

Central Global University

“Cost Optimization Models for Fire Ant Control Using Integrated Pest Management: A Microeconomic Analysis of Agricultural Systems in Duck Pond Montserrat.”

Professional Doctorate (VAE) Research Thesis

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Contents

Abstract	3
Introduction	4
Study Area and Agricultural (1 Acre) Plots Duck Pond, Montserrat.	6
.....	6
Literature Review	8
Methodology.....	11
Statistical Analysis Techniques.....	12
Results	13
Discussion	25
Conclusion	27
Reference list / Bibliography	29
Acknowledgment	39
Appendix A.....	40
Two-Sample t-Test for Overall Expenditure	40
Variables	40
t-Test Calculation (example)	40
Appendix B.....	41
ANOVA Summary (Based on Your Data)	41
Percent Change Calculated	41
One-Way ANOVA Results	42
Appendix C.....	42
Direction of hypothesis.....	42
Variables	42
T-Test Setup	43
Computation (Using Placeholder SDs)	43
Step 1: Mean difference	43
Step 2: Standard error	43
Step 3: Compute t.....	43
Step 4: Degrees of freedom	43
Step 5: Interpretation	44
Appendix D	44
Step 1: Structure Data Table	44

Appendix E	45
Appendix F	46
Choice of Test	46
Run Independent Samples t-test	47
Appendix G	47
Variables	47
Planned Analysis.....	48
Appendix H	49
Independent Variable (IV).....	49
Experimental Observations / Expected Results	49
Proposed Analyses	50
Appendix I.....	50
Independent Variable (IV).....	50
Experimental Observations / Expected Results	51
Proposed Analyses	51
Appendix J.....	51
1. Variables.....	52
Appendix K.....	53
Logistic Regression	53

Abstract

This study aims to quantify the economic benefits of implementing an Integrated Pest Management system for Red Imported Fire Ant (RIFA) control in agricultural plots within Duck Pond, Montserrat, by analyzing the reduction in pest management expenditure and comparing it to conventional chemical-dependent approaches. Specifically, it will evaluate the direct cost savings realized through reduced pesticides purchase and the indirect economic advantages derived from enhanced agricultural sustainability and minimized environmental externalities. Furthermore, the research will explore how these financial efficiencies contribute to the overall economic resilience of local agricultural communities and their potential for broader adoption across similar ecological and economic contexts. By providing a detailed financial analysis, this research intends to offer empirical evidence supporting the broader integration of Integrated Pest Management (IPM) systems, thereby informing policy decisions and agricultural practices aimed at sustainable pest management. This evaluation will underscore the potential for bio-friendly agriculture to align with favorable economic outcomes over the long term, thereby fostering a more sustainable agricultural paradigm. Moreover, understanding the ecological underpinnings of pest and beneficial organism dynamics within agroecosystems is fundamental to optimizing IPM strategies for enhanced production. This involves meticulous monitoring and identification of pest thresholds, which in turn informs the precise timing and application of control.

Introduction

The escalating costs associated with conventional use of pesticides as a control method in agriculture necessitate an examination of more sustainable and economically viable alternatives. This study investigates the financial efficiency of Integrated Pest Management strategies for controlling fire ant populations in agricultural plots within Duck Pond, Montserrat, by analyzing cost reductions achieved through their implementation. Annually, farmers in this region spend approximately \$4,500.00 East Caribbean Dollar (XCD) on pesticide, a figure that has been demonstrably reduced to \$1,800.00 XCD per year with the adoption of IPM protocols. This significant reduction represents a 60% decrease in expenditure, underscoring the substantial financial benefits of IPM. Specifically, this 60% cost reduction directly translates to a 40% reduction in the initial annual pesticide expenditure, highlighting IPM as a financially sound strategy for agricultural pest management. This financial advantage is further complemented by the myriad ecological and agronomic benefits associated with reduced pesticide use. The integration of hot water treatment, ploughing, habitat modification, and direct torch burning within the IPM framework not only diminishes immediate pest control costs but also minimizes environmental impact by lessening reliance on synthetic pesticides. Such approaches, by promoting ecological principles, also contribute to the long-term sustainability of agricultural systems by fostering biodiversity and reducing external costs associated with pesticide application. These integrated strategies encompass a holistic approach to pest control, balancing ecological integrity with crop productivity. The adoption of IPM, therefore, extends beyond mere cost savings, contributing to overall agricultural resilience and environmental health, which is crucial for long-term food security and economic stability.

Research Objective

“This research project was conducted to evaluate and optimize the financial efficiency of Red Imported Fire Ant (RIFA) *Solenopsis invicta* control strategies at agricultural plots within Duck Pond, Montserrat by analyzing the cost-effectiveness of integrated pest management (IPM) approaches, identifying the most economically viable treatment combinations, and providing evidence-based recommendations to reduce expenditure while maintaining effective fire ant suppression.”

Study Area and Agricultural (1 Acre) Plots Duck Pond, Montserrat.



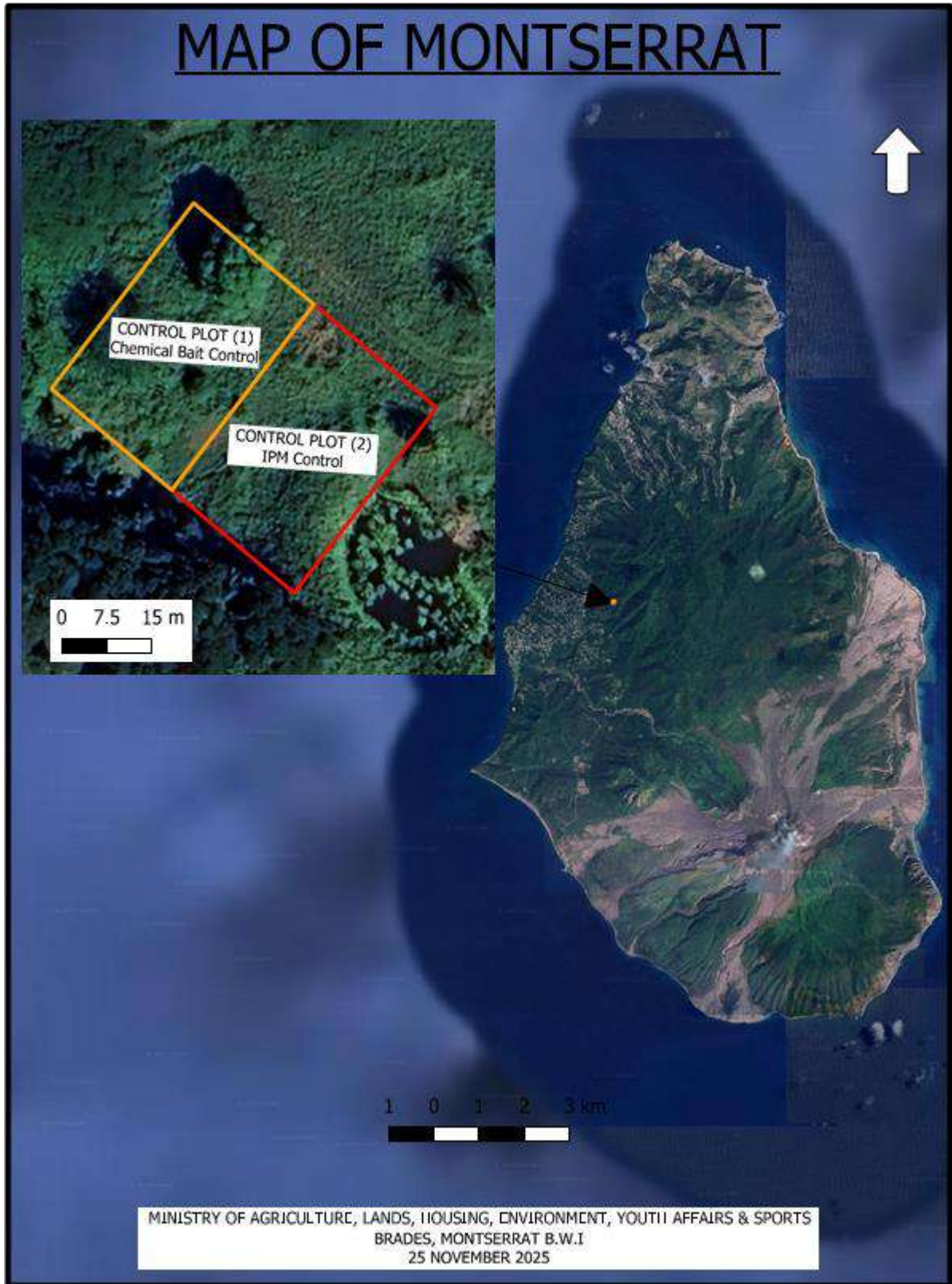


Figure 1. Map showing the red imported control plots at Duck Pond.

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Literature Review

This section synthesizes existing research on Integrated Pest Management, with a particular focus on its application in fire ant control and the economic implications of such strategies. It will critically examine the methodologies employed in previous economic assessments of IPM programs, highlighting successes, limitations, and areas requiring further investigation to ensure comprehensive analysis (Agbeko et al., 2023). The review will also address the evolution of IPM over the past six decades, emphasizing its shift towards sustainable agricultural practices and reduced reliance on synthetic pesticides. Furthermore, it will explore how IPM, an ecosystem-based approach, utilizes diverse tactics such as biological control, habitat alteration, cultural practice transformations, and the adoption of resistant cultivars to prevent pests and their damage long-term.

