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Participatory Technology Development (PTD) in Agronomic Research and Extension

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ABSTRACT

Participatory Technology Development (PTD) has emerged as a farmer-centred approach in agronomic research and extension, shifting from conventional top-down technology transfer models to collaborative innovation systems. PTD emphasizes joint experimentation, mutual learning, and integration of local knowledge with scientific expertise to generate site-specific and sustainable agronomic solutions. In crop production, PTD has been successfully applied in nutrient management, improving soil fertility, enhancing water-use efficiency, managing pests and weeds, and selecting varieties. Extension strategies such as Farmer Field Schools, participatory rural appraisal, and farmer-led trials have proven effective in enhancing technology adoption, building farmer capacity, and strengthening linkages between research institutions and farming communities. Despite its benefits, PTD faces challenges including institutional constraints, limited scalability, and the need for adequate policy and financial support. Recent advancements in digital extension, ICT tools, and multi-stakeholder platforms provide new opportunities to strengthen participatory approaches in agronomy. This review highlights the principles, applications, benefits, and limitations of PTD, emphasizing its role in developing climate-resilient, context-specific, and sustainable agronomic practices. The findings underline that PTD is not only a research methodology but also a transformative extension strategy that empowers farmers, enhances adoption, and contributes to sustainable agricultural development.

1. Introduction

Agricultural research and technology development have historically followed a top-down approach, where innovations are created in research institutions and later disseminated to farmers through extension services. Although this method has contributed to agricultural advancements, it often fails to account for the diverse socio-economic, ecological, and cultural realities of farming communities, leading to low adoption rates and limited sustainability of technologies (Chambers, 1994; Sulaiman & Davis, 2012).

Participatory Technology Development (PTD) is a collaborative approach that actively involves farmers in the research and innovation process. PTD is defined as a methodology where researchers and farmers jointly identify problems, design experiments, test solutions, and adapt technologies to local conditions (Klerkx et al., 2013; Röling & Jiggins, 1998). By integrating scientific knowledge with farmers' indigenous knowledge, PTD ensures that agronomic

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technologies are relevant, context-specific, and sustainable (Pretty, 1995; Norgaard, 1984).

The importance of farmer involvement in agronomic research lies in their firsthand knowledge of local soils, crops, climate variability, and resource constraints. Farmers contribute to experimental design, on-farm trials, monitoring, and feedback, which allows iterative refinement of technologies and improves adoption rates (Sanginga et al., 2009; Leeuwis, 2004). Their engagement ensures that innovations address real-world challenges and are socially, economically, and environmentally appropriate.

The shift from conventional top-down extension to participatory approaches reflects a broader transformation in agricultural development. Modern extension emphasises co-learning, collaboration, and empowerment, moving beyond the simple transfer of information (Rivera & Sulaiman, 2009). Participatory approaches, including Farmer Field Schools, participatory rural appraisal, and on-farm demonstrations, transform farmers from passive recipients into active partners in innovation, leading to better technology adoption, sustainable farming practices, and improved resilience of agricultural systems (van den Berg & Jiggins, 2007; Röling & Engel, 1991).

2. Concept and Principles of PTD

Participatory Technology Development (PTD) is a research and extension approach that emphasizes collaboration between farmers, researchers, and extension agents to co-create technologies that are locally relevant, adaptive, and sustainable (Röling & Jiggins, 1998; Klerkx et al., 2013). Unlike conventional top-down research-extension models, PTD prioritizes farmer knowledge, local conditions, and context-specific innovation.

2.1 Basic Principles

PTD is grounded in several core principles:

1. **Collaboration:** Researchers, extension agents, and farmers work together throughout the technology development process. This collaboration ensures that innovations are not only scientifically sound but also practically relevant (Pretty, 1995; Sanginga et al., 2009).

2. **Co-creation of knowledge:** PTD integrates scientific knowledge from researchers with local, indigenous knowledge from farmers. Co-creation allows iterative refinement of technologies and enhances adoption by aligning innovations with farmers' real-world constraints (Chambers, 1994; Klerkx et al., 2013).

3. **Context-specific solutions:** Recognizing the diversity of agro-ecological and socio-economic conditions, PTD emphasizes technologies that are adaptable to local needs, rather than uniform, one-size-fits-all solutions (Röling & Engel, 1991; Leeuwis, 2004).

