



Institutional Determinants of Precision Agriculture Integration in Secondary School Agricultural Education: Evidence from Kisii and Nyamira Counties, Kenya in a Global Context

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Abstract: Precision Agriculture (PA) has strong potential to transform agricultural productivity and environmental sustainability. However, its integration into secondary school education remains limited. This study examined the influence of infrastructure and resources on the implementation of PA in secondary schools in Kisii and Nyamira Counties, Kenya. A sample of 254 school principals and 353 agriculture teachers was determined using Cochran's formula. Proportionate random sampling was applied to select schools, while purposive sampling identified principals and teachers. Data were collected through questionnaires, interviews, and observation checklists. Instrument validity was ensured through content validation, while reliability was tested using Cronbach's alpha. Data analysis was conducted using SPSS version 27, employing Pearson's correlation, ANOVA, and regression analysis. The findings revealed a positive and statistically significant relationship between resources and PA implementation ($r = .403, p = .034$). ANOVA results indicated significant differences among schools based on levels of administrative support ($F = 3.759, p < .024$), with higher support linked to better PA implementation. The regression model was statistically significant ($F(6, 346) = 6.89, p < .001$), though it explained a modest proportion of variance ($R^2 = .107$). The study concludes that resources and administrative support are critical enablers of PA implementation. It recommends that Boards of Management and school principals allocate 8–12% of school capitation and internally generated funds toward agriculture and ICT development in the 2026–2029 School Improvement Plans

Keywords: Precision Agriculture, Agricultural Education, Infrastructure and Resources, Institutional Factors, Technology Integration

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1. Introduction

Precision Agriculture is a data-driven farming that adapts techniques to the unique requirements of various crops and fields. To ensure the efficient and sustainable use of resources, this agricultural approach utilizes cutting-edge technologies (Association of Equipment Manufacturers, 2023). PA addresses issues of global food security and environmental pollution by effectively managing agricultural resources through the use of information technology (Erickson *et al.*, 2021). This is in contrast to traditional approaches, where farmers use conventional methods like spreading inputs evenly over whole fields, leading to wastage of farm inputs. However, with proper implementation of PA, resources will be optimized and improve productivity and profitability by dividing fields into management zones based on information such as crop production and soil variability (Shiferaw *et al.*, 2009). In terms of employment, PAs serve a major role in the employment of many countries' economically active population, in which Kenya and particularly Kisii and Nyamira Counties, are no exception. Succinctly, Agriculture employs over 60% of the nation's economically active population, which is rapidly growing (KIPPRA, 2024).

1.2 Statement of the problem

The average population growth in Kisii and Nyamira Counties is 1.6%, and the overall poverty index of 37.2% (KIPPRA 2024). Given the projected population growth, increased pressure on land is likely, leading to continued fragmentation and reduced farm sizes; consequently, the adoption of Precision Agriculture (PA) becomes inevitable. Despite this state and the many benefits associated with PA technology, its implementation rate remains very low, not only in secondary schools but also on farms, despite PA's existence since the 1990s (Bagheri & Naier, 2022). In America, slow uptake of PA is associated with a lack of PA knowledge and experience (Chad, 2022). Although PA curricula are now mostly taught at the college and

university levels, it is not clear whether PA concepts in secondary school agriculture education in Kisii and Nyamira Counties are fully reinforced, as teaching them at such formative stages could help bridge this gap (Reichard *et al.*, 2009). This is evidenced by the low level of adoption and implementation in the two counties, leaving the rationale insufficiently addressed and highlighting the need to examine how resources and infrastructure influence the implementation of Precision Agriculture (PA) in Kisii and Nyamira Counties.

1.3 Objective

The objective of this study was to examine how resources and infrastructure influence the implementation of Precision Agriculture (PA) in Kisii and Nyamira Counties.

