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An Introduction to Economic Analysis of Pest Management: A Case Study of Nematode Management[1]

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Introduction

The economic performance of pest management practices is a critical factor when farmers are deciding whether or not to adopt a new crop. Partial budget analysis is a widely used tool to evaluate the financial effects of different management practices in agricultural production (Cao et al. 2019; Soto-Caro et al. 2023). It provides the economic rationale for selecting the best treatment plan by evaluating the cost-effectiveness of each treatment.

This publication explains how partial budget analysis is used by providing a step-by-step guide using a real-world example, namely nematode management for tomatoes. In it, we examine the costs and benefits of using two different approaches, fumigation and nematicides, to manage nematodes on Florida's tomato crops.

This is the second in a series of Ask IFAS publications on the topic of economic analysis of pest management. This publication aims to provide researchers and Extension personnel with a practical guide for cost and benefit analysis. It is also intended to promote interdisciplinary communication and collaboration.

Background

Florida produces more fresh tomatoes than any state in the United States, supplying nearly all the fresh-market tomatoes produced domestically from October through June (over 50% year-round) (USDA NASS 2023). However, Florida's warm and humid environment throughout the year makes it the state with arguably the highest pest pressure, particularly challenging due to the presence of plant-parasitic nematodes. It is estimated that nematodes cause a staggering annual yield loss of over 100 billion USD globally (Forghani and Hajihassani 2020; Thoden et al. 2011). Figure 1 shows tomato roots damaged by root-knot nematodes, a common plant-parasitic nematode in Florida.

Various treatments have been used to mitigate nematode damages, including quarantine measures and sanitation practices (Seid et al. 2015), physical soil treatments (Kokalis-Burelle et al. 2017), plant host resistance (Regmi and Desaeger 2020), fumigants (Cao et al. 2019), non-fumigant nematicides (Watson and Desaeger 2019), biological control (Watson et al. 2020), and the adoption of grafting techniques and improved crop management (Nian et al. 2022). When choosing among these approaches, most growers opt to rely on commercial fumigation treatments (Seid et al. 2015).However, the primary fumigant, methyl bromide (MBr) was phased out due to its environmental impact and potential harm to human health (Cao et al.

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2019). This change, along with increasing regulatory pressure on many traditional nematicides and a growing demand among consumers for safer and more selective products, has spurred interest in non-fumigant nematicides (Desaeger et al. 2020).

Figure 1. Top and bottom left,, southern root-knot nematode damage to tomato production even with C-35 fumigation; bottom right, tomato damaged by *Meloidogyne incognita*.
Credits: UF/IFAS GCREC

While new non-fumigant nematicides are more environmentally friendly, they have so far proven to be both more expensive than traditional fumigants and less effective for nematode control (Forghani and Hajihassani 2020). Currently, no published research has investigated the question whether the new non-fumigant nematicides could one day prove to be satisfactory substitutes for fumigants considering both efficacy and economic advantage. Despite extensive research on tomatoes in previous studies, the focus has predominantly been on yield outcomes (Regmi and Desaeger 2020; Desaeger et al. 2017) rather than overall farm profitability.It is crucial to extend analysis beyond yield and consider economic viability, which hinges on both the yields (revenues) specific treatments could achieve and the costs to produce those yields.

Understanding the cost-effectiveness of treatments is critical when making pest-management decisions. For example, a treatment that increases crop yields—thus boosting revenues—while also being less expensive is highly desirable. However, scenarios vary: some treatments may lead to higher yields but come at higher costs. Alternatively, other methods might result in both lower yields and reduced costs. The worst-case scenario occurs when a treatment leads to lower yields and higher costs.

By considering cost-effectiveness, farmers can optimize nematode-management strategies to not only enhance yields but also maximize profits. Profit maximization is the ultimate goal of a business operation.

Step-by-Step Guide

Using nematode management in Florida tomato production as a case, this section provides a step-by-step guide to partial budgeting to evaluate pest-management practices using fumigant and non-fumigant nematicides as an example. Cai et al. (2024) provide a detailed explanation of the concept for various pest-management strategies including fumigation and the use of non-fumigant nematicides.

Step 1: Set up the experiment and define control and treatment groups.