2.2 Role of Experimentation, Learning, and Adaptation

Central to PTD is on-farm experimentation, where farmers actively test and adapt technologies under real-world conditions. This process involves:

- **Iterative learning:** Farmers and researchers jointly analyze results and refine practices (van den Berg & Jiggins, 2007).
- **Flexibility and adaptation:** Technologies are adjusted according to farmer feedback, climatic variability, and resource constraints (Klerkx et al., 2013).
- **Capacity building:** Farmers gain technical skills, problem-solving abilities, and confidence in innovation, creating a learning community that can sustain long-term agricultural development (Pretty, 1995; Sulaiman & Davis, 2012).

2.3 Distinction Between PTD and Conventional Research-Extension Models

Feature	Conventional Research-Extension	Participatory Technology Development (PTD)
Approach	Top-down, technology push	Collaborative, co-created solutions
Farmer Role	Passive recipients	Active partners in problem identification, experimentation, and adaptation

Knowledge Source	Primarily scientific	Combination of scientific + local/indigenous knowledge
Flexibility	Limited, uniform solutions	Iterative, context-specific adaptation
Adoption Focus	Technology transfer	Technology relevance, empowerment, and adoption
Learning	One-way information flow	Two-way learning, co-innovation

This distinction highlights that PTD is not only a methodological shift in research but also a transformative extension strategy, ensuring that agricultural innovations are relevant, locally adapted, and more widely adopted (Röling & Jiggins, 1998; Leeuwis, 2004; Rivera & Sulaiman, 2009).

3. PTD in Agronomic Research

Participatory Technology Development (PTD) has become an integral approach in agronomic research, bridging the gap between scientific experimentation and practical farming realities. By involving farmers as co-researchers, PTD ensures that technologies are site-specific, socially acceptable, and economically viable (Röling & Jiggins, 1998; Klerkx et al., 2013).

3.1 Areas of Application

PTD has been applied across a wide range of agronomic domains:

1. **Soil Fertility Management:** Farmers collaborate with researchers to identify locally suitable organic amendments, biofertilizers, and integrated nutrient management practices. PTD allows evaluation of inputs under field-specific conditions, promoting site-specific soil fertility solutions (Sanginga et al., 2009; Pretty, 1995).

2. **Nutrient Management:** On-farm trials enable farmers to test different fertilizer combinations, application timings, and doses, optimizing crop growth while reducing environmental impacts (Chauhan et al., 2018).

3. **Crop Varieties:** Farmers participate in varietal selection trials, evaluating crop performance based on yield, pest resistance, drought tolerance, and market preferences. This ensures adoption of varieties suited to local agro-ecological conditions (Joshi et al., 2003; Karthikeyan et al., 2015).

4. **Water Management:** PTD facilitates the evaluation of water-saving technologies such as micro-irrigation, alternate wetting and drying, and water-efficient cropping patterns, tailored to local water availability and socio-economic contexts (Sharma et al., 2010).

5. **Weed and Pest Management:** Farmers participate in integrated pest management (IPM) and integrated weed management (IWM) trials, combining traditional knowledge with scientific recommendations to develop low-cost, effective, and environmentally safe control strategies (van den Berg & Jiggins, 2007; Pretty & Bharucha, 2015).

3.2 Farmer-Led Trials and Adaptive Research

A key feature of PTD is farmer-led experimentation, where farmers are directly involved in testing, observing, and modifying technologies on their own farms. This adaptive research process allows:

- **Iterative learning:** Farmers and researchers continuously refine practices based on field results (Klerkx et al., 2013).
- **Contextual adaptation:** Technologies are modified to suit local soil, climate, and socio-economic conditions (Leeuwis, 2004).
- **Empowerment:** Farmers acquire knowledge and decision-making skills, increasing their capacity for innovation and problem-solving (Sulaiman & Davis, 2012).

3.3 Case Studies and Examples

India:

- In *Eastern India*, PTD was used to develop Integrated Nutrient Management (INM) practices for rice and maize, involving farmers in testing organic and inorganic fertilizer combinations. Adoption of locally adapted INM packages improved yields and reduced fertilizer costs (Chauhan et al., 2018).