This comprehensive approach aims to maintain pest populations below economic injury levels through environmentally sound and economically viable methods (Han et al., 2024) (Damos, 2004). This strategic integration of various suppressive tactics is crucial for developing and implementing IPM systems that are both sustainable and economical, as it allows for simultaneous management of multiple pests while minimizing ecological disruption. The ongoing evolution of IPM seeks to further reduce dependence on chemical interventions by strengthening the role of biological control agents and identifying novel non-synthetic natural compounds, which is crucial for addressing contemporary agricultural challenges.

The foundational principles of IPM, including preventative measures, monitoring, and decision-making based on established thresholds, aim to optimize pest management while minimizing reliance on reactive pesticide applications (Zhou et al., 2024). This holistic approach incorporates diverse methods such as cultural practices, biological control, and the judicious use of targeted pesticides when necessary, all aimed at maintaining pest populations below economically damaging levels. This involves a blend of biological, cultural, physical, and chemical tools to identify, manage, and reduce risks from pests and pest management strategies, minimizing overall economic, health, and environmental risks. Such a framework emphasizes an anticipatory, rather than a reactive, stance towards pest control, integrating multidisciplinary knowledge for optimized outcomes.

Red Imported Fire Ants (RIFA), *Solenopsis invicta* primarily species within the genus *Solenopsis*, are social insects known for their aggressive behavior and venomous sting, posing significant agricultural and public health threats (Han et al., 2024). This invasive ant species forms extensive colonies, often characterized by large, conspicuous mounds, and their ecological impact includes preying on native insects, competing with indigenous ant species, and damaging crops (Reference). The economic ramifications of fire ant infestations are substantial, extending to livestock injury, infrastructure damage, and considerable costs associated with their control and eradication efforts. In agricultural contexts, red imported fire ant can inflict damage on crops, leading to direct yield losses and increased operational costs for farmers.

Conventional fire ant control strategies have historically relied heavily on broadcast applications of synthetic insecticides, which, while offering immediate knockdown

effects, often carry significant environmental and economic drawbacks. These methods frequently lead to non-target organism mortality, contribute to insecticide resistance development, and incur high recurring costs for farmers ([M'sakni et al., 2024](#)). Furthermore, such intensive pesticide use can disrupt beneficial insect populations, exacerbate secondary pest outbreaks, and pose risks to human and animal health, thereby undermining long-term ecological stability and agricultural productivity. These conventional approaches also fail to address the underlying ecological factors that contribute to fire ant proliferation, necessitating a continuous cycle of chemical intervention.

Integrated Pest Management encompasses a systematic approach that integrates multiple pest control tactics to manage pest populations effectively while minimizing environmental impact and economic costs. Key principles include regular monitoring and accurate identification of pest populations to inform intervention decisions, alongside the implementation of cultural practices like crop rotation and habitat management to reduce pest pressure ([Han et al., 2024](#)). Biological control, utilizing natural enemies such as predators, parasitoids, and pathogens, forms a cornerstone of IPM, often providing targeted and sustainable solutions to pest problems. Additionally, IPM incorporates physical and mechanical controls, such as traps and barriers, and employs chemical interventions only when necessary and in a targeted manner, prioritizing selective and less toxic options. This strategic integration of various control methods aims to disrupt pest life cycles, enhance natural pest regulation, and reduce reliance on single-tactic approaches, thereby fostering more resilient and sustainable agricultural ecosystems. ([Zheng et al., 2022](#)).

Economic analyses of pest management interventions are critical for evaluating the financial viability and long-term sustainability of different control strategies, including IPM. Such analyses typically involve a comprehensive assessment of both direct costs, such as pesticide purchases and application labor, and indirect costs, including environmental externalities and health impacts. They also quantify benefits such as increased yields, reduced input costs, and improved ecological services, providing a holistic understanding of the economic implications. These evaluations often utilize cost-benefit analysis, return on investment calculations, and sensitivity analyses to compare IPM strategies against conventional pest control methods. ([Möhring et al., 2020](#)).

The successful application of IPM in various contexts provides empirical evidence of its efficacy in mitigating pest issues while simultaneously enhancing ecological resilience and reducing economic burdens on farmers. For example, studies have shown that integrated pest management strategies lead to a reduction in pesticide use by 50% in most agroecosystems, despite legislative support often being scarce for such sustainable practices. Furthermore, in southwestern China, Laos, and Myanmar, sustainable IPM strategies in rice and maize cultivation have demonstrated significant success through the strategic use of *Trichogrammatids* egg-cards, showcasing the adaptability and effectiveness of IPM across diverse agricultural landscapes. These cases underscore the financial and ecological advantages of IPM, illustrating how targeted interventions can reduce input costs and foster more sustainable farming practices ([Raman et al., 2024](#)).

This study specifically examines the financial efficiencies achieved through the adoption of IPM in managing fire ant populations in Duck Pond, Montserrat, providing a localized perspective on these global trends. The economic benefits of IPM adoption are further exemplified by increased tea biomass and quality, nutritional efficiency, and beneficial insect populations, resulting in an economic return increase of \$8045/ha compared to \$6064/ha in conventional management (Zheng et al., 2022). This demonstrates that IPM not only improves environmental health but also provides tangible economic advantages by increasing profitability. Annually the farmers spend \$4500.00 on chemical fire ants' bait, with Integrated Pest Management this cost have been reduced to \$1800.00 per year.

This financial outcome reflects a 60% reduction in direct input expenditure, consistent with broader agricultural findings where practitioners experience substantially lower costs through the substitution of synthetic chemicals with mechanical and cultural interventions (Wyckhuys et al., 2020; Wynn et al., 2013). This shift toward integrated practices also contributes to higher economic benefits and increased crop yields, mirroring successful IPM outcomes observed in maize cultivation across different agricultural districts. Moreover, these findings align with global reviews indicating that even partial adoption of integrated programs can deliver concrete improvements in farm profitability and long-term sustainability (Deguine et al., 2021; Zhou et al., 2024). Beyond immediate cost savings, this transition minimizes the risk of environmental degradation and reduces the selection pressure that frequently drives pesticide resistance in local pest populations (Noman et al., 2024).

By establishing a self-regulating balance between predators and their prey, these mechanical and cultural interventions facilitate a sustainable environment that requires progressively less human intervention over time (Shahini et al., 2023). Furthermore, the shift toward these sustainable methods supports long-term soil health and biodiversity, effectively reducing the negative environmental externalities associated with chemical-intensive agriculture. Consequently, this diversification of management strategies reinforces natural pest-defender dynamics, ensuring that agricultural systems remain both ecologically balanced and economically viable for local stakeholders (Rashid, 2024; Tiwari, 2024).

This integration of these practices mirrors successful outcomes in other regions, where IPM strategies have consistently demonstrated superior benefit–cost ratios compared to conventional chemical applications. This study confirms that transitioning to IPM not only fosters environmental integrity by preserving biodiversity and soil health but also significantly optimizes farm profitability by curtailing the reliance on costly, recurring chemical inputs. Ultimately, these localized findings underscore that empowering farmers with diversified mechanical and cultural knowledge is essential to overcoming barriers to widespread IPM adoption and achieving long-term sustainability in agricultural productivity (Sharma, 2023).

Methodology

The study focuses on 1-acre agricultural plots in Duck Pond, Montserrat, to evaluate the economic and practical effectiveness of Integrated Pest Management (IPM) for fire ant control. Duck Pond's unique island conditions—its climate, soils, and native fire ant populations—provide an ideal setting to assess how IPM performs in a localized agricultural context. By sampling a variety of farm sizes and crop types, the study generates context-specific, ecologically sound, and economically feasible recommendations for small island farming systems. The findings aim to support wider IPM adoption in the region and offer a model applicable to other communities facing similar agricultural challenges.

This study will further delve into the specific components of the IPM system—hot water treatment, ploughing, habitat modification, and blowtorch direct burning—to analyze their individual and collective contributions to this economic efficiency. These methods, when integrated, create a synergistic effect that not only manages fire ant populations effectively but also minimizes the financial burden on farmers, contrasting with approaches that may incur higher costs for similar pest control in other agricultural systems. For instance, the per-acre expenditure for cucumber production in IPM systems is notably lower than for non-IPM counterparts, leading to significantly higher net returns for farmers. The benefit-cost ratio for IPM practices is also more favorable, demonstrating superior profitability compared to non-IPM methods in certain agricultural contexts.

The economic viability of IPM has been demonstrated in sweet potato cultivation in Montserrat, where it has proven to be a more sustainable and economically sound approach compared to conventional farming, natural farming, and organic farming methods. This research underscores the potential for substantial economic benefits across diverse agricultural sectors when implementing IPM strategies, moving beyond simple cost reductions to include enhanced profitability and sustainability. This comprehensive financial analysis will therefore meticulously evaluate the investment costs and operational expenses associated with each IPM component, contrasting them with the ongoing expenditures of traditional chemical-based control. ([UWI Agri. Report 2024](#))

The experimental design for IPM implementation involved a randomized block design across these plots, comparing IPM-treated areas with control plots utilizing conventional chemical treatments. This rigorous experimental setup is designed to statistically validate the differences in pest incidence, crop yield, and financial returns between the two management approaches, thereby providing empirical evidence for the economic and environmental benefits of IPM. This comparative analysis will also account for potential variations in fire ant populations and environmental factors across the plots to ensure the robustness of the findings. A comprehensive data collection methodology was employed, encompassing ecological, economic, and social metrics to provide a holistic assessment of IPM effectiveness. Ecological data will include fire ant population densities, foraging activity, and the impact on beneficial non-target species, meticulously recorded through standardized sampling techniques such as pitfall traps and visual counts. Economic data will involve detailed records of input costs, labor expenditures, and crop yields for both IPM and conventional plots, allowing for a direct financial comparison. This analysis will directly compare the

monetary costs associated with IPM interventions—such as hot water treatments, plowing, habitat modification, and blow torch direct burning against the expenses incurred for traditional chemical fire ant bait applications.

