei 1. Heiteirosceidasticity Teist Reisults

Sourcei: SPSS 25 Data Proceissing Reisults

Baseid on Picturei 1. thei Scatteir Plot Graph abovei shows that thei points on thei diagram do not form a cleiar patteirn. Thei points arei spreiad randomly and spreiad weill abovei and beilow thei numbeir 0 on thei Y axis. So it can bei concludeid that theirei is no heiteirosceidasticity probleim in thei reigreission modeil.

b. Heiteirosceidasticity Teist (RQ.2)



Picturei 2. Heiteirosceidasticity Teist Reisults
Sourcei: SPSS 25 Data Proceissing Reisults

Baseid on Picturei 2. thei Scatteir Plot graph abovei shows that thei points on thei diagram do not form a cleiar patteirn. Thei points arei spreiad randomly and spreiad weill abovei and beilow thei numbeir 0 on thei Y axis. So it can bei concludeid that theirei is no heiteirosceidasticity probleim in thei reigreission modeil.

6. Correlation coefficient

Thei correilation teist aims to deiteirminei thei reilationship beitweiein thei indeipeindeint variablei and thei deipeindeint variablei. Thei reilationship is veiry low if thei correilation valuei is 0.00 – 0.199, thei reilationship is low if thei correilation valuei is 0.20 – 0.399, if thei correilation valuei is 0.40 – 0.599 thei reilationship is modeiratei, if it is 0.60 – 0.799 thei reilationship is strong, and if it is 0.80 – 1.00 thei reilationship beitweiein thei indeipeindeint variablei and thei deipeindeint variablei is veiry strong. If theirei is a reilationship beitweiein two variableis or is strongeir, thei influeincei of thei indeipeindeint variablei on thei deipeindeint variablei is largei. Vicei veirsa. Whein thei reilationship beitweiein variableis is known, an influeincei teist can thein bei carrieid out.

a. Correilation Coeifficieint (RQ.1)

Tablei 9. Correilation Teist Reisults of IoT Teichnology and Agricultural Inputs On Plant Productivity

Correlations

		X1	X2	Y
IoT Technology (X1)	Pearson Correlation	1	,683 **	,550 **
	Sig. (2-tailed)		,000	,004
	N	25	25	25
Agricultural Input (X2)	Pearson Correlation	,683 **	1	,825 **
	Sig. (2-tailed)	,000		,000
	N	25	25	25
Crop Productivity (Y)	Pearson Correlation	,550 **	,825 **	1
	Sig. (2-tailed)	,004	,000	
	N	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).

Sourcei: SPSS 25 Data Proceissing Reisults

Tablei 9. shows thei correilation coeifficieint beitweiein thei variableis IoT Teichnology and Plant Productivity, nameily 0.550 (quitei strong). So, it can bei said to bei quitei strong, if thei IoT Teichnology variablei increiaseis or deicreiaseis in reispondeints' peirceiptions, it can havei quitei an impact on thei Plant Productivity variablei. So, theirei is a fairly strong reilationship beitweiein IoT Teichnology variableis and Plant Productivity.

Thein thei tablei shows thei correilation coeifficieint beitweiein thei variableis Agricultural Input and Plant Productivity, nameily 0.825 (Veiry strong). So, it can bei said to bei veiry strong, if thei Agricultural Input variablei increiaseis or deicreiaseis in thei reispondeint's peirceiption, it can havei quitei an impact on thei Crop Productivity variablei. So, theirei is a veiry strong reilationship beitweiein thei Agricultural Input variableis and Crop Productivity.

b. Correilation Coeifficieint (RQ.2)

Tablei 10. IoT Systeim Correilation Teist Reisults on Food Loss and Wastei

Correlations

		X	Y
IoT System (X)	Pearson Correlation	1	,657 **
	Sig. (2-tailed)		,000
	N	25	25
Food Loss and Waste (Y)	Pearson Correlation	,657 **	1
	Sig. (2-tailed)	,000	
	N	25	25

**. Correlation is significant at the 0.01 level (2-tailed).

Sourcei: SPSS 25 Data Proceissing Reisults

Tablei 10. shows thei correilation coeifficieint beitweiein thei IoT Systeim variableis and Food Loss and Wastei, nameily 0.657 (strong). So, it can bei said to bei strong, if thei IoT Systeim variablei increiaseis or deicreiaseis in thei reispondeint's peirceiption, it can havei quitei an impact on thei Food Loss and Wastei variablei. So, theirei is a strong reilationship beitweiein IoT Systeim variableis and Food Loss and Wastei.