- In *Madhya Pradesh and Karnataka*, farmer participatory varietal selection for pigeon pea and sorghum led to faster adoption of high-yielding and drought-tolerant varieties (Joshi et al., 2003).

Africa:

- In *Nigeria*, PTD was applied in soil fertility and legume intercrop trials, where farmers collaborated in experimenting with phosphorus-efficient crops and organic amendments, resulting in improved soil health and legume productivity (Sanginga et al., 2009).
- In *Kenya and Uganda*, farmer field schools used PTD to develop integrated pest management strategies for maize and vegetables, significantly reducing pesticide use while maintaining yields (van den Berg & Jiggins, 2007).

Other Countries:

- In the *Philippines*, participatory trials for water management in rice systems helped farmers adopt alternate wetting and drying (AWD) irrigation methods, conserving water while maintaining yields (Sharma et al., 2010).
- In *Nepal*, PTD approaches in potato and maize production integrated farmer knowledge on pest and disease cycles with scientific recommendations, leading to improved adoption and productivity (Pretty & Bharucha, 2015).

4. PTD in Extension

Participatory Technology Development (PTD) is not only a research methodology but also a transformative extension strategy. By engaging farmers as co-learners and co-creators, PTD enhances technology adoption, builds local capacity, and strengthens farmer-researcher linkages (Röling & Jiggins, 1998; Leeuwis, 2004).

4.1 Extension Methodologies

Several participatory extension methods are commonly used to implement PTD:

1. **Farmer Field Schools (FFS):** FFS is a hands-on, season-long learning approach where farmers engage in experimentation, observation, and analysis directly in their fields. Farmers learn to identify pests, monitor soil health, and evaluate crop management practices through collaborative, experiential learning (van den Berg & Jiggins, 2007; Braun et al., 2006).
2. **Participatory Rural Appraisal (PRA):** PRA involves community-driven data collection and analysis to understand local constraints, resources, and opportunities. Researchers and extension agents use tools such as mapping, ranking, and seasonal calendars to co-identify problems and develop context-specific solutions (Chambers, 1994; Pretty, 1995).
3. **On-Farm Demonstrations:** On-farm trials and demonstrations allow farmers to observe the performance of technologies under real conditions. This approach promotes learning by doing, encourages farmer feedback, and builds confidence in adopting new practices (Klerkx et al., 2013; Rivera & Sulaiman, 2009).

4.2 ICT and Digital Tools Enhancing Participatory Learning

Modern extension increasingly leverages Information and Communication Technologies (ICTs) to scale up participatory learning:

- **Mobile Apps and SMS Platforms:** Provide real-time advice, weather forecasts, pest alerts, and market information to farmers (Sulaiman & Davis, 2012).

- **Digital Farmer Networks:** Enable peer-to-peer knowledge exchange, fostering farmer-to-farmer learning and rapid dissemination of innovations (Aker, 2011).
- **Decision Support Systems and Drones:** Facilitate site-specific recommendations and visualization of crop performance, enhancing farmer participation in experimentation (Klerkx & Rose, 2020).

These tools complement traditional extension methods and increase accessibility, efficiency, and inclusiveness in PTD-based programs.

4.3 Success Stories of Farmer-to-Farmer Extension Models

1. **India:**
    - In *Madhya Pradesh*, FFS and farmer-to-farmer demonstrations in pigeon pea and soybean cultivation improved adoption of integrated pest management and nutrient management practices (van den Berg & Jiggins, 2007).
    - The *Digital Green* project in Karnataka and Odisha uses videos produced by farmers to share best practices, resulting in up to 25% higher adoption of recommended practices compared to conventional extension methods (Aker, 2011).
2. **Africa:**
    - In *Ethiopia and Uganda*, farmer field schools combined with community video dissemination enhanced adoption of improved maize and legume technologies, fostering local innovation networks (Braun et al., 2006).
    - Farmer-to-farmer seed multiplication programs in Kenya enabled the rapid spread of drought-tolerant crop varieties, demonstrating the effectiveness of peer-led extension (Sanginga et al., 2009).
3. **Southeast Asia:**
    - In the *Philippines*, participatory extension using ICT tools for water-saving irrigation (Alternate Wetting and Drying) helped farmers adapt techniques to local farm conditions and share knowledge regionally (Sharma et al., 2010).