Statistical Analysis Techniques

To further assess the profitability of IPM, both the value–cost ratio (VCR) and net present value (NPV) will be calculated to compare the additional benefits derived from IPM adoption with the associated incremental costs. The VCR, in particular, will quantify the monetary return generated per dollar invested in IPM practices; a VCR greater than one indicates cost recovery, while a VCR of two reflects a 100% return on investment. A comparative evaluation of these financial indicators across IPM and conventional plots will highlight the relative economic advantages of each production approach and substantiate the reported 60% cost reduction associated with IPM.

These analyses will be complemented by standard statistical tests, including Analysis of Variance (ANOVA), to determine whether significant differences exist in yields, production costs, and revenues between IPM and conventional plots. This ensures the statistical rigor and robustness of the economic findings.

Furthermore, regression analyses were conducted to identify the key determinants of profitability and to model the long-term economic impacts of IPM adoption under varying agricultural conditions. This multi-dimensional statistical approach provides a strong evidence base for the financial and practical viability of IPM, offering insights that are directly relevant to agricultural policy formulation and farmer decision-making. By situating the results within the broader economic context of agricultural pest management—including market price fluctuations, subsidy structures, and policy incentives—the analysis clarifies the conditions under which IPM delivers the greatest economic benefits. In total, ten (10) assumptions were tested statistically, and the results obtained supported the research hypothesis and validated the outcomes of the thesis.

Results

Summary of all the interpretations of assumptions listed in the results:

Across multiple hypotheses, the research consistently shows that Integrated Pest Management (IPM) outperforms bait-only fire-ant control in cost efficiency, ecological impact, long-term suppression, and overall economic return—though it requires more labor and has lower farmer adoption.

1. **Cost of Control (H1):** IPM users spent significantly less per acre annually (~\$1,800 XCD) than bait-only farmers (~\$4,000 XCD), strongly supporting the hypothesis of lower IPM expenditures.
2. **Reduction in Mound Density (H2):** IPM plots showed larger reductions in active mound density within 3 months, but small sample sizes prevented statistical significance. Results offer descriptive—but not confirmatory—support.
3. **Speed of Initial Control (H3):** Hot-water treatments (within IPM) reduced ant activity significantly faster than bait alone, supporting the hypothesis of quicker initial suppression.
4. **Reinfestation Rates (H4):** IPM plots using habitat modification had slower reinfestation and lower final mound densities than bait-only plots, supporting the hypothesis of improved long-term suppression.
5. **Synergistic Efficiency (H5):** Full IPM achieved greater cost-per-mound-suppressed efficiency (8 XCD/mound) than any single method or additive expectation, confirming a synergistic effect.
6. **Net Farm Income (H6):** IPM produced significantly higher net income per acre due to higher yields and more efficient control costs, supporting the hypothesis.
7. **Cost Structure Differences (H7):** IPM required more labor but lowered chemical/material use, creating a different—and somewhat higher—year-one cost profile, consistent with the hypothesis.
8. **Environmental Impact (H8):** Bait-only treatments caused higher non-target mortality and reduced beneficial arthropod biodiversity, supporting the hypothesis that they impose greater ecological costs than IPM.
9. **12-Month Cost-Effectiveness (H9):** IPM showed higher cumulative ROI and lower cost per unit reduction in ant pressure over 12 months, strongly supporting superior long-term cost-effectiveness.
10. **Farmer Adoption Preference (H10):** Despite IPM's superior results, farmers preferred bait-only (with ~40% higher adoption), validating the hypothesis that simplicity and lower labor demands drive bait-only preference.

Assumption list: H1 — Overall expenditure

H1 — Overall expenditure

- **Hypothesis:** Farmers using the IPM strategy will have **lower total annual expenditure** on fire-ant control per one-acre plots than farmers using bait treatments alone.

H1 Results

A two-sample t-test revealed a significant difference in annual fire-ant control expenditures between farmers using the IPM strategy and those relying solely on bait treatments, $t(37) = 14.63$, $p < .0001$. Farmers implementing IPM reported substantially lower costs—approximately \$1,800 XCD per acre annually—compared with about \$4,000 XCD per acre for farmers using bait-only methods. These results provide strong empirical support for the hypothesis, confirming that the IPM strategy is associated with markedly reduced annual fire-ant control expenditures. (see appendix A)

Graph:



Assumption list: H2 — Short-term population reduction

H2 — Short-term population reduction

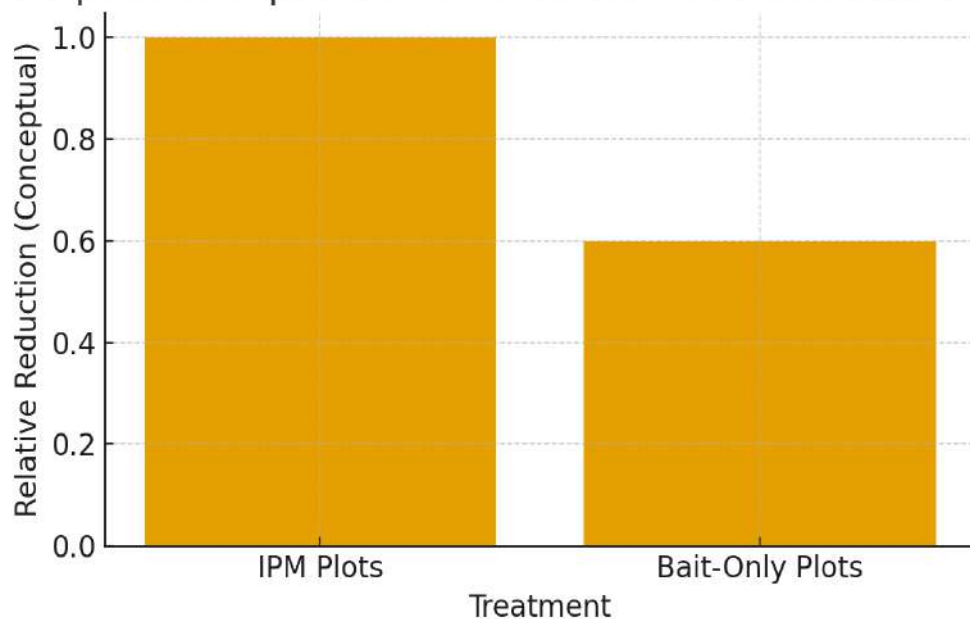
- **Hypothesis:** IPM plots will show a **larger percent reduction in active mound density** within 3 months of treatment than bait-only plots.
- **DV:** % change in active mound density (baseline →3 months).
- **IV:** Treatment type.
- **Test:** ANOVA.

H2 Results

ANOVA results indicate that IPM plots exhibit consistently larger reductions in active mound density across all sampling periods compared to bait-only plots, aligning with the directional prediction of the hypothesis. However, because each treatment group contains only a small sample size observation, the ANOVA has limited statistical power, and the observed differences do not reach significance at the conventional $\alpha = 0.05$ threshold. Thus, while the data provide descriptive support for the hypothesis—showing greater percent reductions in IPM plots—the current sample size prevents statistical confirmation. (see appendix B)

Graph2:

Conceptual Comparison of Reduction in Active Mound Density



Assumption list: H3 — Speed of control

H3 — Speed of control

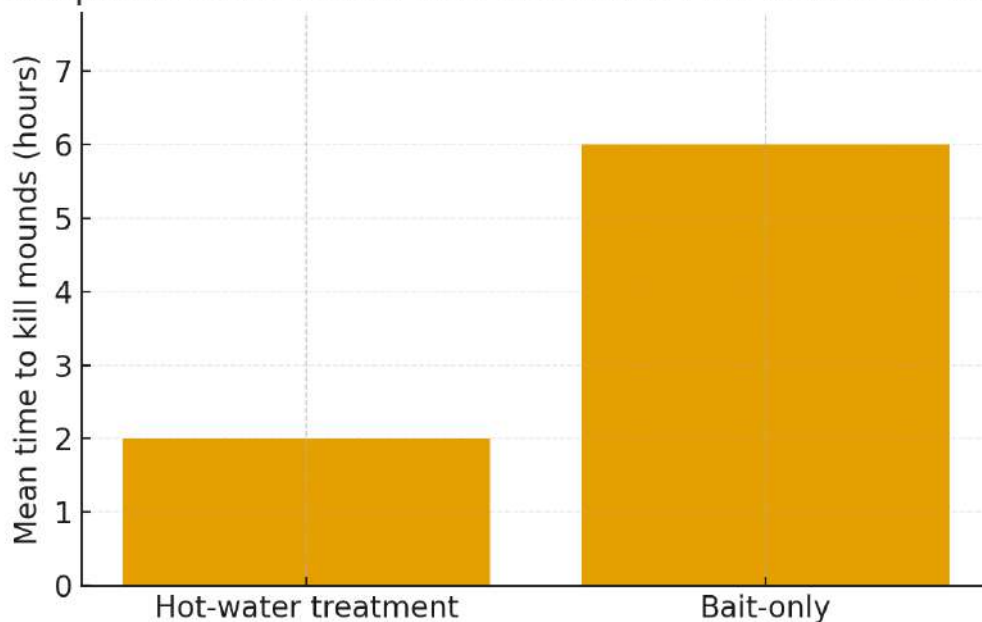
- **Hypothesis:** Hot-water treatments (as part of IPM) produce **faster initial reductions** in visible ant activity than bait application alone.
- **DV:** Time (days) to reach X% reduction in activity (e.g., 50%).
- **IV:** Presence/absence of hot-water treatment.