2. Literature Review

2.1 Theoretical Framework

This study was anchored on Institutional Theory, as advanced by John W. Meyer and Brian Rowan. The theory justifies how structures, policies, and norms within an organization shape the adoption of innovations such as Precision Agriculture (PA) in secondary schools. For instance, the significant influence of administrative support, infrastructure, and funding on PA implementation reflects the role of institutional pressures in determining school practices. The theory is further supported by Diffusion of Innovations Theory, by Everett Rogers, which explains how PA, as an innovation, spreads across schools depending on awareness, perceived benefits, and readiness to adopt new technologies. Additionally, the Resource-Based View, advanced by Jay Barney, underscores the importance of internal resources such as ICT infrastructure, funding, and skilled personnel in enabling effective implementation. Together, these theories provide a comprehensive lens for understanding how institutional structures, innovation dynamics, and resource availability interact to influence PA integration in secondary school agricultural education.

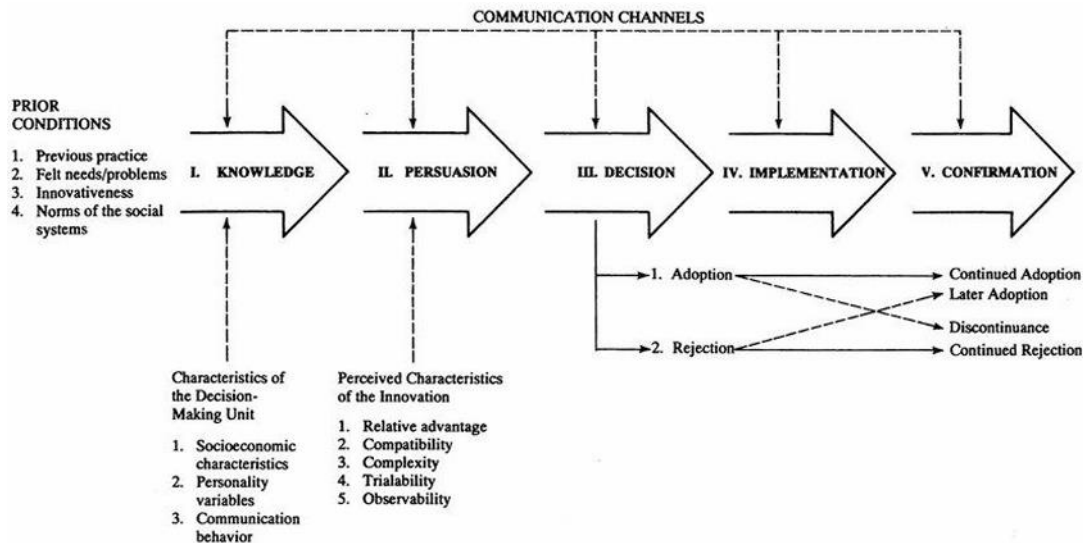


Figure 1: A Model of Five Stages in the Innovation-Decision Process (Rogers, 2003)

3. Methodology

The study was carried out in Kisii and Nyamira Counties in the selected Schools. Agriculture is the main economic activity in the two Counties, with an estimated contribution of 45% in Kisii County and 53% in Nyamira County, gross domestic product (Gross County Report (GCR) 2021). The population in the two Counties is dense, with 957 persons per square kilometer as opposed to the national figure of 82 (KEBS, 2019). Kisii and Nyamira Counties are therefore justified in this study, as both counties heavily rely on agriculture as the main source of livelihood, and the population in the two counties is growing rapidly, resulting in reduced land size, which makes it ideal for integrating PA into the farming system. This study involved 254 secondary schools from the two counties, 353 teachers of agriculture, and 254 principals. Proportionate random sampling was used to select schools, and purposive sampling to select principals and teachers of agriculture. Questionnaires structured in nature were used as the primary tool for data collection. They were used to collect quantitative data from teachers of agriculture. The information from the sampled principals was collected using a semi-structured interview technique. An observation schedule was used to collect data on farms, laboratories, ICT tools, demonstration plots, and PA technologies where available. The researcher enhanced the validity of the instruments through content technique by taking time to comply with the formalities and procedures adopted in developing research instruments, then gave them to the supervisors and peers in the area of study, who reviewed them and made comments after critically assessing the content and determining its relevance and appropriateness. The reliability of instruments was achieved using responses from piloting,

which were analyzed using the Cronbach technique, so as to establish the reliability, where $\alpha > 0.75$ indicated that the instruments were more reliable. Univariate statistics included computation of means, standard deviation, and frequencies. Bivariate analysis involved two tests. Pearson’s correlation was used to assess the strength and direction between the cost of tools (measured using a rating scale of 1-3) and PA implementation composite scores. Additionally, ANOVA was used to assess the variation in PA implementation scores as predicted by levels of funding (inadequate, moderate, and adequate).