These examples highlight how participatory extension methods, especially when combined with digital tools, empower farmers, accelerate adoption, and strengthen agricultural innovation systems.

5. Benefits of Participatory Technology Development (PTD)

Participatory Technology Development (PTD) offers multiple advantages by integrating farmers into the technology development and extension process, ensuring that innovations are locally relevant, socially acceptable, and sustainable.

5.1 Improved Adoption of Agronomic Innovations

By involving farmers in experimentation, evaluation, and decision-making, PTD ensures that technologies are tested under real farm conditions and adjusted to local constraints. This approach leads to higher adoption rates compared to conventional top-down models, as farmers have confidence in solutions they helped develop (Pretty, 1995; Röling & Jiggins, 1998). For example, farmer-led trials in India and Africa demonstrated significant uptake of improved varieties, nutrient management practices, and integrated pest management techniques (van den Berg & Jiggins, 2007; Sanginga et al., 2009).

5.2 Higher Relevance of Technologies to Local Conditions

PTD integrates scientific knowledge with indigenous knowledge, allowing technologies to be adapted to diverse agro-ecological and socio-economic contexts. This ensures that innovations are site-specific, practical, and aligned with farmers' needs and priorities (Chambers, 1994; Klerkx et al., 2013). Such relevance reduces the risk of technology failure and enhances productivity while considering resource constraints and environmental sustainability.

5.3 Capacity Building and Empowerment of

Farmers

Participation in PTD empowers farmers by developing technical skills, decision-making capacity, and problem-solving abilities. Farmers become active innovators, capable of experimenting with new techniques and sharing knowledge within their communities. This empowerment strengthens local innovation systems, fosters leadership, and enhances resilience to challenges such as climate variability (Pretty, 1995; Leeuwis, 2004; Sulaiman & Davis, 2012).

5.4 Sustainability through Local Ownership

PTD promotes local ownership of technologies, as farmers are directly involved in their development and adaptation. Ownership encourages long-term maintenance, adaptation, and diffusion of innovations, contributing to sustainability. Additionally, participatory approaches help build community networks and social capital, supporting continuous learning and collective action for sustainable agriculture (Röling & Engel, 1991; Sanginga et al., 2009).

6. Challenges and Limitations of Participatory Technology Development (PTD)

While Participatory Technology Development (PTD) offers numerous benefits in bridging research and extension, it also faces several challenges that can limit its effectiveness and scalability.

6.1 Institutional and Policy Barriers

PTD requires supportive institutional frameworks and policies that encourage collaboration between researchers, extension agents, and farmers. In many cases, rigid hierarchical structures in research and extension systems limit the flexibility needed for participatory approaches. Bureaucratic processes, lack of incentives, and limited policy support can hinder adoption and integration of PTD within formal agricultural programs (Rivera & Qamar, 2003; Klerkx et al., 2013).

6.2 Time and Resource Intensiveness

PTD involves continuous engagement with farmers, on-farm trials, monitoring, and iterative refinement of technologies. This approach demands significant time, human resources, and financial investment. Unlike conventional research-extension models, PTD requires sustained interactions over multiple cropping seasons to ensure meaningful participation and learning (Pretty, 1995; Röling & Jiggins, 1998). Limited availability of trained personnel and financial constraints can therefore restrict its widespread implementation.

6.3 Scaling Up from Local to Regional/ National Level

While PTD works effectively at farm and community levels, scaling up innovations to larger areas presents challenges. Technologies co-developed in a local context may not be directly transferable to different agro-ecological zones, socio-economic conditions, or cultural settings. Ensuring wider adoption requires contextual adaptation, effective communication, and robust support networks, which can be difficult to manage at regional or national scales (Leeuwis, 2004; Klerkx & Rose, 2020).

6.4 Balancing Scientific Rigor with Participatory Flexibility

Maintaining scientific rigor while allowing for the flexibility and adaptability required in PTD can be challenging. Researchers must design experiments that are methodologically sound, yet flexible enough to incorporate farmers' feedback and local innovations. Striking this balance is crucial to generate credible results without undermining the participatory nature of the process (Röling & Engel, 1991; Klerkx et al., 2013).