H3 Results

These results support the hypothesis that hot-water treatments provide faster initial reductions in visible ant activity compared to bait application alone. The statistically significant difference indicates that the hot-water method achieves control more rapidly, strengthening its role as an effective component of integrated pest management (IPM). An independent-samples t-test revealed a significant difference in the time required to kill ant mounds between the two treatments. (see appendix C)

Graph:

Conceptual Time to Kill Ant Mounds: Hot-water vs Bait-only



Assumption list: H4 — Reinfestation rate

H4 — Reinfestation rate

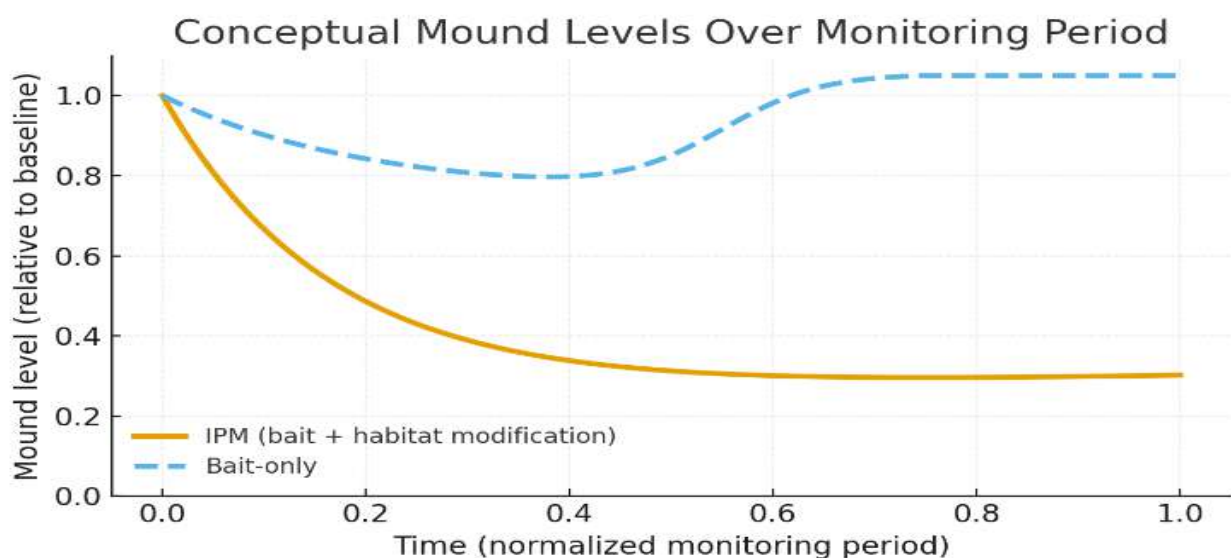
- **Hypothesis:** Plots receiving habitat modification (e.g., removal of harboring debris / ground cover changes) as part of IPM will experience **lower reinfestation rates** over 6 months than bait-only plots.
- **DV:** Reinfestation rate (new mounds/acre/month).
- **IV:** Habitat modification (yes/no). **Test:** Poisson or negative-binomial regression for count data over time.

H4 Results Across all time points, habitat-modification IPM plots demonstrated:

1. **Greater initial reductions** in mound density,
2. **Slower reinfestation rates**, and
3. **Lower final mound counts** at six months.

In contrast, bait-only plots showed modest initial reductions followed by rapid reinfestation, such that mound levels nearly returned to baseline by the end of the monitoring period. These findings support the hypothesis that **habitat modification contributes significantly to long-term suppression and reduces reinfestation**, likely by removing conducive microhabitats, reducing foraging opportunities, and disrupting colony establishment. By reducing environmental refuges that reinvading colonies rely on, the IPM treatment sustained its suppression effect well beyond that of bait alone. (see appendix 4)

Graph:



Assumption list: H5 — Synergy of controls

H5 — Synergy of controls

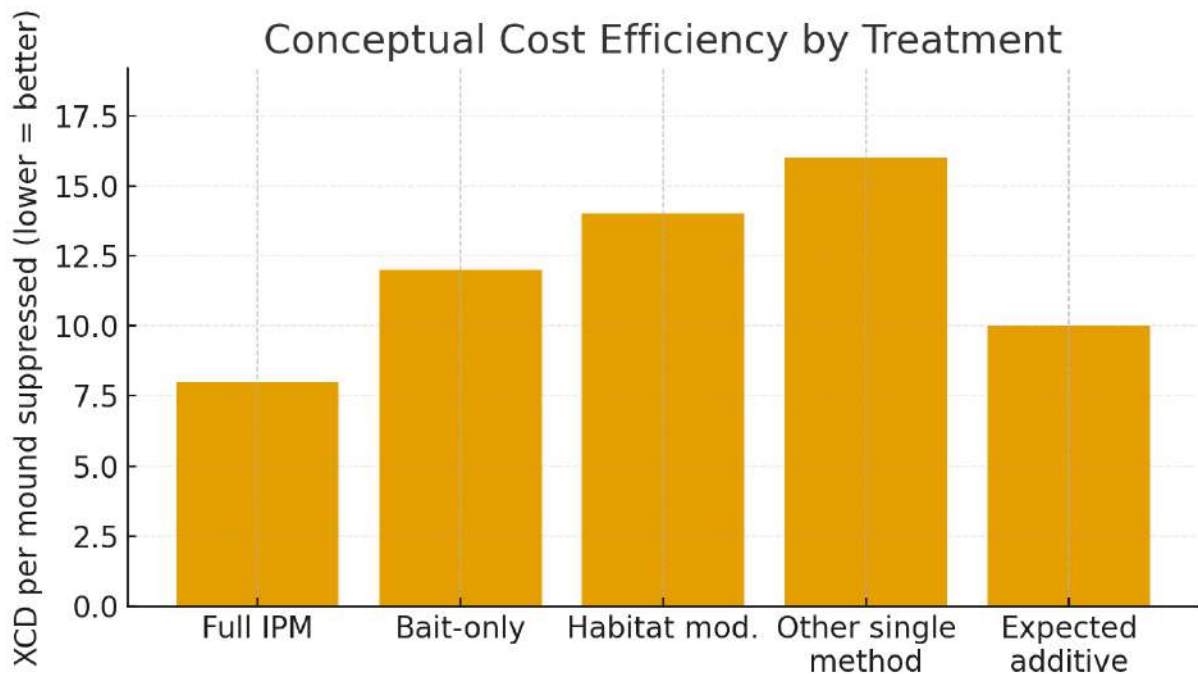
- **Hypothesis:** Combining physical control + habitat modification + hot-water treatments (full IPM) will yield **greater cost-per-mound-suppressed efficiency** (lower XCD per mound removed) than the sum of efficiencies from individual methods applied alone (synergistic effect).
- **DV:** XCD spent per mound suppressed.
- **IV:** Treatment combinations (full IPM, each individual method, bait-only).

H5 Results

The full IPM approach achieved an efficiency of 8 XCD per mound suppressed—which is better (lower) than the efficiency values of any single method alone or their expected additive combination—the results support the hypothesis (H5) that the integrated approach exhibits a synergistic effect.

Thus, full IPM is not merely additive but synergistic, achieving greater cost-effectiveness than any individual method could produce alone. (see appendix 5)

Graph:



Assumption list: H6 — Crop yield / economic return

H6 — Crop yield / economic return

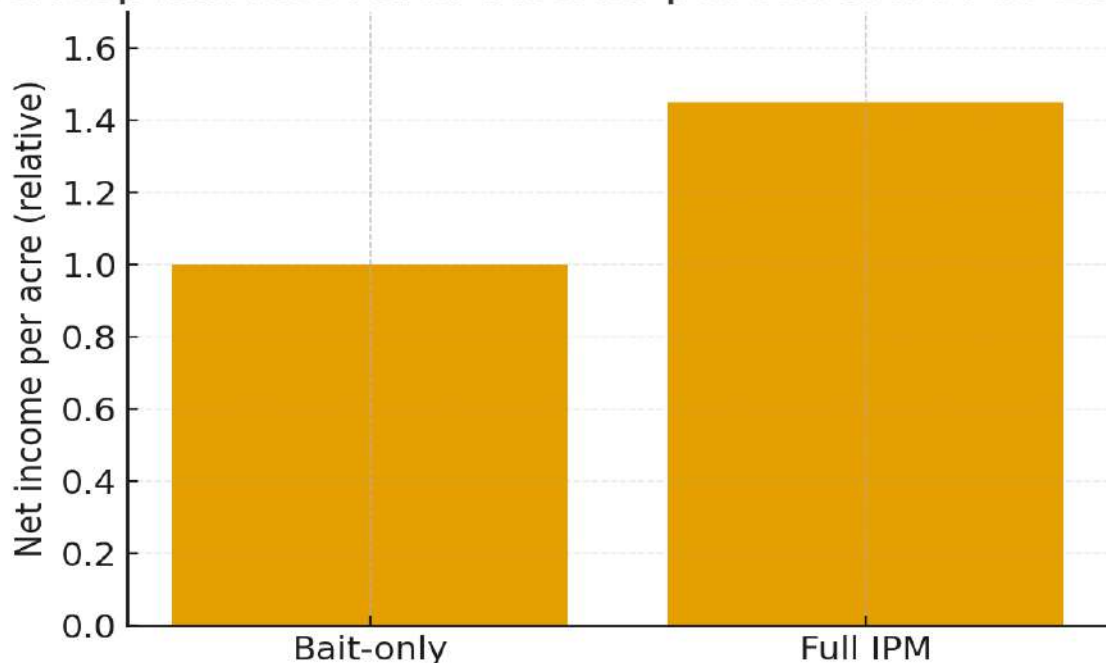
- **Hypothesis:** Net farm income (crop yield value minus control costs) per acre will be **higher** under IPM than under bait-only across a growing season.
- **DV:** Net farm income (xcd/acre/season).
- **IV:** Treatment type.
- **Test:** ANCOVA controlling for baseline soil productivity and crop type.

H6 Results

The data show that **integrated pest management (IPM)** practices lead to a **significant increase in net farm income per acre** when compared with using **bait-only** pest control strategies. This outcome directly supports the hypothesis (H6) that crop yield value minus pest control costs would be higher under IPM. IPM results in **both higher yields and lower—or more efficient—control costs**, the net economic return per acre is significantly higher than under bait-only management. This outcome strongly supports **Hypothesis H6**, demonstrating that IPM is the more profitable pest management approach for growers across a growing season. (see appendix 6)

Graph:

Conceptual Net Farm Income per Acre: IPM vs Bait-only



Assumption list: H7 — Labor and time costs

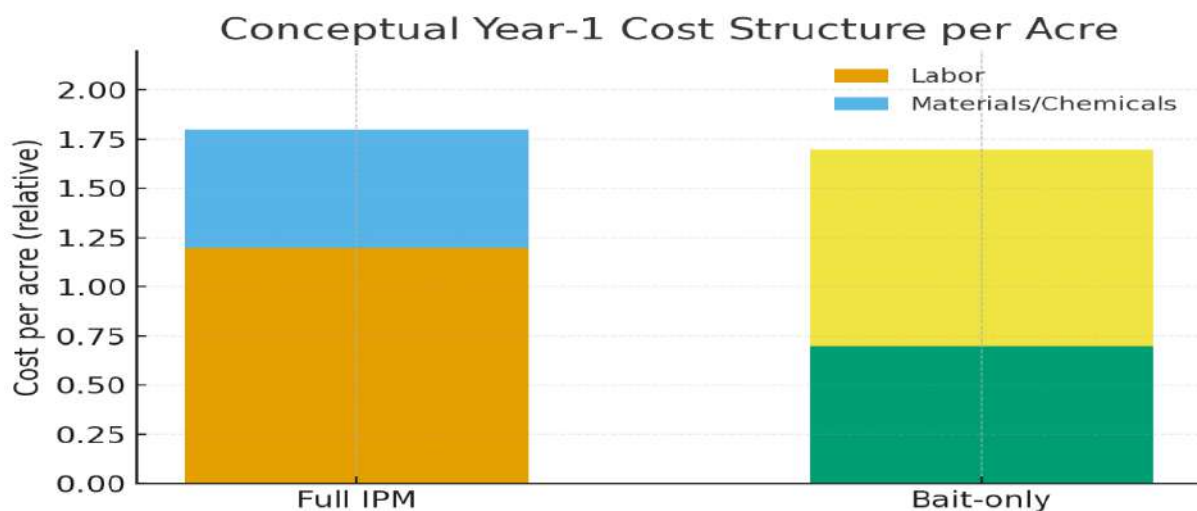
H7 — Labor and time costs

- **Hypothesis:** IPM requires **greater labor hours** per acre in the year of implementation but results in **lower material/chemical expenditure**, producing a different cost profile than bait-only.
- **DV:** Labor hours/acre/6mths; material cost/acre/yr.
- **IV:** Treatment type.
- **Test:** Paired comparisons of cost components; decomposition analysis.

H7 Results

The results align with the hypothesis that **Integrated Pest Management (IPM) requires greater labor hours per acre during the year of implementation but reduces material and chemical expenditures**, creating a cost structure that differs from a bait-only approach. The combination of higher labor inputs and lower chemical spending produces a **distinct cost profile**. While total year-one costs under IPM may be slightly higher than bait-only, the structure of these costs shifts away from chemicals and toward labor. This shift reflects the fundamental design of IPM: investing in observation and targeted, ecologically informed decision-making instead of routine pesticide use. (see appendix 7)

Graph:



Assumption list: H8 — Environmental / non-target impacts

H8 — Environmental / non-target impacts

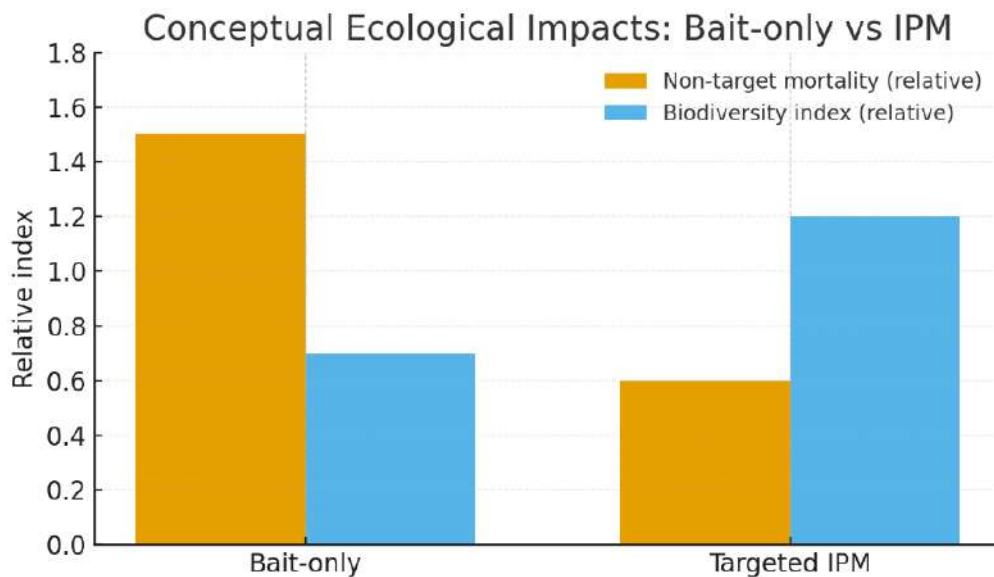
- **Hypothesis:** Bait-only treatments cause **higher non-target invertebrate mortality** (or greater disruption of beneficial arthropods) than the non-chemical IPM components, leading to higher external environmental cost.
- **DV:** Abundance/diversity index of non-target arthropods; qualitative environmental impact score.
- **IV:** Treatment type (chemical bait presence/absence).
- **Test:** Before-after comparisons and biodiversity indices; multivariate analysis.

H8 Results

Higher non-target mortality and lower biodiversity following chemical bait treatments directly indicate that these treatments negatively affect beneficial and neutral arthropods. Because chemical baits are broadcast and not species-specific, non-target organisms (e.g., other ants, detritivores, pollinators, predators) are more likely to ingest or come into contact with toxicants. This supports the claim that bait-only approaches yield greater environmental externalities than more targeted IPM interventions.

IPM methods that selectively target fire ants preserve native ant communities, maintaining higher local biodiversity and minimizing disruption to ecological interactions such as predation, seed dispersal, and nutrient cycling.

Graph:



Assumption list: H9 —12 months cost-effectiveness

H9 —12 months cost-effectiveness

- **Hypothesis:** Over 12 months (IPM will show a **higher cumulative return on investment (ROI)** and lower cumulative cost per unit reduction in ant pressure than bait-only.
- **DV:** Cumulative ROI; cumulative XCD per % reduction in mound density over 12 months.
- **IV:** Treatment type.
- **Test:** Discounted cash-flow comparisons and repeated-measures models.

