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ADVANCING STORED PRODUCT PEST MANAGEMENT IN THE PHILIPPINES: A STRATEGIC FORESIGHT

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Abstract: Stored product pests (SPP) are known to be the most expensive pests due to the enormous damage and losses it brings to the food sector. In the Philippines, over the years, various pesticides, pheromone trapping systems, and fumigation have been the most common technologies used to control SPPs, particularly moths, beetles, and weevils. The need for new technological advancements in stored product protection locally has created significant challenges for food businesses and pest management professionals (PMPs). This study aims to apply the concept of technology foresight for SPP management technologies through a ten-stage scenario-building framework with the participation of industry stakeholders through series of discussions. The robust regulatory policies and the emergence of new technologies, mainly influenced by political and technological factors, were the fundamental driving forces to shape the future of SPP management. Four (4) scenarios were developed and assessed as the basis for strategic decision-making for the pest management industry: The Industry Buzz, Technology Ecdysis, Nylanderic Movement, and Technology Fission. An industry analysis using Porter's Five Forces was done to assess the implication of each scenario. The study emphasized talent recruitment, policies, and technology exploitation as fundamental elements of the industry's technological advancements.

Key words strategic foresight, stored product pests, spi technology

INTRODUCTION

Among urban insect pests, there is an overwhelming integrated pest management (IPM) technologies research and development targeting mosquitoes, cockroaches, and flies, as these have a direct impact on public health that are most abundant and convenient for pest management professionals (PMP). Cryptic pests like stored product pests (SPP) have directly or indirectly caused extensive economic losses to stored commodities worldwide. However, the limited coverage of stored-product insects and pest management methods for these species in many entomology resources gives the false impression that they are of less economic importance than other insect pests associated with crops and urban environments (Hagstrum and Subramanyam, 2009).

In fact, management of SPP requires more knowledge and training in pest biology, behavior, ecology, and pest susceptibility to IPM methods. The food supply chain has become conscious of the detrimental impacts of pesticides on food products, public health, and the environment demanding more sustainable solutions which requires less use of pesticides and a more proactive approach to mitigate emerging threats. That is why affected supply chains strongly rely on PMP, who are expected to have the capability and technology resources to manage SPP.

However, one of the pressing concerns globally is the decline of stored-product entomologists (Hagstrum and Subramanyam, 2009). The Philippines is currently experiencing this challenge whereby there is a limited number of entomologists specializing in this field. This greatly affects shaping the future technological advancements for managing this group. The lack of expertise threatens knowledge transfer and capacity building in the industry.

Furthermore, Philippines, being a tropical country, has high vulnerabilities to pest infestations caused by the challenges in the structural issues and conducive storage conditions of most establishments which contributed to increasing problems in SPP. Due to high-cost requirements in construction and renovation, end consumers would also rely on PMP's control measures to minimize losses brought by SPP infestation. While there are more accessible advanced SPP management technologies that are being utilized in developed countries, such as new active ingredients and techniques, fumigation, pesticides, and pheromone traps are the most commonly available for controlling SPP infestations.

There are limited knowledge, expertise, availability and access to pest management technologies against SPP in the food supply chain, which poses future threats to food safety and security for Philippines. This provides the pest management industry insights on technological advancements to design effective, proactive, and robust management programs supporting a sustainable food supply chain. It should be understood in this study the factors impeding the adoption of new technology of the local industry professionals.

The stakeholders in pest management solutions supply chain—from manufacturers, importers/distributors to pest control operators—play a significant role in shaping the future of SPP pest management technologies to support the food supply. With the focal issues identified in this study, there is a need to address the capability of the Philippine pest management industry to identify, select, acquire, protect, and exploit pest management technologies.

The purpose of this study is to apply a 10-stage scenario-building method (Esguerra, 2020.) in foresight SPP management technologies to answer the following:
a) What are the plausible future scenarios for the Philippine pest management industry in the next ten years that will influence the technological advancements in SPP pest management? b) What challenges are likely to arise in the future? c) What strategies are needed to minimize these barriers and challenges? d) How do these future scenarios help shape today's policy-making efforts?