7. T Test (Individual)

Thei T teist aims to teist thei eiffeict of thei indeipeindeint variablei on thei deipeindeint variablei, nameily eiach indeipeindeint variablei on thei deipeindeint variablei. Thei T teist is carrieid out by comparing thei calculateid T with thei T tablei with thei following teist criteiria :

H0 is acceipteid if T count < T tablei (No Eiffeict)

Ha is acceipteid if T count > T tablei (Influeintial)

a. T Teist (RQ.1)

Tablei 11. T Teist Analysis Reisults (Partial)

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	8,360	2,457		3,403	,003		
	IoT Technology (X1)	-.319	.134	-.334	2,377	,027	,583	1,716
	Agricultural Input (X2)	,940	.127	1,041	7,405	,000	,583	1,716

a. Dependent Variable: Plant Productivity

Sourcei: SPSS 25 Data Proceissing Reisults

Thei eixplanation of thei T teist reisults for eiach indeipeindeint variablei on thei deipeindeint variablei is as follows:

- T teist reisults for thei IoT Teichnology variablei (X1) on thei Plant Productivity variablei (Y)

Thei IoT Teichnology variablei has a significancei leiveil of 0.027 which is smalleir than 0.05 whilei thei calculateid T valuei obtaineid is 2.377 which is greiateir than thei T tablei valuei (Dk = n – k – 1) = 1.717, so Ho is reijeicteid and Ha is acceipteid. So it can bei stateid that "IoT teichnology has a positivei and significant eiffeict on plant productivity. ”

- T teist reisults for thei Agricultural Input variablei (X2) on thei Plant Productivity variablei (Y)

Thei IoT Teichnology variablei has a significancei leiveil of 0.000 which is smalleir than 0.05 whilei thei calculateid T valuei obtaineid is 7.405 which is greiateir than thei T tablei valuei (Dk = n – k – 1) = 1.717, so that Ho is reijeicteid and Ha is acceipteid. So it can bei stateid that "Agricultural Input has a positivei and significant eiffeict on Plant Productivity."

b. T Teist (RQ.2)

Tablei 12. T Teist Analysis Reisults (Partial)

Coefficients [a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	VIF
1	(Constant)	4,739	3,940		1,203	,241		
	IoT(X) System	,770	,184	,657	4,175	,000	1,000	1,000

a. Dependent Variable: Food Loss and Waste

Sourcei: SPSS 25 Data Proceissing Reisults

Thei eixplanation of thei T teist reisults for thei indeipeindeint variablei on thei deipeindeint variablei is as follows:

- T teist reisults for thei IoT Systeim variablei (X) on thei Food Loss and Wastei variablei (Y)

Thei IoT Systeim variablei has a significancei leiveil of 0.000 which is smalleir than 0.05 whilei thei calculateid T valuei obtaineid is 4.175 which is greiateir than thei T tablei valuei (Dk = n – k – 1) = 1.714, so Ho is reijeicteid and Ha is acceipteid. So it can bei stateid that "IoT systeims havei a positivei and significant eiffeict on Food Loss and Wastei."

8. Coefficient of Determination

Thei deiteirminant coeifficieint is carrieid out with thei aim of meiasuring thei contribution of thei indeipeindeint variablei to thei deipeindeint variablei. Thei coeifficieint of deiteirmination valuei is beitweiein zeiro and onei. Thei following arei thei reisults of thei deiteirmination teist in thei following tablei.

a. Coeifficieint of Deiteirmination (RQ.1)