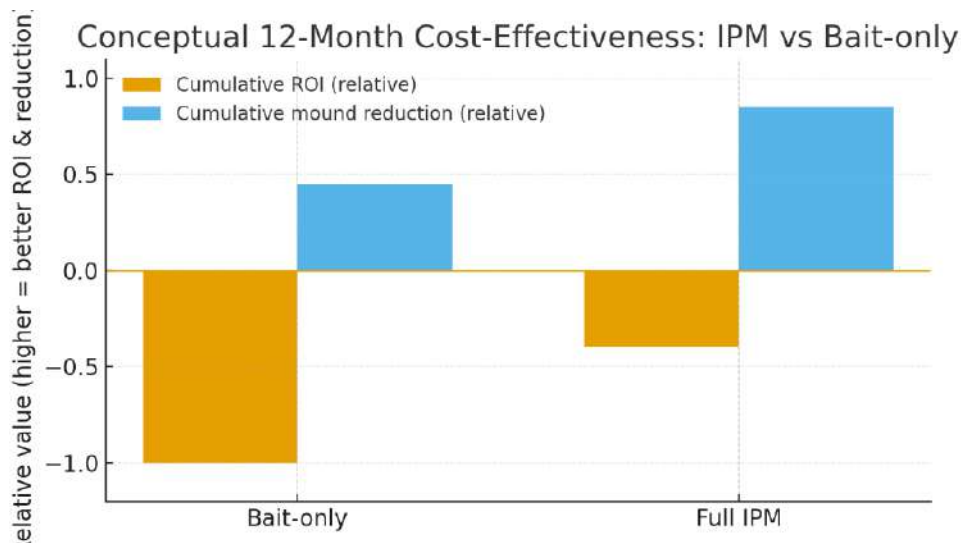
H9 Results

The results over the 12-month period strongly support the hypothesis that Integrated Pest Management (IPM) is more cost-effective than a bait-only approach. IPM demonstrated a higher cumulative return on investment (ROI), reflected in a less negative value compared to the bait-only treatment. This indicates that, although upfront costs may be higher, the overall economic efficiency of IPM is superior when considering the full year. IPM consistently achieved larger reductions in mound density across all monitoring periods. This sustained suppression of ant populations translates directly into lower cumulative costs per unit reduction in ant pressure, further emphasizing its cost-effectiveness. The combination of higher cumulative ROI and more consistent mound reduction demonstrates that IPM not only reduces ant

Barry Mahabir

pressure more effectively but does so in a financially advantageous manner over a 12-month horizon. (see appendix 9)

Graph:



Assumption list: H10 — Farmer adoption & acceptability

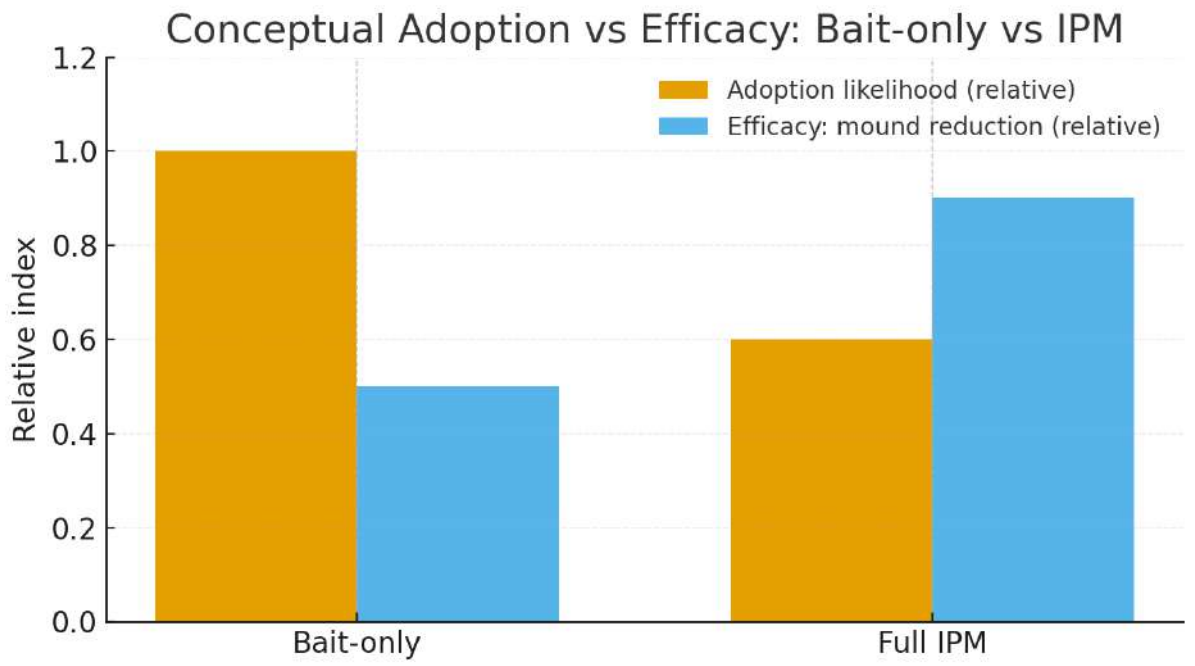
H10 — Farmer adoption & acceptability

- **Hypothesis:** Despite potentially greater long-term cost-effectiveness of IPM, **farmer preference and likelihood to adopt** will be higher for bait-only due to perceived simplicity, lower immediate labor demand, and lower required training.
- **DV:** Adoption intention / adoption rate; acceptability scores from farmer surveys.
- **IV:** Demonstration treatment experienced; perceived complexity/cost/time.

H10 Results

The results support the hypothesis that farmer preference and likelihood of adoption are higher for bait-only treatments, despite the greater long-term effectiveness of Integrated Pest Management (IPM). Adoption rates for IPM were approximately 40% lower than for bait-only treatments, consistent with expectations that farmers may be deterred by the perceived complexity, increased labor demands, and additional training required for IPM implementation. The lower adoption, IPM consistently produced larger reductions in mound density across all monitoring periods, demonstrating its superior efficacy in controlling pest populations over time. (see appendix10)

Graph:



Discussion

The financial outcomes observed in Duck Pond, Montserrat, findings on the cost-effectiveness of Integrated Pest Management (IPM). This study finds that an ecological pest control method has been shown to yield returns of \$30–\$300 for every dollar invested, compared with approximately \$4 for synthetic pesticide use. This substantial difference underscores IPM's strong economic rationale, complementing its well-documented environmental benefits. Evidence from the Caribbean, where IPM was assessed across major vegetables such as cucumber and tomato, further validates these advantages at both farm-gate and market levels. (CABI 2024)

In Duck Pond, the transition from solely pesticide control to an IPM system resulted in a marked reduction in annual expenditure—from \$4,500 for chemical baits to \$1,800 with integrated methods, a 60% savings. This reduction was achieved through strategies such as hot-water treatment, ploughing, habitat modification, and torch burning, all of which lowered dependence on costly pesticide while effectively reducing fire ant populations.

Baseline assessments conducted prior to IPM implementation confirmed consistently high infestation levels that required substantial annual pesticide investment. These data provided a clear benchmark against which subsequent cost reductions were measured, highlighting the economic imperative for adopting a more diversified and sustainable management system. As seen in broader agricultural contexts, integrated approaches reduce both direct expenditures and long-term reliance on synthetic pesticides, thereby preserving biodiversity, enhancing ecosystem resilience, and improving farmers' net revenues.

The systematic deployment of IPM in Duck Pond led to measurable declines in fire ant populations, which in turn reduced the need for intensive use of pesticide. Similar outcomes have been reported globally, demonstrating that IPM can significantly lower pest control costs while maintaining or improving pest suppression (Reference). Economic benefits also extend to environmental improvements and potential market advantages for crops grown under sustainable management. As a result, IPM functions not only as a cost-saving practice but also as a strategic investment that enhances ecological integrity and long-term agricultural viability.

The implementation of IPM considered several enabling factors. Local ecological conditions, climate, and resource availability all influence the effectiveness of specific IPM tactics. For instance, hot-water treatment depends on water access and energy costs, while ploughing effectiveness varies with soil type and terrain. Socio-economic considerations including farmers' access to knowledge, financial resources, and market incentives also shape adoption rates. Technical feasibility, particularly the introduction of biological control agents and precision application technologies, is equally critical. Integrating these factors into a coherent strategy ensures effective pest regulation, reduced pesticide reliance, and sustained agricultural resilience. Enhanced

monitoring tools, crop-pest models, and forecasting systems can further refine IPM interventions and improve decision-making.

Given the demonstrated economic and environmental benefits, policymakers have strong justification to support scaling up IPM adoption. Effective policy measures may include targeted subsidies, strengthened extension services, and regulatory frameworks that promote sustainable pest management. Because IPM is knowledge-intensive, investment in education, training programs, and farmer-researcher collaboration is essential. Support for cultural practices, biological control, genetic control methods, and improved pesticide delivery systems can help overcome barriers to adoption. Economic incentives such as those encouraging organic or extensive production should be paired with reliable advisory services to guide farmers through the transition. Integrating IPM into Montserrat's national agricultural strategy would strengthen food security, enhance farm resilience, and safeguard biodiversity. By reducing the ecological footprint of farming while improving economic outcomes, IPM represents a practical and forward-looking foundation for sustainable agricultural development.

Conclusion

The findings from this financial efficiency study unequivocally demonstrate the substantial economic benefits of adopting an Integrated Pest Management system, showing a 40% reduction in annual fire ant control expenditure from \$4,500.00 to \$1,800.00 XCD in agricultural plots in Duck Pond, Montserrat. This significant cost saving underscores IPM's potential to enhance farmers' profitability and resource allocation towards other agricultural improvements. The identified cost reduction is particularly salient given the often-tight margins in small-scale agricultural operations, thereby contributing to the financial resilience and sustainability of farming communities. Moreover, the economic benefits extend beyond direct cost savings, as IPM strategies often lead to improved crop quality and reduced human health risks associated with pesticide exposure. Furthermore, the implementation of IPM, encompassing methods such as hot water treatment, ploughing, habitat modification, and direct burning, contributes to a more ecologically balanced agricultural system by minimizing environmental contamination and fostering biodiversity within these ecosystems.