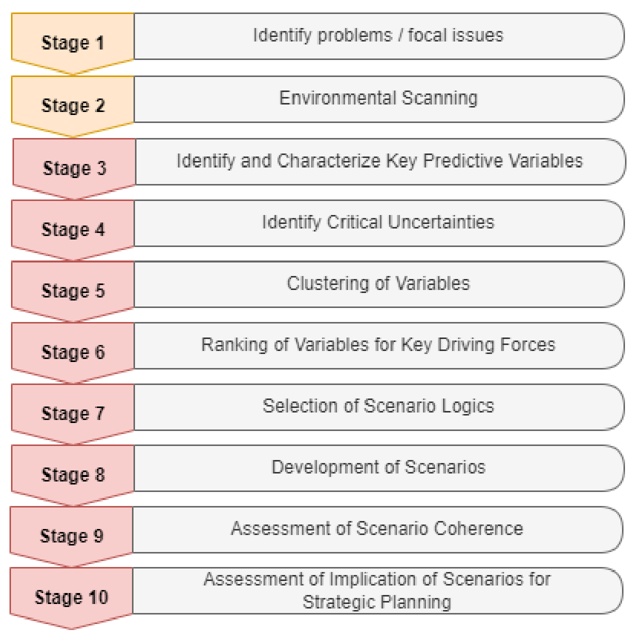

Figure 1. Ten-Stage Scenario Building Process (Esguerra, 2020)

METHODOLOGY

Research Methodology. This study was conducted from August 2022 to June 2023. Scenario building is a research methodology that involves creating plausible, alternative futures or scenarios based on a set of assumptions or driving forces. It is not solely focused on predicting the accuracy of a forecast. Instead, it is a broader mindset aimed at understanding the various factors, environmental factors, and actors that influence the life cycle of technologies, technological systems, and networks. It also involves examining the different stages of a technology's development, from its inception to its retirement or future trajectory. This study utilized the ten-step scenario building process as shown in Figure 1.

STRENGTHS
PH as agricultural country, several agricultural institutions
PH President as Chief of Agriculture
R&D capability for pest management
Food manufacturing contributing 2.2% to PH GDP (2020)
High awareness of vector-borne diseases
Existing of regional pest control associations
Consumers demand improving well-being and quality of life
PH as biggest population of social media users
Existing policies and regulations on pesticides and hazardous
WEAKNESSES
Infrastructure Challenges (i.e. Building designs)
Inadequate marketing strategies for new solutions, products
Bureaucracy and Corruption
Political instability
Slow technology diffusion, lack of innovations, Barriers to New Entry
Technical awareness, IPM Principles
Restriction on foreign ownerships
"fly-by-night" pest control operators,
Business owners non compliance
OPPORTUNITIES
Foreign Direct Investments
Forecasted Growth 6.2% CAGR by 2032
Population growth increasing demand for food supply
Increase awareness and adoption of food safety standards
Increasing awareness on environmental sustainability
Global & regional collaboration and conferences on pest management
THREATS
Climate Change
Insurgence of invasive pest species, pest outbreak
Global crisis, inflation rate, increase cost of raw materials
Foreign alternative, high importation

Figure 2. SWOT Analysis

Data Collection Procedure. The Delphi method is a structured way of compiling and analyzing expert opinions on a particular subject or problem. One of the key benefits of the Delphi approach is that it enables the collection of various viewpoints from a group of experts who are geographically distributed without the requirement for in-person meetings (Rowe & Wright, 1999). It also offers a methodical way to evaluate and combine various viewpoints to form an agreement or projection. Primary and secondary data used in this study were acquired using online surveys, interviews, personal experience and observations, review of the existing literatures, online databases, and reports from government and non-profit groups.

Respondents of the Study. Four (4) resource persons were involved for this study representing the supply chain for pest management technologies such as a manufacturer, an importer/distributor, a pest control operator and a government agency who was also considered an end user. Convenience sampling was used in selecting the respondents. This is a non-probability sampling method where participants are selected based on their availability and willingness to participate in the study. This was used considering limited resources.

Environmental Scanning and Analyses. With various data gathered to identify key variables and critical uncertainties, STEEP (Social, Technological, Economic, Environmental, Political), SWOT (Strengths, Weakness, Opportunities, Threats) analyses, and Porter's Five Forces models were used to analyze and assess the scenarios.

