



# A Model for the Effective Adoption and Integration of Precision Agriculture in the Secondary School Agriculture Curriculum: Evidence from Kisii and Nyamira Counties, Kenya

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**Abstract:** Precision Agriculture (PA) is a data-driven approach that enhances efficiency, productivity, and sustainability in agriculture. Despite its potential, its integration into secondary school curricula remains limited, particularly in developing countries. This study developed an empirically grounded model for the adoption and integration of PA into Competency-Based Education (CBE) in secondary schools in Kisii and Nyamira Counties, Kenya. A concurrent mixed-methods design was employed, involving 353 agriculture teachers and 254 principals. Quantitative data were analyzed using correlation and multiple regression analyses, while qualitative data were analyzed thematically. Findings revealed that teacher preparedness is the strongest predictor of PA implementation ( $R^2 = 0.784$ ), institutional resources act as enablers ( $R^2 = 0.107$ ), and systemic barriers function as suppressors ( $R^2 = 0.095$ ). The study proposes a three-layer adoption model integrating teacher capacity, institutional support, and systemic constraints. The model provides a scalable framework for integrating emerging agricultural technologies into secondary education systems.

**Keywords:** Precision Agriculture, Curriculum Integration, Competency-Based Education, Teacher Preparedness, Institutional Resources, Systemic Barriers

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## 1. Introduction

Agriculture remains a central pillar of Kenya's economy, employing a significant proportion of the population and contributing substantially to food security and national development (KIPPRRA, 2024). However, the sector faces increasing challenges, including population growth, land fragmentation, declining soil fertility, and climate variability. These challenges necessitate adopting efficient and sustainable farming practices. Precision Agriculture

(PA), which relies on technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), and data analytics, provides a viable solution by enabling site-specific management of agricultural inputs (Erickson et al., 2021). In the education sector, Kenya has adopted Competency-Based Education (CBE), which emphasizes the development of practical skills, critical thinking, and problem-solving abilities. Agriculture, as a practical subject, is well-positioned to integrate PA concepts to prepare learners for modern agricultural

practices. However, despite the inclusion of some technology-related concepts in the curriculum, the actual implementation of PA in secondary schools remains limited (KICD, 2019). The gap between curriculum intentions and classroom practice raises concerns about the preparedness of students to engage in modern agriculture. This gap is particularly evident in Kisii and Nyamira Counties, where agriculture is the primary livelihood, yet land sizes are shrinking, and productivity challenges persist. Therefore, there is a need to develop a structured model that explains how PA can be effectively adopted and integrated into secondary school agriculture curricula.

## 2. Literature Review

Precision Agriculture refers to the application of technology and data analytics to optimize agricultural inputs and improve productivity while minimizing environmental impact (Shannon et al., 2018). It involves the use of tools such as sensors, drones, and mapping technologies to monitor and manage variability in agricultural fields (Balafoutis et al., 2017). By applying inputs such as fertilizers and water at the right time and place, PA enhances efficiency and sustainability.

Teacher preparedness is widely recognized as a critical factor in the successful implementation of educational innovations. It encompasses subject knowledge, pedagogical skills, technological competence, and attitudes toward innovation (Heidenreich et al., 2018). Studies indicate that many agriculture teachers lack adequate training in PA technologies, limiting their ability to integrate these concepts into teaching (FAO, 2021). In developing countries, this challenge is compounded by limited access to professional development opportunities and insufficient exposure to modern agricultural technologies. Furthermore, teachers' attitudes toward technology influence their willingness to adopt new practices. Positive attitudes and confidence in using ICT tools are associated with higher levels of implementation, while resistance to change can hinder adoption. The availability of institutional resources is essential for the effective implementation of PA. These resources include ICT infrastructure, school farms, laboratories, and financial support. Research shows that schools with adequate infrastructure are more likely to integrate technology into teaching (Manning et al., 2022). ICT tools enable students to engage in data-driven learning, while school farms provide opportunities for the practical application of PA concepts. However, in many developing regions, schools face challenges such as inadequate funding, poor infrastructure, and limited access to modern technologies. These constraints limit the ability of teachers to implement PA effectively. Several barriers hinder the adoption of PA in secondary education. These include high costs of technology, lack of training, inadequate infrastructure, and limited policy support (Bagheri & Naier, 2022).