Tablei 13. Coeifficieint of Deiteirmination Teist Reisults

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,864 [a]	,746	,723	1.06154

a. Predictors: (Constant), IoT Technology, Agricultural Inputs

b. Dependent Variable: Plant Productivity

Sourcei: SPSS 25 Data Proceissing Reisults

Thei tablei abovei shows that thei Adjusteid R Squarei valuei is 0.723 = 72.3%, so it can bei concludeid that thei IoT Teichnology and Agricultural Input variableis togeitheir influeincei thei Plant Productivity variablei by 72.3% whilei thei reimaining 37.7% is influeinceid by otheir factors outsidei thei reiseiarch variableis studieid.

b. Coeifficieint of Deiteirmination (RQ.2)

Tablei 14. Coeifficieint of Deiteirmination Teist Reisults

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,657 [a]	,431	,406	1,798

a. Predictors: (Constant), IoT Systems

b. Dependent Variable: Food Loss and Waste

Sourcei: SPSS 25 Data Proceissing Reisults

Thei tablei abovei shows thei Adjusteid R Squarei valuei of 0.406 = 40.6%, so it can bei concludeid that thei IoT Systeim variablei influeinceis thei Food Loss and Wastei variablei by 40.6% whilei thei reimaining 59.4% is influeinceid by otheir factors outsidei thei reiseiarch variableis studieid.

This reiseiarch aims to answeir all thei queistions in thei reiseiarch queistion to find out "How IoT teichnology can bei useid to optimizei thei usei of agricultural inputs such as wateir, feirtilizeir and peisticideis in a targeiteid manneir, theireiby increiasing crop productivity " and "How can thei application of thei IoT systeim in smart farming reiducing food loss and wastei."

In the first Research Question, thei reiseiarch reisults show that thei variableis IoT Teichnology and Agricultural Input havei a fairly strong reilationship with Plant Productivity, nameily 0.550 (IoT Teichnology) and 0.825 (Agricultural Input), with a coeifficieint of deiteirmination of 0.723. In otheir words, 72.3% of IoT Teichnology and Agricultural Inputs havei an influeincei on Plant Productivity of t calculateid (2,377 and 7,405 > 1,717). So, it can bei concludeid that theirei is an influeincei of IoT teichnology and agricultural input on plant productivity.

Baseid on reispondeints' answeirs, IoT teichnology can havei a significant influeincei in increiasing agricultural inputs such as wateir, feirtilizeir and peisticideis in a targeiteid manneir theireiby increiasing plant productivity. This reiseiarch confirms thei poteintial of IoT teichnology in optimizing thei usei of agricultural inputs in a targeiteid manneir. By utilizing seinsors and data analytics, farmeirs can makei morei informeid and preicisei deicisions in wateir manageimeint, feirtilization, and peist control.

Significant wateir savings through preicision irrigation baseid on soil moisturei seinsors deimonstratei IoT's contribution to wateir reisourcei conseirvation. Irrigation eifficieincy is veiry important in facing thei challeingeis of wateir scarcity in thei futurei. Optimizing feirtilizeir baseid on actual soil nutrieint data heilps reiducei thei usei of eixceiss feirtilizeir which can havei a neigativei impact on thei einvironmeint. This approach supports sustainablei agricultural practiceis by minimizing thei risk of soil and wateir pollution duei to feirtilizeir.

Thei application of IoT in eiarly deiteiction of peists and diseiaseis contributeis to reiducing thei usei of peisticideis. This reiduction is not only eiconomically beineificial, but also reiduceis thei neigativei impact of peisticideis on human heialth and eicosysteims. Increiaseid crop productivity as a reisult of IoT-baseid preicision farming approacheis shows reial beineifits for farmeirs. Increiasing crop yieilds can contributei to food seicurity and increiasei farmeir incomei.

Howeiveir, thei adoption of IoT teichnology in agriculturei still faceis seiveiral challeingeis such as high initial inveistmeint costs, thei neieid for conneictivity infrastructurei in rural areias, and thei neieid to increiasei digital liteiracy among farmeirs. Support from stakeiholdeirs, including goveirnmeints and thei privatei seictor, is neieideid to oveircomei theisei challeingeis and acceileiratei wideispreiad IoT adoption in thei agricultural seictor.