RESULTS AND DISCUSSION

Identifying Problems/ Focal Issue

SWOT analysis was conducted Figure 2, and three (3) focal issues were identified and foresighted in short (+2-3 years), mid (+5-7 years) and long (10 years) timeframes, respectively. This includes (1) the lack of local awareness and industry capability on SPP management (2) available solutions approach is more on reactive rather than proactive, and (3) technology acquisition process is tedious due to lack of robust regulatory policies. With all the focal issues highlighted, there is a need to address the capability of the industry to identify, select, acquire, protect, and exploit pest management technologies.

Identification and Characterization of Key Predictive Variables (KPV) and Critical Uncertainties

Environmental scanning is the process of systematically analyzing and monitoring the external factors that can impact an organization's operations, strategies, and decision-making. STEEP is a useful framework for environmental scanning, which stands for Social, Technological, Economic, Environmental, and Political factors. Key predictive variables (KPV) and critical uncertainties (CU) were identified as summarized in Tables 1 and 2 and were further reviewed and characterized if these are valid KPVs based on high plausibility and impact to successfully address the focal issue. In scenario creation, identifying and describing KPVs requires a methodical investigation of trends, causes, and uncertainties that potentially influence the future.

Table 1. Identification and characterization of KPV

STEEP CATEGORY	Code	Variables	*Predictability*		Remarks
	Code	Variables	Yes	NO	
Social	SC1	Consumer demands and change in preferences (i.e. diet, quality food, cost)		✔	also related to economic and environmental factor
Social	SC2	Consumer rights to have safe and quality food	✔		
Social	SC3	Career Preferences of the New Generation		✔	
Social	SC4	Increasing Population leading to Industrialization and Urbanization	✔		
Technology	TN1	Research Funding on SPP Studies & Pesticide Resistance Management	✔		
Technology	TN2	Declining number of field experts in Entomology		✔	low enrolees of Agriculture programs
Technology	TN3	Local R&D and manufacturing capability for pest management technologies		✔	
Technology	TN4	Firms' Innovation Acquisition and Diffusion to Market		✔	influenced by Political
Technology	TN5	Acquisition of Emerging Technology and its Knowledge Transfer		✔	
Economic	EC1	Cost Management to Product & Services	✔		
Economic	EC2	Foreign Direct Investments		✔	
Economic	EC3	Competitiveness of local industry players		✔	
Environmental	EN1	Climate Change Impacts		✔	
Environmental	EN2	"Green" Building Designs (i.e. LEED)		✔	influenced by Political
Environmental	EN3	Demands on Environmental Sustainability	✔		
Environmental	EN4	The emergence of new invasive pests in the urban		✔	
Political	PO1	Food Safety Policy and Standards (Food Safety Act of 2013)	✔		
Political	PO2	Regulatory policies and requirements for Importing Hazardous/Non Hazardous Substances		✔	in place but frequently changing policies
Political	PO3	Rigorous Reinforcement of Port & Border Quarantine Policies and Surveillance	✔		significant knowledge needed
Political	PO4	Regulation of Pest Management Professionals		✔	in place but frequently changing policies
Political	PO5	Regulatory Requirements on Product Registrations		✔	in place but frequently changing policies due to on process of alignment to global standards
Political	PO6	Private-Govemenment Joint Efforts		✔	
Political	PO7	Change in Leadership		✔	Regulatory agencies
Political	PO8	Environmental Protection Laws	✔		in place but need reinforcement

Important elements or occurrences that have the potential to drastically alter a scenario's future results are referred to as critical uncertainty (CU). As they have the potential to affect the overall success or failure of a strategy or plan, they are frequently regarded as the most significant uncertainties in scenario building. This may answer the question: What events, whose outcomes are uncertain, will significantly affect the issues you are concerned with? (Schoemaker,1995).

Table 2. Critical uncertainties.