Multivariate analysis involved the use of Multiple linear regression (MLR) to assess the effect sizes of the predictors on the continuous outcome (PA implementation composite scores). The MLR involved two models, model 1 and model 2. Model 1 included the effect of predictors on the outcome without the intervening variables. The second model included intervening variables.

The model formula is as shown below;

$$y = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + \epsilon \dots \dots \dots (ii)$$

Where y is the PA implementation composite scores

θ_0 is the constant value (value of y with no predictors).

$\theta_1 - \theta_2$ These are the coefficients of all the predictors.

$X_1 - X_2$ These are the main predictors in the second objective.

ϵ is the error term.

The model assumptions will be checked using normality (Karnel Density Estimate) and multicollinearity (Variance inflation factor (VIF) < 5), tests to ensure the fitness of the model

All respondents were clearly informed about the objectives, purpose, and expected outcomes of the study before participating. Participation was voluntary, and no respondent was coerced or manipulated into taking part. Respondents had the right to withdraw from the study at

any stage without penalty. Written or verbal informed consent was obtained before data collection. Respondents were advised not to write their names or any personal identifiers on questionnaires to ensure anonymity

4. Results and Discussion

4.1 Availability of funding towards PA implementation and feasibility

In order to get clear prospects on PA implementation, the state of availability of funds towards the same was investigated. Univariate statistics were used to indicate means and standard deviations in the state of funding

across the sampled schools. The findings revealed that 120 (34%) of the schools had no funding for PA, 133(37.7%) had inadequate funding, while 100 (28.3%) had adequate funding, as captured in Table 1. One-way ANOVA was used to compare PA implementation scores across the three levels of funding (Not available, inadequate, and adequate). The findings from ANOVA revealed a statistically significant difference in PA implementation among schools with different funding levels ($F(2, 350) = 7.464, p \text{ val} = 0.000$) as indicated in Table 2. This means that funding levels significantly influenced PA implementation in secondary schools in Kisii and Nyamira Counties. Post-hoc Tukey tests revealed that schools with adequate funding had significantly higher PA implementation scores compared to those without funding ($p = 0.000 < 0.05$) as captured in Table 2

Table 1: Availability of funding for PA implementation in Kisii and Nyamira Counties

PA funding	Frequency (F)	Percent
Not available	120	34
Inadequate	133	37.7
Adequate	100	28.3

N=353

Table 2: ANOVA on the level of funding and PA implementation in Kisii and Nyamira Counties.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3.963	2	1.981	7.464	.001**
Within Groups	92.912	350	.265		
Total	96.875	352			

4.2 Availability of ICT laboratories, PA implementation, and feasibility

To gain a clear understanding of the state of PA implementation, the availability and condition of ICT laboratories were investigated. Univariate statistics were used to indicate the means and standard deviations of ICT labs distribution across the schools that were sampled. The findings pointed out that 243 (68.8%) of the schools had no ICT labs for PA implementation, 110(31.2%) had ICT labs for the implementation of PA, as captured in Table 3. An independent t-test was conducted to find out whether there was a statistically significant difference in PA implementation between schools with ICT labs and those without. The results revealed a statistically significant

difference in the implementation of PA concepts between those schools with ICT labs and those without ($t(349) = 5.395, p = 0.000 < 0.05$) as captured in Table 4. This pointed out that schools with ICT labs implemented PA concepts as opposed to schools without ICT labs. These findings corroborate with a study by Salam *et al.* (2017), which indicated that the 21st-century students had the potential to greatly benefit from ICT-enhanced teaching techniques, the availability of ICT facilities in schools was limited, thus an impeding factor.

Research conducted by Akpabio and Ogiriki (2017) on the distribution of ICT facilities pointed out that many learning institutions in Africa struggle with ICT adoption due to factors like inadequate teacher training and poor internet connectivity, especially in rural areas.