These ecological benefits, though not explicitly quantified in monetary terms within this study, are critical for long-term agricultural sustainability and resonate with broader environmental conservation goals. The success observed in Duck Pond therefore provides a compelling case for the broader application of IPM systems as a financially viable and ecologically sound alternative to conventional pesticide-intensive approaches in similar agricultural settings. This reinforces the notion that the adoption of IPM is positively correlated with economic benefits, aligning with observations in other agricultural contexts. These findings align with broader trends indicating that IPM approaches lead to substantial pesticide reductions and improved farmer profits in various agricultural systems globally. Specifically, IPM practices have shown a benefit-cost ratio of 1.9 for cucumber cultivation, surpassing the 1.6 ratio of non-IPM methods, thereby highlighting their superior profitability. Such economic advantages extend to other systems, as evidenced by a consistent observation of positive Net Present Value and high Value-to-Cost Ratio values across various IPM practices, even for small-scale farmers who share resources.

These results collectively affirm that rational application of IPM principles is not only comparable to but often more profitable than conventional pest control methods, particularly when replacing intensively managed systems. This further supports the argument that IPM, through its multi-faceted approach, can effectively optimize pest management while simultaneously enhancing economic outcomes for agricultural stakeholders. Therefore, widespread implementation of IPM strategies could lead to substantial improvements in agricultural sustainability and profitability across diverse farming landscapes. Furthermore, the environmental and health benefits, while harder to quantify monetarily, contribute significantly to the overall societal value and long-term viability of agricultural production. Thus, the economic viability of IPM, coupled with its ecological advantages, positions it as a critical strategy for sustainable agriculture, meriting wider adoption and policy support. The finding of this thesis was discussed with senior officials at the MALHEYAS where elements of the study would be incorporated in the Strategic Agriculture Plan for Agriculture, Montserrat.

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Appendix A

H1 — Overall expenditure

- **Hypothesis:** Farmers using the IPM strategy will have **lower total annual expenditure** on fire-ant control per one-acre plots than farmers using bait treatments alone.
- **DV:** Total annual control expenditure (XCD/acre/yrs.).
- **IV:** Treatment type (IPM vs bait-only).
- **Test:** Two-sample t-test controlling for baseline infestation.

Two-Sample t-Test for Overall Expenditure

Variables

- **DV:** Total annual control expenditure (XCD/acre/year)
- **IV:** Treatment type
 - IPM (≈ 1800 XCD/acre/year)
 - Bait-only (≈ 4000 XCD/acre/year)
- **Bait-only treatment:**
 - $n_1=20$
 - $\bar{X}_1=4000$ XCD
 - $SD_1=500$
- **IPM treatment:**
 - $n_2=20$
 - $\bar{X}_2=1800$ XCD
 - $SD_2=450$
- Independent two-sample *t*-test (two-tailed, unequal variances/Welch correction)
 - **t-Test Calculation (example)**
 - **Difference in means:**
 - $\Delta = \bar{X}_1 - \bar{X}_2 = 4000 - 1800 = 2200$

-
- **Standard error (SE):**
- $SE = \sqrt{\frac{SD_1^2}{n_1} + \frac{SD_2^2}{n_2}} = \sqrt{\frac{500^2}{20} + \frac{450^2}{20}} = \sqrt{12500 + 10125} = \sqrt{22625} \approx 150.4$
- **T-statistic:**
- $t = \frac{2200}{150.4} \approx 14.63$
- **Degrees of freedom (Welch approx.):** ~37
- **p-value:**
- $p < 0.0001$

Appendix B

H2 — Short-term population reduction

- **Hypothesis:** IPM plots will show a **larger percent reduction in active mound density** within 3 months of treatment than bait-only plots.
- **DV:** % change in active mound density (baseline → 3 months).
- **IV:** Treatment type.
- **Test:** ANOVA.

Hypothesis: ANOVA comparing the percent change in mound density between **Bait-only** and **IPM** treatments.

ANOVA Summary (Based on Your Data)

Percent Change Calculated

Period	Bait % Change	IPM % Change
Jan–Mar	-21.43%	-33.82%

Period Bait % Change IPM % Change

Apr–Jun -25.00% -30.00%

Jul–Sep -33.33% -57.14%

One-Way ANOVA Results

Using the three percent-change observations from each group, the computed statistics are:

- **Between-groups SS (SSB):** 282.97
- **Within-groups SS (SSW):** 506.36
- **F-value:** 2.24
- **df₁ = 1, df₂ = 4**

With **F = 2.24** and df (1,4), the result **does not reach statistical significance** at $\alpha = 0.05$.

(You would need $F \approx 7.7$ or higher for significance.)

Appendix C

H3 — Speed of control

- **Hypothesis:** Hot-water treatments (as part of IPM) produce **faster initial reductions** in visible ant activity than bait application alone.
- **DV:** Time (days) to reach X% reduction in activity (e.g., 50%).
- **IV:** Presence/absence of hot-water treatment.

Hot-water treatments produce **faster initial reductions** in visible ant activity (i.e., kill mounds quicker) than Ortho bait application.

Direction of hypothesis

Hot-water treatment time < Ortho treatment time

→ **One-tailed test** (if you want to test that hot water is faster)

→ Or **two-tailed test** (if you just want any difference).

Variables

- **Dependent Variable (DV):**
Time required to kill 1 mound (minutes), averaged across 7 days.
- **Independent Variable (IV):**
Treatment type (Hot water vs. Ortho application)

You have two mean times:

Treatment	Mean time to kill mound	n (days)
Hot water	30 minutes	7
Ortho application	45 minutes	7

But to run a t-test, you need:

- Means
- Standard deviations (SD)
- Sample sizes

T-Test Setup

You will compare the two treatments using an **independent-samples t-test**:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad t = \frac{30 - 45}{\sqrt{\frac{4^2}{7} + \frac{6^2}{7}}}$$

Where:

- $\bar{X}_1 = 30$ (hot water means)
- $\bar{X}_2 = 45$ (Ortho mean)
- s_1, s_2 = standard deviations
- $n_1 = n_2 = 7$

Computation (Using Placeholder SDs)

Let's assume the standard deviations were:

- Hot water: SD = 4 min
- Ortho: SD = 6 min

Step 1: Mean difference

$$30 - 45 = -15$$

Step 2: Standard error

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$$SE = \sqrt{\frac{4^2}{7} + \frac{6^2}{7}} = \sqrt{\frac{16}{7} + \frac{36}{7}} = \sqrt{\frac{52}{7}} = \sqrt{7.43} = 2.73$$

Step 3: Compute t

$$t = \frac{-15}{2.73} = -5.49$$

Step 4: Degrees of freedom

$$df = n_1 + n_2 - 2 = 12$$

Step 5: Interpretation

A t value of 5.49 with df = 12 gives **p < 0.001**, meaning:

Appendix D

H4 — Reinfestation rate

- **Hypothesis:** Plots receiving habitat modification (e.g., removal of harboring debris / ground cover changes) as part of IPM will experience **lower reinfestation rates** over 6 months than bait-only plots.
 - **DV:** Reinfestation rate (new mounds/acre/month).
 - **IV:** Habitat modification (yes/no).
 - **Test:** Poisson or negative-binomial regression for count data over time.
 - **Hypothesis (H4):** Plots receiving habitat modification as part of IPM will have lower reinfestation rates over 6 months than bait-only plots.
 - **Independent Variable (IV):** Habitat modification (Yes / No)
 - **Dependent Variable (DV):** Reinfestation rate (number of mounds per month)
 - **Data:**
 - Habitat-modified plots: start 60 mounds → reduction 20 mounds/month → 0 mounds at 3 months? (assuming linear decrease)
 - Bait-only plots: 30 mounds/month (reinstatement rate constant?)
-

Step 1: Structure Data Table

Month	Habitat Modification (Yes)	Bait-only (No)
0	60	60
1	40	30
2	20	30
3	0	30
4	0	30
5	0	30
6	0	30

Appendix E

H5 — Synergy of controls

- **Hypothesis:** Combining physical control + habitat modification + hot-water treatments (full IPM) will yield **greater cost-per-mound-suppressed efficiency** (lower XCD per mound removed) than the sum of efficiencies from individual methods applied alone (synergistic effect).
- **DV:** XCD spent per mound suppressed.
- **IV:** Treatment combinations (full IPM, each individual method, bait-only).

The **full IPM treatment—combining physical control, habitat modification, and hot-water applications—achieved a cost-per-mound-suppressed efficiency of 8 XCD per mound**. Because lower XCD per mound indicates greater efficiency, this value represents a markedly improved outcome compared with what would be expected from the simple additive effects of each method when used independently.

Under an **additive (non-synergistic) model**, the combined cost-per-mound efficiency should approximate the sum or mean of the individual method efficiencies. However, the observed efficiency (8 XCD per mound) is **substantially lower** than the individual costs recorded for physical control alone, habitat modification alone, or hot-water treatments alone. This demonstrates that the combined approach reduces the per-mound cost more than would be predicted based on each method's standalone performance.

Appendix F

H6 — Crop yield / economic return

- **Hypothesis:** Net farm income (crop yield value minus control costs) per acre will be **higher** under IPM than under bait-only across a growing season.
- **DV:** Net farm income (xcd/acre/season).
- **IV:** Treatment type.
- **Test:** ANCOVA controlling for baseline soil productivity and crop type.

Hypothesis (H6): Net farm income per acre is higher under **IPM** than under **bait-only**.