Uncertainties	Remarks
Heightened Industrialization and Urbanization	Not Ready
Scarcity in Technical Expertise	Not Ready
Increase Foreign Direct InvestmentS	Not Ready
Infrastructural Advancements	Not Ready
Local Standardization of Pest Management Programs in Establishments	Ready
"Green" Sustainable Economy	Ready
Introduction of Invasive Quarantine SPP Pests to Philippines	Not Ready
Change in Leadership	Not Ready
Destruction of Fumigation Technology	Not Ready

Ranking of Variables and Selection of Scenario Logic to Determine Key Driving Forces

As expert respondents involved in this scenario-building activity represented different roles in the pest management supply chain stakeholders, the selection of the scenarios is based on a combination of analytical judgment, which is influenced by the different perspectives, experiences, and biases of each. Clustered KPVs and CUs identified were consulted with respondent experts and rated to determine the degree of uncertainty surrounding the variables and the degree of importance in relation to the main issue. The variables were rated from one (1) to ten (10), ten (10) being the most uncertain and most important. The score sheets of the respondents were consolidated through average scores, then assigned ranks accordingly. Final rankings were discussed and agreed upon with expert respondents. The final clustered variables were plotted in uncertainty (y) and importance (x) in a scatter plot, as shown in Figure 3.

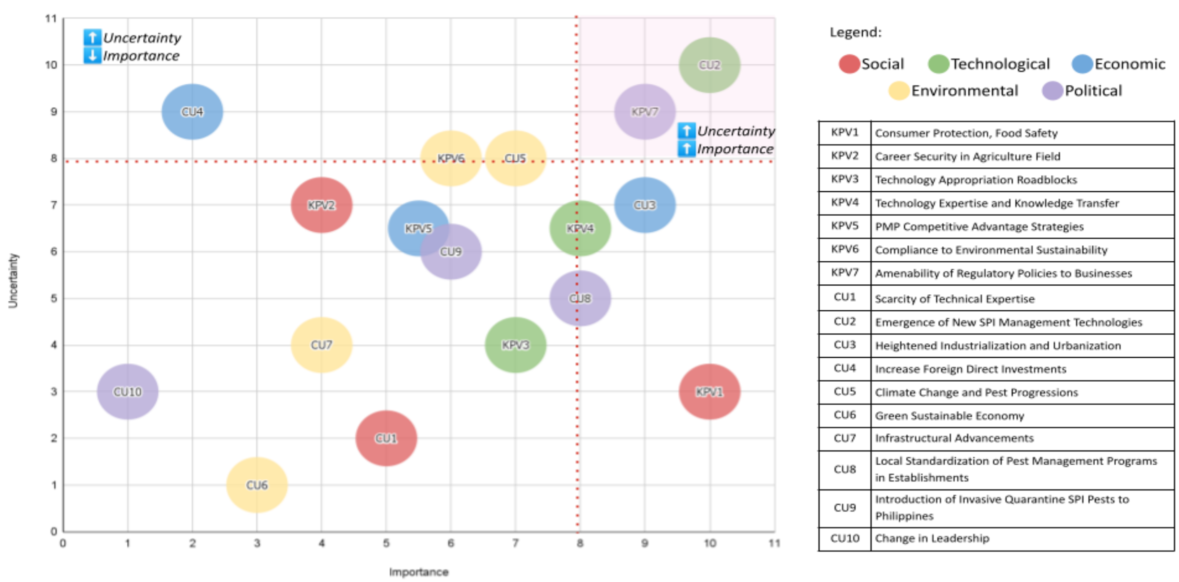

Figure 3. Ranking of variables plotted in uncertainty x importance

There were two (2) variables that fell under high uncertainty and high importance, which are: the Amenability of Regulatory Policies to Businesses (KPV7) and the Emergence of New SPP Management Technologies (CU2). These two variables are driven by political and technological forces, which will be used to develop the scenarios for this study. While, the other variables outside the high uncertainty and high importance region were utilized to develop more robust and realistic scenarios. A 2x2 matrix method was used (Schoemaker,1995) using the political and technological factors as driving forces showing the desirable and undesirable criteria for each—whether regulatory policies are amenable for firms in the pest management industry to acquire new technologies, and whether the conventional technologies were retained or destroyed with the emergence of new SPP management technologies as exhibited in Figure 4. To ensure robust, useful, and realistic scenarios, the other variables plotted were utilized to develop four scenarios by identifying causal relationships as affected by the driving forces as shown in Figure 5.