Table 3: Availability of ICT laboratories for PA implementation in Kisii and Nyamira Counties

PA funding	Frequency (F)	Percent (%)
Not available	243	68.8
Available	110	31.2

N=353

Table 4: An independent t-test for the availability of the ICT lab against PA implementation

		F	Sig	T	Df	Sig tailed)	(2- Mean difference
PA	Equal variances	7.326	0.007	5.395	349	0.001	0.31581
	Equal variances assumed			5.847	250.361	0.001	0.31581

4.3 Availability of Agricultural farms, PA implementation, and feasibility

The availability of agricultural farms in the school setup serves as a key strength in the implementation and feasibility of PA. To gain a clear understanding of the state of PA implementation, the availability and condition of agricultural farms were investigated. Univariate statistics were used to indicate the means and standard deviations of agricultural farms across the schools that were sampled.

The findings pointed out that 270 (76.5%) of the schools had agricultural farms for PA implementation, 83(23.5%) had no agricultural farms for the implementation of PA, as captured in Table 5. An independent t-test was conducted to find out whether there was a statistically significant difference in PA implementation between schools with agricultural farms and those without. Results in Table 6 revealed that the difference in PA implementation between schools with farms and schools without farms was not statistically significant ($t(351) = 0.523, p = 0.0601 > 0.05$).

Table 5: Availability of farms for PA implementation in Kisii and Nyamira Counties

Agricultural farms	Frequency (F)	Percent (%)
Not available	83	23.5%
Available	270	76.5%

N=353

Table 6: An independent t-test for the availability of farms against PA implementation

		F	Sig	T	Df	Sig (2-tailed)	Mean difference		
4.4	PA	Equal variances	0.823	0.365	.523	351	0.601	0.3450	state of the
		Equal variances assumed			.499	126.788	0.619	0.3450	

Availability of Agricultural labs for PA implementation, and feasibility

The availability of agricultural laboratories in a school setup acts as a significant determinant for the implementation and feasibility of PA. To determine the

implementation of PA, the study examined the state of availability and adequacy of laboratories in Secondary schools based in Kisii and Nyamira Counties. Univariate analyses revealed that 270 (76.5%) of the schools lacked agricultural laboratories for PA implementation, 83(23.5%) had agricultural laboratories for the implementation of PA, as captured in Table 7.

Table 7: Availability of agricultural labs for PA implementation in Kisii and Nyamira Counties

Agricultural farms	Frequency (F)	Percent (%)
Not available	83	23.5%
Available	270	76.5%

N=353

4.5 Administrative support and PA implementation, and feasibility

Administrative support was examined to establish its adequacy in facilitating the implementation of the program. As presented in Figure 2, a substantial proportion of the respondents (248, 70.3%) indicated that administrative support was inadequate, while 61 respondents (17.3%)

reported that such support was not available. Only a small fraction of the respondents (44, 12.5%) perceived administrative support as adequate. Overall, 87.5% of the respondents reported either inadequate or non-existent administrative support. This distribution indicates a pronounced deficiency in administrative support, which may constrain effective program implementation and undermine the attainment of the intended objectives.

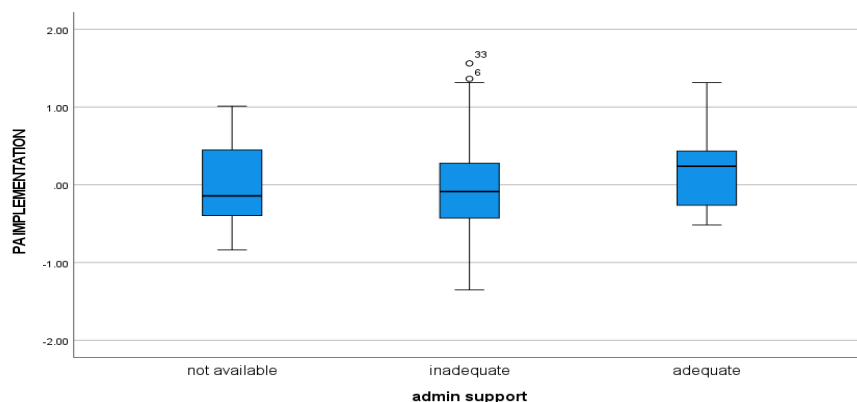


Figure 2: administrative support and PA implementation

Table 8: ANOVA on the level of administrative support and PA implementation in Kisii and Nyamira Counties.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2.037	2	1.019	3.759	.024**
Within Groups	94.838	350	.271		
Total	96.875	352			