Institutional barriers, such as a lack of administrative support and misalignment between curriculum and practice, further complicate implementation. In addition, time constraints and competing academic priorities reduce the emphasis placed on practical agricultural training. These challenges highlight the need for a comprehensive approach that addresses both enabling and constraining factors. This study is anchored on three key theories: Diffusion of Innovation Theory (Rogers, 2003): which explains how new technologies are adopted within a social system and highlights the importance of knowledge and communication. Systems Theory (Bertalanffy, 1968): Emphasizes the interdependence of various components within an organization, such as teachers, resources, and policies. Constructivist Learning Theory: Supports experiential and learner-centered approaches, which are central to CBE. Together, these theories provide a foundation for understanding how PA can be integrated into education systems through the interaction of multiple factors.

## 3. Methodology

The study employed a mixed-methods research design to capture both quantitative and qualitative data. 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. Data were collected using questionnaires from teachers, interviews, observation checklists, and document analysis. Quantitative data were analyzed using descriptive statistics, correlation, and regression analysis, while qualitative data were analyzed thematically. This approach enabled a comprehensive understanding of the factors influencing PA implementation and informed the development of the proposed 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

The findings indicate that teacher preparedness has a strong positive influence on PA implementation ( $r = 0.836$ ,  $p < .001$ ),  $R^2 = .784$ . Teachers with higher levels of ICT competence, subject knowledge, and teaching experience are more likely to integrate PA into their lessons. Institutional resources, including ICT laboratories ( $\beta = .252$ ,  $t = 4.87$ ,  $p < .001$ ) and funding (.156,  $t = 3.03$ ,  $p = .003$ ,

show a moderate positive influence. Schools with better infrastructure provide more opportunities for practical learning and technology integration. However, barriers such as inadequate funding, poor infrastructure, and lack of training negatively affect implementation. These barriers reduce the effectiveness of both teacher preparedness and institutional resources.

#### 4.1 Proposed Model for PA Integration

The study proposes a three-component model for the adoption and integration of PA: Teacher Preparedness (Core Driver) accounting for the largest proportion of explained variance ( $R^2 = .784$ ) and exhibiting a strong positive association with implementation ( $r = .836$ ,  $p < .001$ ), thereby justifying its placement as the core mediating mechanism in the model: This component represents the central determinant of PA implementation. It includes: Subject matter knowledge, ICT competence, Pedagogical skills, Attitudes toward innovation. Background characteristics, particularly age ( $\beta = .702$ ,  $p < .001$ ) and years of teaching experience ( $\beta = .071$ ,  $p = .009$ ), exerted significant but largely indirect effects, supporting their conceptualization as distal determinants whose influence operates primarily through preparedness. Institutional Resources (Enablers): contributed additional explanatory power to PA implementation, with ICT laboratories ( $\beta = .252$ ,  $p < .001$ ) and PA funding ( $\beta = .156$ ,  $p = .003$ ) emerging as significant predictors, although the overall model explained a comparatively smaller proportion of variance ( $R^2 = .107$ ), thus positioning these factors as contextual enablers rather than primary drivers, these factors support and enhance implementation. They include: ICT infrastructure, School farms and laboratories,

financial resources, and administrative support. Barriers (Constraints), these factors limit the effectiveness of implementation. Inadequate funding ( $\beta = -.169$ ,  $p = .002$ ) and poor infrastructure ( $\beta = -.176$ ,  $p = .001$ ) significantly and negatively predicted PA implementation, while collectively accounting for modest variance ( $R^2 = .095$ ), reinforcing their role as constraining forces that suppress effective implementation. They include: Inadequate funding, Poor infrastructure, Policy gaps.