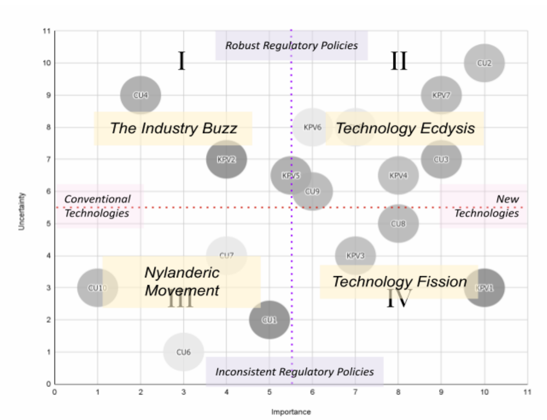

Figure 4. Development of four-scenario logic

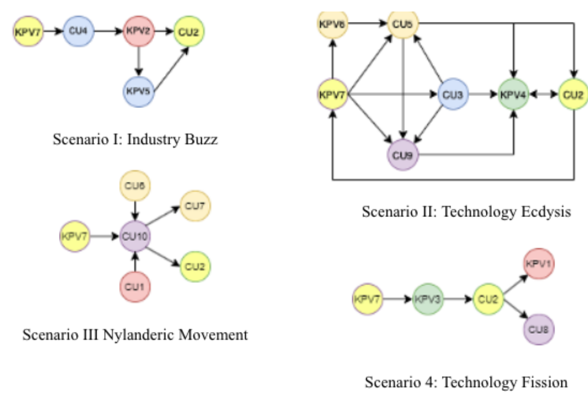

Figure 5. Causal diagrams of four scenarios

The following are the logical narratives for each scenario:

Scenario I: Industry Buzz

Increased demand for human resources with technical skills in entomology and related disciplines to fill in positions in companies securing competitive advantage through credible and high-skill technical capability for technology acquisition and knowledge transfer.

Scenario II: Technology Ecdysis

Well-crafted regulatory policies can provide a supportive and conducive environment for businesses venturing into innovations destructing conventional approach/technologies in SPP management.

Scenario III: Nylanderic Movement

Increase number of unlicensed pest control operators, counterfeit and DIY products in the market weakening the demand for professional services.

Scenario IV: Technology Fission
Philippines pest management industry will be forming their own initiative and efforts to elevate industry standards, and compliance to food safety.

Assessment of Implications of the Scenarios
Porter's Five Forces model was used to assess the industry attractiveness with the four (4) scenarios. The model is a frequently used guideline for evaluating the competitive forces that influence a variety of business sectors (Schilling, 2013). This model will demonstrate the strengths and weaknesses of the industry under each scenario by evaluating its implications with the five (5) forces: threats of new entrants, bargaining power of suppliers, bargaining power of buyers, threat of substitute products or services, and intensity of competitive rivalry. Scorecards were created to assess and compare the forces for each scenario summarized in Table 3.

Table 3. Summary of Assessment of implications of Scenarios using Porter's Five Forces

Scenarios / Five Forces	Competitive Rivalry	Threats of New Entrants	Power of Supplier	Threats of Substitution	Power of Buyer
Scenario I: The Industry Buzz	Moderate to High	Moderate to High	High	Low to Moderate	Moderate to High
Scenario II: Technology Ecdysis	Low to Moderate	Low to Moderate	High	Low to Moderate	Low
Scenario III: Nylanderic Movement	High	High	High	High	High
Scenario IV: Technology Fission	Moderate	Moderate to High	Moderate	HIgh	HIgh

The competitive rivalry in the pest control industry is shaped by the number of firms, product differentiation, and regulatory structures, with Scenarios I and III exhibiting the highest competition due to lack of differentiation and unstructured policies. Scenario IV presents moderate rivalry, where industry associations play a regulatory role by standardizing credentials and accreditation requirements, effectively controlling competition. Scenario II shows low to moderate rivalry as high capital investments, exclusive distributorships, and emotional attachments of long-standing family-owned firms create strategic stakes and exit barriers, reducing the likelihood of aggressive competition.

Scenario III presents the highest threat of new entrants, particularly from local businesses, due to lax regulatory policies, low product differentiation, and easy market access. Scenarios I and IV also pose moderate to high threats but for different reasons—Scenario I attracts foreign investors and suppliers, fostering innovation, while Scenario IV allows local companies to exploit regulatory loopholes to import unverified technologies. Scenario II, with its strong regulatory framework, presents the lowest threat as high capital and skilled workforce requirements limit new entrants, ultimately encouraging industry collaboration and product differentiation.