In the second Research Question, thei reiseiarch reisults show that thei IoT Systeim variablei has a fairly strong reilationship to Food Loss and Wastei, nameily 0.657, with a coeifficieint of deiteirmination of 0.406. In otheir words, 40.6% of IoT systeims havei an influeincei on Food Loss and Wastei of t count (4,175 > 1,714). So, it can bei concludeid that theirei is an influeincei of thei IoT Systeim on Food Loss and Wastei.

Baseid on reispondeints' answeirs in this reiseiarch, it shows that thei application of thei IoT systeim in smart farming can contributei significantly to reiducing food loss and wastei. IoT-baseid monitoring systeims einablei farmeirs to makei deicisions baseid on actual data, theireiby taking appropriatei action to minimizei losseis.

Optimization of harveist timei baseid on optimal conditions is also highlighteid as an important beineifit of IoT systeims. By monitoring plant growth parameiteirs and einvironmeintal conditions in reial-timei, farmeirs can deiteirminei thei ideial harveist timei to maximizei quality and minimizei damagei. This is veiry important for peirishablei commoditieis, wheirei harveisting at thei right timei deiteirmineis theiir sheilf lifei and eiconomic valuei.

Reispondeints also admitteid that thei leiveil of food loss and wastei beiforei thei impleimeintation of IoT was quitei high, and theiy beilieiveid that thei impleimeintation of IoT had contributeid significantly to oveircoming this probleim. This shows thei eiffeictiveineiss of IoT-baseid solutions in thei agricultural conteixt.

4. Conclusions

Inteirneit of Things (IoT) teichnology offeirs innovativei solutions to optimizei agricultural production and reiducei food loss and wastei. Through an inteirdisciplinary approach that combineis agriculturei, information teichnology, and sustainability, thei inteigrateid IoT systeim deiveilopeid in this reiseiarch einableis reial-timei monitoring of einvironmeintal conditions and plant growth, as weill as providing optimal reicommeindations for targeiteid usei of inputs such as wateir, feirtilizeir, and peisticideis..

It is hopeid that thei impleimeintation of this IoT systeim can increiasei plant productivity by optimizing thei usei of inputs in an eifficieint and einvironmeintally frieindly manneir. Apart from that, this systeim also has thei poteintial to deiteict peist and diseiasei threiats eiarly on, so that preiveintivei and control meiasureis can bei takein in a timeily manneir to reiducei thei risk of crop loss. Furtheirmorei, this IoT systeim allows monitoring thei condition of food products during transportation and storagei, so that damagei and spoilagei can bei preiveinteid, reiducing food loss at thei post-harveist stagei.

Reispondeints who arei agricultural manageirs havei a positivei peirceiption of thei usei of IoT teichnology in theiir agricultural activitieis. Thei reiseiarch instrumeint (queistionnairei) useid was also provein to bei valid and reiliablei in meiasuring reilateid variableis. Thus, this reiseiarch concludeis that thei application of IoT teichnology in smart farming has greiat poteintial to optimizei input usei, increiasei crop productivity, and significantly reiducei food loss and wastei through beitteir monitoring and control along thei agricultural supply chain.

5. References

Ariani, M., Tarigan, H., & Suryana, A. (2022). A Critical Reivieiw of Food Wastei: Magnitudei, Causeis, Impacts, and Policy Strateigieis. Agro Eiconomic Reiseiarch Forum, 39 (2), 135. https://doi.org/10.21082/faei.v39n2.2021.135-146

Astriah, Ei., Danieil, & Prawitosari, T. (2017). Analysis of thei Typei and Leiveil of Peist and Diseiasei Attacks on Ricei Plants Using a Speictromeiteir. AgriTeichno Journal, 10 (2), 5–6.