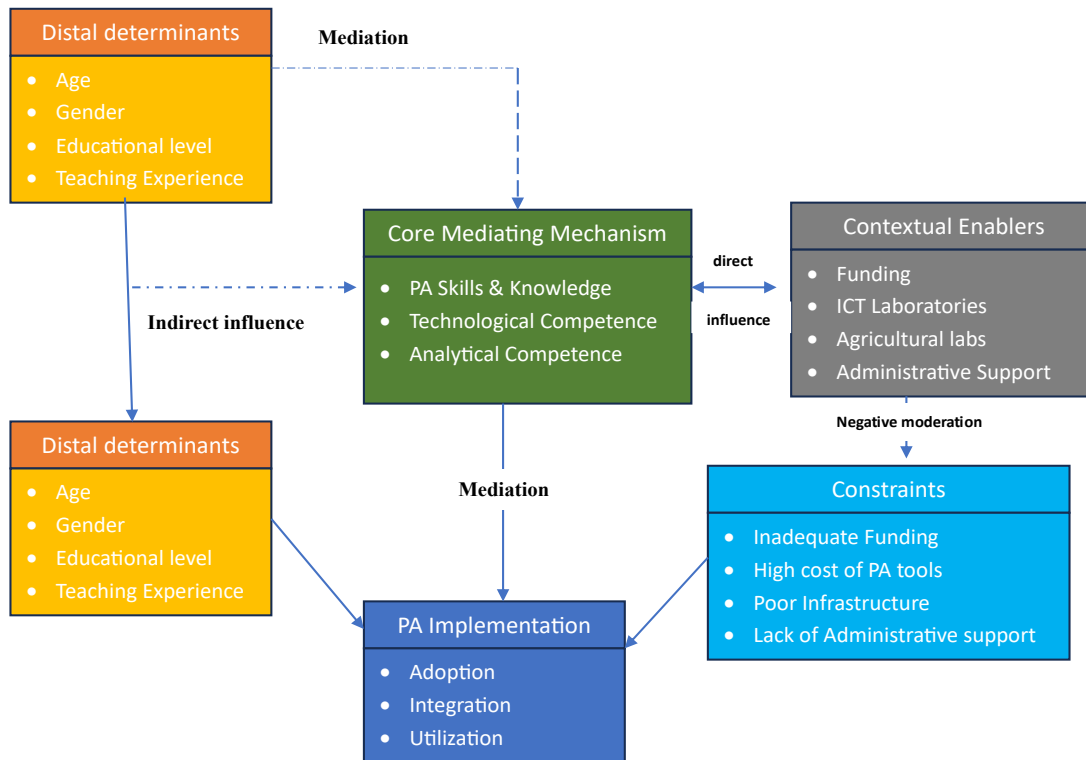
#### 4.2 Model Interaction

The model suggests that PA implementation is influenced by the interaction of these components:

**PA Implementation = Teacher Preparedness + Institutional Resources – Barriers**

This formulation aligns with Constructivist Learning Theory, which emphasizes experiential, learner-centered approaches supported by enabling environments. It also reinforces the notion that effective implementation requires a balance between capacity, support, and constraint mitigation.

In the broader context, the findings underscore that integrating PA into secondary education is not merely a technical issue but a systemic transformation process. As noted by Shannon et al. (2018), PA represents a paradigm shift toward data-driven agriculture, requiring corresponding changes in education systems to prepare future farmers. Therefore, failure to address teacher preparedness, infrastructure gaps, and systemic barriers risks widening the gap between curriculum policy and classroom practice.