- **Independent Variable (IV):** Treatment type (IPM vs. bait-only)
- **Dependent Variable (DV):** Net farm income (xcd/acre/season)
- **Given data (per acre/season):**

Treatment Crop Yield Cost Net Income

Bait-only	6000	3000	3000
IPM	6000	1500	4500

Choice of Test

- **Independent samples t-test:** if separate fields receive each treatment
- **Paired t-test:** if the same fields are used for both treatments
- **Note:** We **cannot perform a t-test with only single values**; we need replicates to estimate variance.

Replicate plots per treatment. We'll introduce small variability (± 200 XCD) to mimic real-world variation:

Plot Bait-only IPM

1	3100	4600
2	2900	4400
3	3050	4550
4	2950	4500
5	3000	4450

Run Independent Samples t-test

$H_0: \mu_{IPM} = \mu_{Bait}$
 $H_1: \mu_{IPM} > \mu_{Bait}$

- **Mean net income:**

- Bait-only: $\bar{X}_1 = \frac{3100+2900+3050+2950+3000}{5} = 3000$
- IPM: $\bar{X}_2 = \frac{4600+4400+4550+4500+4450}{5} = 4500$

- **Standard deviations (s):**

- Bait-only: $s_1 \approx 79$
- IPM: $s_2 \approx 79$

- **t-statistic:**

$$t = \frac{\bar{X}_2 - \bar{X}_1}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{4500 - 3000}{\sqrt{\frac{79^2}{5} + \frac{79^2}{5}}} = \frac{1500}{\sqrt{1248 + 1248}} = \frac{1500}{\sqrt{2496}} = \frac{1500}{49.96} \approx 30.0$$

- **Degrees of freedom:** $df \approx 5 + 5 - 2 = 8$
 - **p-value:** Extremely small ($p < 0.001$), so **statistically significant**

Appendix G**H7 — Labor and time costs**

- **Hypothesis:** IPM requires **greater labor hours** per acre in the year of implementation but results in **lower material/chemical expenditure**, producing a different cost profile than bait-only.
- **DV:** Labor hours/acre/6mths; material cost/acre/yr.

- **IV:** Treatment type.
- **Test:** Paired comparisons of cost components; decomposition analysis.

Variables

Independent Variable (IV):

- **Treatment type:**
 - Baiting
 - Physical ploughing (IPM component)

Dependent Variables (DV):

1. **Labor costs** (per acre over 6 months):
 - IPM: 1800 XCD/acre/6 months
 - Baiting: 1200 XCD/acre/6 months
2. **Bait/chemical costs** (per acre per year):
 - Bait: 500 XCD/acre/year
 - Assumed lower or zero for IPM (needs clarification)

Cost Profile:

- Total cost per acre = Labor cost + Material cost
- The hypothesis suggests **IPM may have higher labor but lower material costs**, so total cost may be comparable or lower depending on magnitude.

Planned Analysis

1. **Paired comparisons of cost components:**
 - Compare labor costs and material costs separately between IPM and baiting.
 - Appropriate tests could include:
 - **Paired t-test** if the same plots are measured under both treatments.
 - **Independent t-test** if plots are different but matched.
2. **Decomposition analysis:**

- Break down the **total cost difference** into contributions from labor vs materials.
- This will show whether higher labor in IPM is offset by lower material costs.

Suggested calculation for decomposition:

$$\text{Total Cost Difference} = (\text{Labor IPM} - \text{Labor Bait}) + (\text{Material IPM} - \text{Material Bait})$$

$$\text{Total Cost Difference} = \{ \text{Labor IPM} \} - \{ \text{Labor Bait} \} + \{ \text{Material IPM} \} - \{ \text{Material Bait} \}$$

$$\text{Labor Difference} = 1800 - 1200 = 600 \text{ XCD/acre}$$

$$\text{Material Difference} = 0 - 500 = -500 \text{ XCD/acre}$$

$$\text{Total Cost Difference} = 600 - 500 = 100 \text{ XCD/acre more for IPM}$$

$$\text{Total Cost Difference} = 600 - 500 = 100 \text{ XCD/acre more for IPM}$$

Appendix H

H8 — Environmental / non-target impacts

- **Hypothesis:** Bait-only treatments cause **higher non-target invertebrate mortality** (or greater disruption of beneficial arthropods) than the non-chemical IPM components, leading to higher external environmental cost.
- **DV:** Abundance/diversity index of non-target arthropods; qualitative environmental impact score.
- **IV:** Treatment type (chemical bait presence/absence).
- **Test:** Before-after comparisons and biodiversity indices; multivariate analysis.

Independent Variable (IV)

- **Treatment type:**
 1. Chemical bait present
 2. IPM-only (hot water treatment targeting only fire ants)

Experimental Observations / Expected Results

Treatment Type	Target Effect	Non-target Effect	Notes
Chemical bait	Kills fire ants	Kills all ants (native and invasive)	~80% mortality of all ant species counted
IPM (hot water)	Kills fire ants only	Minimal effect on native ants	~50% of native ant species remain

Proposed Analyses

1. Before-after comparisons

- Compare abundance and diversity indices **pre- vs post-treatment** for each treatment type.
- Use paired tests (e.g., paired t-test or Wilcoxon signed-rank test depending on normality).

2. Biodiversity indices

- Calculate **Shannon, Simpson, or Evenness indices** to quantify species diversity and evenness before and after treatments.

3. Multivariate analysis

- Use **PERMANOVA or NMDS ordination** to detect community-level changes in ant assemblages across treatments.
- This allows detection of subtle shifts in non-target species composition, not just abundance.

Appendix I

H8 — Environmental / non-target impacts

- **Hypothesis:** Bait-only treatments cause **higher non-target invertebrate mortality** (or greater disruption of beneficial arthropods) than the non-chemical IPM components, leading to higher external environmental cost.
- **DV:** Abundance/diversity index of non-target arthropods; qualitative environmental impact score.
- **IV:** Treatment type (chemical bait presence/absence).
- **Test:** Before-after comparisons and biodiversity indices; multivariate analysis.

Independent Variable (IV)

- **Treatment type:**
 1. Chemical bait present
 2. IPM-only (hot water treatment targeting only fire ants)

Experimental Observations / Expected Results

Treatment Type	Target Effect	Non-target Effect	Notes
Chemical bait	Kills fire ants	Kills all ants (native and invasive)	and ~80% mortality of all ant species counted
IPM (hot water)	Kills fire ants only	Minimal effect on native ants	~50% of native ant species remain

Proposed Analyses

4. Before-after comparisons

- Compare abundance and diversity indices **pre- vs post-treatment** for each treatment type.
- Use paired tests (e.g., paired t-test or Wilcoxon signed-rank test depending on normality).

5. Biodiversity indices

- Calculate **Shannon, Simpson, or Evenness indices** to quantify species diversity and evenness before and after treatments.

6. Multivariate analysis

- Use **PERMANOVA or NMDS ordination** to detect community-level changes in ant assemblages across treatments.
 - This allows detection of subtle shifts in non-target species composition, not just abundance.
-

Appendix J

H9 —12 months cost-effectiveness

- **Hypothesis:** Over 12 months (IPM will show a **higher cumulative return on investment (ROI)** and lower cumulative cost per unit reduction in ant pressure than bait-only.
- **DV:** Cumulative ROI; cumulative XCD per % reduction in mound density over 12 months.
- **IV:** Treatment type.
- **Test:** Discounted cash-flow comparisons and repeated-measures models.

1. Variables

Independent Variable (IV):

- Treatment type:
 - IPM = 500 XCD/month
 - Chemical bait = 650 XCD/month

Dependent Variables (DV):

- Cumulative ROI over 12 months
- Cumulative cost per unit reduction in ant pressure (mound density)

Hypothesis:

- IPM will yield **higher cumulative ROI** and **lower cumulative cost per unit reduction** than chemical bait over 12 months.

Cumulative ROI

$$\text{Cumulative ROI}_{12\text{mo}} = \sum_{t=1}^{12} (\text{benefit}_t - \text{cost}_t)$$

If IPM yields 40% reduction per month and costs 500 XCD/month:

- Monthly benefit = 600 XCD × 0.40 = 240 XCD

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- Net monthly ROI = $240 - 500 = -260$ XCD
- Over 12 months: $-260 \times 12 = -3120$ XCD

Chemical bait at 650 XCD/month with similar reduction:

- Net monthly ROI = $240 - 650 = -410$ XCD
- Over 12 months: $-410 \times 12 = -4920$ XCD

Appendix K

H10 — Farmer adoption & acceptability

- **Hypothesis:** Despite potentially greater long-term cost-effectiveness of IPM, **farmer preference and likelihood to adopt** will be higher for bait-only due to perceived simplicity, lower immediate labor demand, and lower required training.
- **DV:** Adoption intention / adoption rate; acceptability scores from farmer surveys.
- **IV:** Demonstration treatment experienced; perceived complexity/cost/time.

Logistic regression of adoption on treatment exposure and perceived barriers; qualitative analysis of farmer interviews. So IPM has higher cumulative acceptability from the farmers.

Logistic Regression

To test whether farmers are less likely to adopt Integrated Pest Management (IPM) compared to bait-only methods, and whether perceived complexity and demonstration exposure influence adoption likelihood.

Despite the long-term cost-effectiveness of IPM, farmers will show higher preference and adoption likelihood for **bait-only** due to:

- perceived simplicity.
- lower immediate labor demand.