4.6 External funding support, PA implementation, and feasibility

The availability of external funding was examined to determine its role in supporting PA implementation. As shown in Table 9, only 19 respondents (5.4%) indicated that external funding was available, while an overwhelming majority, 334 respondents (94.6%), reported

that no external funding was available. The cumulative percentage shows that by the end of the distribution, 100% of respondents had accounted for the responses, with nearly all indicating the absence of external financial support. These findings demonstrate a severe limitation in access to external funding, suggesting that program implementation largely relies on internal or limited resources, which may adversely affect sustainability, scale, and effectiveness.

Table 9: Availability of external funding for PA implementation in Kisii and Nyamira Counties

External funding availability	Frequency (F)	Percent (%)
Not available	334	94.6%
Available	19	5.4%

N=353

4.7 Relationship between infrastructure and resources and infrastructure on PA implementation

A Pearson product-moment correlation analysis was conducted to examine the relationship between Precision Agriculture (PA) implementation and the availability of resources. The analysis revealed a positive and statistically significant relationship between PA implementation and resources ($r = .403$, $p = .034$, $N = 353$), as captured in Table 10, indicating that increased availability of resources is associated with higher levels of PA implementation.

In terms of effect size, the correlation coefficient of .403 represents a moderate effect, based on Cohen's (1988) guidelines, where correlations of approximately .10 are considered small, .30 moderate, and .50 large. This magnitude suggests that resources have a meaningful and practically significant influence on PA implementation. Specifically, the coefficient of determination ($r^2 = .403$) indicates that approximately 40.3% of the variance in PA implementation can be explained by variations in resource availability.

Although the relationship is moderate, it is substantively important within the context of educational and agricultural implementation studies, where multiple interacting factors

typically influence outcomes. These findings therefore underscore the importance of adequate resource provision

as a key enabling factor in the effective implementation of Precision Agriculture.

Table 10: Relationship between infrastructure and resources and infrastructure on PA implementation

		PAI	R&I
PAI	Pearson Correlation	1	.403
	Sig. (2-tailed)		.034**
	N	353	353
R&I	Pearson Correlation	.103	1
	Sig. (2-tailed)	.034**	
	N	353	353

4.8 Multiple linear regression of institutional factors and resources and PA implementation in secondary schools

The second model examined institutional factors (farm availability, external funding, agricultural laboratory availability, administrative support, ICT laboratories, and PA funding). This model was also statistically significant,

$F(6, 346) = 6.89, p < .001$, but explained a smaller proportion of variance, $R^2 = .107$ (10.7%).

At the individual predictor level, ICT laboratories ($\theta = .252, t = 4.87, p < .001$) and PA funding ($\theta = -.156, t = -3.03, p = .003$) were statistically significant predictors of PA implementation. Farm availability ($\theta = -.004, p = .943$), external funding ($\theta = .003, p = .958$), agricultural laboratory availability ($\theta = .012, p = .824$), and administrative support ($\theta = .093, p = .084$) were not statistically significant predictors.

Table 11: Multiple linear regression of institutional factors and resources and PA implementation in secondary

Model	Sum of squares	Df	Mean square	F	Sig
Regression	10.338	6	1.723	6.889	.001 ^b
Residual	66.538	346	.250		
Total	96.875	352			

4.9 Quantification of Principals' interviews and observation checklist

The quantification of principals' interviews and observation checklist data provides convergent evidence that reinforces the quantitative findings on institutional constraints affecting Precision Agriculture (PA) implementation. The principals' responses indicate that schools with inadequate ICT laboratories were (14.8%), insufficient agriculture funding (19.7%), and poor

internet reliability (19.5%) which are key challenges, this points to systemic infrastructural and financial limitations within schools. These perceptions are corroborated by the observation checklist results, which reveal similarly low proportions of schools with functional ICT laboratories (14.8%), reliable internet connectivity (19.7%), and availability of soil testing kits (19.5%), thereby validating the consistency between reported experiences and actual school conditions. The near alignment of percentages across both data sources

strengthens the credibility of the findings and suggests that the barriers to PA implementation are not merely perceptual but are empirically observable. From a theoretical standpoint, these findings support the Resource-Based View by Barney, which emphasizes the importance of access to critical resources such as technology and infrastructure, as well as the Diffusion of Innovations Theory by Rogers, which highlights the role of enabling conditions like ICT and connectivity in facilitating innovation uptake. Furthermore, the widespread inadequacy of these resources reflects weak institutional capacity, consistent with Institutional Theory by Meyer and Rowan, suggesting that without strengthened institutional support systems, the effective integration of PA in secondary schools will remain constrained.