**Figure 1: The model for the effective adoption and integration of PA in the agriculture curriculum in secondary schools.**

Source: Onyancha FG. 2026

### 4.3 Discussion

The findings of this study strongly establish teacher preparedness as the most influential determinant of Precision Agriculture (PA) integration in secondary school agriculture curriculum. The high explanatory power ( $R^2 = 0.784$ ) and strong positive relationship ( $r = 0.836, p < .001$ ) indicate that teachers' competencies in ICT, pedagogy, and subject content are central to translating curriculum reforms into practice. This finding is consistent with prior studies, which argue that teacher capacity is the cornerstone of successful educational innovation (Heidenreich et al., 2018; Food and Agriculture Organization, 2021). Teachers act as change agents, and their ability to interpret and implement new technologies determines the extent to which innovations such as PA are adopted in classrooms. From a theoretical perspective, this aligns with Everett Rogers' Diffusion of Innovation Theory, which emphasizes that knowledge, skills, and attitudes are critical in influencing adoption decisions. Teachers who are knowledgeable and confident in using PA tools are more likely to progress from awareness to implementation stages. Furthermore, the strong mediating role of teacher preparedness supports findings by Ertmer (2005), who distinguishes between first-order barriers (external) and second-order barriers (internal), noting that internal factors

such as beliefs and competence are often more decisive. The study also reveals that teacher demographic characteristics, particularly age and teaching experience, exert indirect effects on PA implementation through preparedness. This finding is supported by Tondeur et al. (2017), who argue that exposure to technology and prior training significantly shape teachers' readiness to integrate digital tools. Younger teachers may demonstrate higher technological adaptability, while experienced teachers contribute pedagogical mastery, suggesting the need for targeted and differentiated professional development programs. Institutional resources were found to have a moderate but significant influence on PA integration ( $R^2 = 0.107$ ), with ICT infrastructure and funding emerging as key enablers. This supports earlier findings by Manning et al. (2022), who observed that access to infrastructure enhances technology integration by enabling practical and experiential learning. Similarly, Balafoutis et al. (2017) emphasize that PA relies heavily on technological tools such as sensors, drones, and GIS systems, which require adequate institutional support to be effectively utilized in educational contexts.

However, the relatively lower explanatory power of institutional resources suggests that availability does not guarantee utilization. This finding corroborates research by Ertmer (2005), which highlights that infrastructure alone

cannot drive integration without corresponding teacher competence and motivation. In line with Ludwig von Bertalanffy's Systems Theory, the effectiveness of PA integration depends on the interaction between system components, teachers, resources, and policies rather than the presence of any single factor in isolation. The study further identifies systemic barriers as significant constraints to PA implementation, with inadequate funding and poor infrastructure exerting negative effects. These findings are consistent with Bagheri & Naier (2022), who report that high costs of technology, lack of training, and weak institutional support are major impediments to PA adoption, particularly in developing countries. Similarly, the Food and Agriculture Organization (2021) highlights that limited access to digital infrastructure and capacity-building opportunities continues to hinder agricultural innovation in Sub-Saharan Africa. Importantly, the results demonstrate that barriers function as suppressor variables, weakening the positive effects of both teacher preparedness and institutional resources. This interaction effect reflects findings by Bingimlas (2009), who argues that external constraints such as lack of funding and policy support can significantly undermine technology integration efforts, even when teachers are willing and capable.

## 5. Conclusion and recommendation

### 5.1 Conclusion

This study developed a comprehensive model for the effective adoption and integration of Precision Agriculture into secondary school agriculture curricula. The model emphasizes the central role of teacher preparedness, supported by institutional resources and constrained by systemic barriers. The findings highlight the need for coordinated efforts to enhance teacher training, improve infrastructure, and address policy gaps to achieve successful implementation.

### 5.2 Recommendations

1. The Ministry of Education and Kenya Institute of Curriculum Development (KICD) should incorporate explicit, measurable Precision Agriculture performance competencies (at least 4–6 observable indicators per grade level) into the agriculture curriculum during the 2028–2032 CBE review.
2. Kisii and Nyamira County Governments Should Establish a dedicated County Precision Agriculture in Education Support Fund (KES 5–15 million annually per county) to finance the procurement of basic PA starter kits for 20–30 pilot schools per year and Internet connectivity subsidies for agriculture departments.
3. School Boards of Management and Principals should ring fence a minimum of 8–12% of school

capitation and other internally generated funds for agriculture and ICT development in the 2026–2029 School Improvement Plans.

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