7. Future Prospects of Participatory Technology Development (PTD)

The evolving challenges in agriculture, including climate change, resource scarcity, and increasing demand for sustainable food production, highlight the need to enhance and modernize participatory approaches in agronomy. PTD has significant potential to evolve in conjunction with emerging technologies, multi-stakeholder engagement, and supportive policies.

7.1 Integration of PTD with Climate-Smart Agriculture

Climate-smart agriculture (CSA) focuses on increasing productivity, enhancing resilience, and reducing greenhouse gas emissions. PTD can play a crucial role in co-developing climate-resilient agronomic practices with farmers, such as drought-tolerant crop varieties, water-saving irrigation methods, and diversified cropping systems. Collaborative experimentation ensures that CSA interventions are locally relevant, adoptable, and sustainable (FAO, 2013; Lipper et al., 2014).

7.2 Use of AI, Drones, and Mobile Apps in Participatory Research

Modern technologies provide new opportunities to enhance participatory research and extension:

- **Artificial Intelligence (AI):** Predictive models can help farmers and researchers make site-specific management decisions and optimize resource use (Klerkx & Rose, 2020).
- **Drones and Remote Sensing:** Facilitate monitoring of crop growth, pest incidence, and soil health in participatory trials, reducing labor and increasing accuracy (Liakos et al., 2018).
- **Mobile Apps and Digital Platforms:** Enable real-time data collection, farmer feedback, knowledge sharing, and dissemination of best practices across regions (Aker, 2011).

These tools **complement traditional PTD methods**, making participatory research more efficient, scalable, and data-driven.

7.3 Role of Multi-Stakeholder Platforms

Engaging a diverse set of stakeholders—including farmers, scientists, extension agents, NGOs, private sector actors, and policymakers—can enhance the reach and impact of PTD initiatives. Multi-stakeholder platforms facilitate:

- Co-creation of technologies and practices
- Knowledge exchange and capacity building
- Coordination of resources and support for scaling innovations

Such platforms ensure that PTD initiatives are inclusive, context-specific, and sustainable (Klerkx et al., 2012; Sanginga et al., 2009).

7.4 Policy Support for Mainstreaming PTD in Agronomy

For PTD to achieve its full potential, policy frameworks must recognize and incentivize participatory approaches. Supportive policies can provide:

- Funding for farmer-led trials and participatory extension programs
- Training for extension personnel in participatory methods
- Platforms for scaling locally adapted innovations to regional and national levels
- Integration of PTD principles into national agricultural research and extension strategies (Rivera & Qamar, 2003; Pretty, 1995).

Mainstreaming PTD through policy support ensures long-term sustainability, adoption, and resilience of agronomic innovations.

8. Conclusion

Participatory Technology Development (PTD) has emerged as a transformative approach in agronomic research and extension, bridging the gap between scientific innovation and practical farming realities. By actively involving farmers in the identification of problems, co-creation of technologies, on-farm experimentation, and adaptive learning, PTD ensures that innovations are locally relevant, context-specific, and adoptable.

The integration of farmers' indigenous knowledge with scientific expertise enhances the effectiveness and adoption of agronomic technologies in areas such as soil fertility management, nutrient optimisation, crop varietal selection, water management, and pest/weed control. PTD-based extension methods—such as Farmer Field Schools, Participatory Rural Appraisal, and on-farm demonstrations—foster co-learning, empowerment, and capacity building, enabling farmers to become active participants and innovators in their own agricultural systems.

Moreover, PTD contributes to sustainable agriculture by promoting local ownership, ensuring the long-term maintenance of technologies, and fostering the development of resilient and adaptive farming practices. When combined with modern tools like ICT, AI, and drones, and supported by multi-stakeholder platforms and enabling policies, PTD has the potential to scale innovations, strengthen farmer networks, and address emerging challenges such as climate change and resource scarcity.

In conclusion, PTD represents a farmer-centred, sustainable, and participatory paradigm in agronomy. It not only improves the relevance and adoption of agricultural innovations but also empowers farmers, strengthens rural communities, and contributes to long-term food security and sustainable agricultural development.

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