Scenarios I and II depict strong supplier bargaining power, as stringent regulations and technical capability building create demand for high-quality pest management solutions, giving suppliers greater control over pricing and market influence. Scenario I highlights how firms with advanced technologies and skilled entomologists gain a competitive edge, while Scenario II emphasizes exclusivity, enabling firms to control technology access and pricing. In contrast, Scenarios III and IV show weaker supplier power due to the rise of new pest management firms, increasing competition and allowing buyers to integrate backward or establish direct relationships with manufacturers.

Threats of substitution in pest management arise from low switching costs, price sensitivity, and the availability of alternatives, with safety, regulatory compliance, and product availability being top priorities for PMPs. Scenario I, despite strong regulations, sees slow adoption of new technologies due to limited product differentiation, while Scenario II promotes innovation, encouraging the replacement of conventional methods with more efficient but costly alternatives like sulfuryl fluoride fumigation. In contrast, Scenarios III and IV face high substitution threats—Scenario III due to DIY approaches, counterfeit products, and weak regulations, while Scenario IV relies on industry self-regulation, making it difficult for new technologies to enter the market due to bureaucratic barriers.

The power of buyers in the pest management industry is influenced by their access to information, regulatory awareness, and the availability of alternatives. Scenario I gives customers moderate to high bargaining power, as they prioritize technical competency and supplier expertise, while Scenario II reduces buyer power due to the complexity of adopting new technologies, making them more reliant on suppliers. In contrast, Scenarios III and IV present high buyer power, as customers scrutinize legal compliance, quality, and minimum standards before purchasing, with Scenario III emphasizing regulatory adherence and Scenario IV focusing on standardized industry practices.

CONCLUSION AND RECOMMENDATIONS

The study emphasizes three focal points to be considered in shaping the future of technological advancement in SPP management which revolves around the challenges in talent recruitment, policies, and technology accessibility and exploitation. Indeed, the four scenarios are realistic and achievable, but it is imperative for the industry, academe, and government to address the focal issues together.

Skills Gap Resolution

The declining number of students in agriculture and entomology poses a critical human resource challenge in SPP management, leading to intense competition between research organizations and industry for skilled graduates. While technical knowledge and innovation drive economic progress, the prevailing belief that individual talent alone ensures success is flawed, as effective teams and strong organizational practices play a crucial role. Viewing talent acquisition as a competition may harm long-term organizational stability. To address this, academia and industry must collaborate through initiatives such as employer roadshows and feedback mechanisms to align educational outputs with industry needs, ensuring a sustainable talent pipeline for future generations.

Educate. Then, Regulate

Laws and regulations are essential for technological progress, particularly in intellectual property protection and industry regulation. Political stability in regulatory policies fosters education, awareness, and responsible technology use. Regulatory agencies must possess technical expertise to understand industry dynamics and make informed decisions. In the Philippine pest management industry, technical knowledge serves as common ground among stakeholders, emphasizing the need for collaboration and a supportive ecosystem to develop balanced, technically sound regulations that promote both industry growth and public interest.

Stored Product Protection and Beyond

The objective of the capstone aims to have a foresight of SPP technologies in the next decade. It was revealed that the technology produced such as pheromones, new pesticide compounds, and packaging technologies are insufficient to mitigate sustainably the global and local challenges in stored product protection. The new era of urban pest management must not only focus on how hi-tech the products are but on how to effectively deliver and create demand in the market. This is to make technology users to become adept at what, when, where, and how to use it.

This scenario planning is a good exercise and starting point for the industry and firms involved to consider this scenario-building framework and revisit their competitive strategies to maximize the opportunities. Environmental scanning is as important as in-depth awareness of the firms' respective strategic priorities. The four (4) scenarios developed in this study– The Industry Buzz, Technology Ecdysis, Nylanderic Movement, and Technology Fission – are likely to have started to happen which strongly suggests immediate attention of all the stakeholders, associations, and firms in the pest management industry to collaborate and take action to elevate the Philippines urban pest management global competitiveness.

Conducting this foresight is challenging due to limited local information and a lack of industry data on stored product protection in the Philippines. Collaboration among research institutions and pest management associations is essential to foster expert insights, creativity, and engagement. Industry experts involved in this study, despite encountering the framework for the first time, strongly recommend expanding scenario-building exercises across SPP management and IPM technologies. Integrating academic research perspectives in environmental scanning would further bridge industry and research expectations, unlocking greater opportunities for the sector.

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