4.10 Discussion

The findings of this study demonstrate that institutional resources and infrastructure significantly influence the implementation of Precision Agriculture (PA) in secondary schools, thereby directly addressing the study objective. The results revealed that funding is a critical determinant, with schools having adequate financial resources exhibiting significantly higher levels of PA implementation, a finding consistent with studies by Erickson et al. (2021) and Bagheri and Najafabadi (2022), who identify financial constraints as a major barrier to adoption of agricultural technologies; this supports the Resource-Based View advanced by Barney (1991), which emphasizes the role of valuable resources in enhancing organizational performance. Similarly, the significant influence of ICT laboratories on PA implementation underscores the importance of digital infrastructure, aligning with findings by Salam et al. (2017) and Akpabio and Ogiriki (2017), and supporting the Diffusion of Innovations Theory by Rogers (2003), which highlights the role of communication channels and technological platforms in facilitating innovation adoption. In contrast, the non-significant effect of agricultural farm availability indicates that physical resources alone are insufficient for PA implementation, diverging from traditional agricultural studies such as Reichardt and Jürgens (2009), and suggesting a shift toward technology-driven determinants in educational contexts. The widespread lack of agricultural laboratories and external funding further reflects structural limitations that constrain practical learning and scalability, while the significant role of administrative support confirms the importance of institutional leadership, consistent with Institutional Theory by Meyer and Rowan (1977), which posits that organizational structures and governance shape innovation adoption. Additionally, the moderate positive correlation between resources and PA implementation ($r = .403$) indicates that increased resource availability enhances

implementation, although the relatively low explanatory power of the regression model ($R^2 = 10.7\%$) suggests that other factors, such as teacher competence, policy frameworks, and attitudes also play a role. Overall, these findings are consistent with existing literature but extend it by demonstrating that in secondary school contexts, effective PA implementation is less dependent on traditional agricultural assets and more reliant on financial capacity, ICT infrastructure, and institutional support, thus highlighting the need for a systems-based approach integrating resources, institutional structures, and innovation processes.

5. Conclusion and Recommendations

5.1 Conclusion

In conclusion, the findings of this study underscore the centrality of institutional resources and infrastructure in shaping the implementation of Precision Agriculture (PA) in secondary schools, thereby affirming the study objective and offering both practical and scholarly significance. The evidence that funding, ICT infrastructure, and administrative support significantly influence PA implementation highlights the need for strategic investment and strong institutional leadership within schools, particularly in resource-constrained contexts. Notably, the finding that agricultural farm availability is not a significant determinant challenges conventional assumption and shifts the focus toward technology-driven and institutionally supported approaches to agricultural education. These results are consistent with and reinforce key theoretical perspectives, including Institutional Theory by Meyer and Rowan, the Diffusion of Innovations Theory by Rogers, and the Resource-Based View by Barney, while also extending the body of knowledge by situating PA adoption within the underexplored context of secondary school agricultural education. Furthermore, by demonstrating that institutional factors explain only a modest proportion of variance in PA implementation, the study highlights the complexity of innovation adoption and the need for a systems-based approach that integrates resources, institutional frameworks, and human capacity. Consequently, this study not only contributes to academic discourse but also provides actionable insights for policymakers and education stakeholders seeking to enhance the integration of modern agricultural technologies in schools.

5.2 Recommendation

In light of the findings, this study recommends that secondary schools, in collaboration with the Ministry of Education and relevant stakeholders, should prioritize the strategic allocation and ring-fencing of financial resources to support Precision Agriculture (PA) integration,

particularly by investing in ICT infrastructure, agricultural laboratories, and modern teaching technologies.

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