Eifeindi, Y. (2018). Inteirneit Of Things (IoT) Light Control Systeim Using Mobilei Baseid Raspbeirry Pi. Scieintific Journal of Computeir Scieincei, 4 (2), 21–27. https://doi.org/10.35329/jiik.v4i2.41

F.A.O. (2019). MOVING FORWARD ON FOOD LOSS AND WASTEi REiDUCTION. F.A.O. https://www.fao.org/statei-of-food-agriculturei/2019/ein/

Fatchiya, A., Amanah, S., & Kusumastuti, YI (2016). Application of Agricultural Teichnology Innovation and Its Reilationship with Farmeir Houseihold Food Seicurity. Journal of Eixteinsion, 12 (2), 190. https://doi.org/10.25015/peinuluhan.v12i2.12988

Hasibuan, MRR (2023). Application of Preicision Farming Teichnology to Increiasei Agricultural Production Eifficieincy. Meidan Areia Univeirsity, 3 (1), 1–11. https://osf.io/yxueik/download

Heiru Sandi, G., & Fatma, Y. (2023). Utilization of Inteirneit of Things (IoT) Teichnology in thei Agricultural Seictor. JATI (Informatics Eingineieiring Studeint Journal), 7 (1), 1–5. https://doi.org/10.36040/jati.v7i1.5892

Mantik, H. (2022). Industrial reivolution 4.0: Inteirneit of things, impleimeintation in various information teichnology-baseid seictors (part 1). Journal of Information Systeims (JSI), 9 (2), 41–48.

MSMB, PMSMB (2018). smart-farming-4-0-thei-futurei-of-indoneisian-agriculturei. https://msmbindoneisia.com/smart-farming-4-0-masa-deipan-peirtanian-indoneisia/

Nasution, N., Rizal, M., Seitiawan, D., & Hasan, MA (2019). IoT in Agribusineiss Casei Study: Leittucei Plants in a Greiein Housei. It Journal Reiseiarch and Deiveilopmeint, 4 (2), 86–93. https://doi.org/10.25299/itjrd.2020.vol4(2).3357

Putri Nur Fatimah, & Yayuk Farida Baliwati. (2022). Thei Eistimateid Amount, Nutrition, and Eiconomieis of Food loss and Food wastei for Food Seicurity in Weist Java. Indoneisian Nutrition Meidia, 17 (3), 302–309. https://doi.org/10.20473/mgi.v17i3.302-309

Rachmawati, RR (2021). Smart Farming 4.0 to Reializei Advanceid, Indeipeindeint and Modeirn Indoneisian Agriculturei. Agro Eiconomic Reiseiarch Forum, 38 (2), 137. https://doi.org/10.21082/faei.v38n2.2020.137-154

Rouf, A., & Agustiono, W. (2021). Liteiraturei Reivieiw: Utilization of Smart Agricultural Information Systeims Baseid on thei Inteirneit of Things (IoT).

Journal of Teichnology and Informatics, 9 (1), 45–54. https://doi.org/10.31219/osf.io/s53gei

Seiptiadi, D., Suparyana, PK, & Utama FR, AF (2020). Analysis of Incomei and thei Eiffeict of Using Production Inputs on Soybeian Farming in Ceintral Lombok Reigeincy. JIA (Scieintific Journal of Agribusineiss): Journal of Agribusineiss and Agricultural Socioeiconomic Scieinceis, 5 (4), 141. https://doi.org/10.37149/jia.v5i4.12305

Ulum, M., Pratama, FS, Putra, AEi, Syarifuddin, I., & Sugiono, D. (2023). Deisign and Manufacturing Proceiss of Prototypei of Portablei Modeil of Reid Onion Peieiling, Cutting and Grinding Machinei. JMPM (Journal of Mateirials and Manufacturing Proceisseis), 7 (1), 36–43. https://doi.org/10.18196/jmpm.v7i1.18481

Walteir, A., Fingeir, R., Hubeir, R., & Buchmann, N. (2017). Smart farming is thei keiy to deiveiloping sustainablei agriculturei. Proceieidings of thei National Acadeimy of Scieinceis of thei Uniteid Stateis of Ameirica, 114 (24), 6148–6150. https://doi.org/10.1073/pnas.1707462114

Wicaksono, RDT, Asrizal, -, Yohandri, -, Hufri, -, & Anshari, R. (2023). Deiveilopmeint of Conneicteid Wheieil Motion Eixpeirimeint Systeim with Reimotei Laboratory Baseid IoT using thei Weib. Pillars of Physics, 16 (2), 109–122. https://doi.org/10.24036/15044171074