The first step involves setting up the experiment and obtaining trial results. Partial budget analysis scrutinizes the differences between the treatment and control groups. In this nematode management case, the control group is defined as tomato production without any nematode management measures, using neither fumigants nor nematicides. Three categories of treatments are compared with this control group: (1) sole fumigation; (2) sole nematicides; and (3) combination of fumigation and nematicides (see Figure 2).

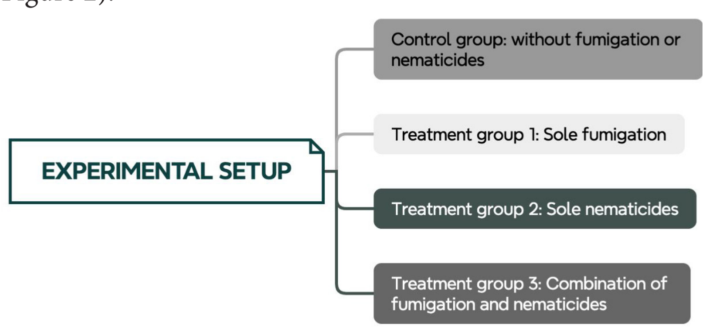

Figure 2. Control and treatment groups for nematode management of Florida tomato production.

Tomato yield data were then collected by season. Yield data were derived from small plot field experiments conducted at the UF/IFAS Gulf Coast Research and Education Center

(GCREC) in Wimauma, Florida, between August 2018 and December 2020. The average yield for each harvest season and for each trial were recorded.

After obtaining trial results, calculating revenues and costs is essential for evaluating the cost-effectiveness of various treatments. To obtain revenues and costs, we offer detailed illustrations in steps 2 and 3.

Step 2: Calculate the revenues of different treatments.

The second step is to calculate the revenues acquired as a result of using a given treatment and the difference in revenues compared to the control. To calculate revenues, market prices and yield data are required. The USDA's Agricultural Marketing Service provides data (https://www.ams.usda.gov/market-news/custom-reports) on average shipping point prices. ("Shipping point prices" are prices for which specialty crops were traded at prominent points in the United States and at ports of entry for imports.) We used shipping point prices of central and south Florida from 2018 to 2020 along with the yield from the first step to calculate revenues.

We determined the gross revenue by multiplying the average price by the yield on a plot level for each treatment group. For example, the gross revenue of the fumigation treatment in spring 2020 is calculated as the average price during the spring 2020 harvest season multiplied by the yield on the plot level of the fumigation treatment group in the same season. Then, we calculate the in-season average gross revenue for each treatment group.

To calculate the *change* in revenues compared to the control, we subtract the revenues earned by the control group from those earned by the treatment group for each season.

Step 3: Calculate the costs of different treatments.

The third step is to calculate the cost changes for each treatment compared to the cost of the control. Cost items considered include labor costs, machinery costs, and material costs per acre (Cao et al. 2019; Wade et al. 2020).

The material cost here is the cost of chemicals based on chemical application rates, while labor cost is determined by the number of applications per season, the time required to spray in each application, and the hourly wage of the tractor driver (for applying fumigants). Machinery cost includes fuel and lubricant consumption for a 75-horse-power tractor.

Other costs, such as planting, land rent, and asset depreciation, which remain constant across control and treatment groups, are excluded from the partial budget analysis, because we do not need to know how much the actual costs are for each treatment; rather, we need to know whether the costs are higher or lower than the costs of the control and by how much. This is why we call this method "partial" budgeting: it focuses not on the entire budget but only on the items that are changed.

We adjusted costs based on inflation factors calculated from a general Producer Price Index (PPI) for fresh fruit and vegetables and the most relevant industry-specific PPIs. The PPI is an economic indicator published by the Bureau of Labor Statistics (BLS) in the United States (https://www.bls.gov/ppi/). It measures the average change over time in the selling prices domestic producers received for their output. It's a crucial tool for assessing inflation at an early stage in the production process, before it affects consumers.

Step 4: Determine positive, negative, and net effects of different treatments.

The fourth step involves identifying the negative, positive, and net effects of each treatment compared to the control group (Table 1). Positive changes include added revenues and reduced costs, while negative changes include reduced revenues and added costs. First, we calculate the total positive changes by summing the added revenues and reduced costs for each season. Then, we determine the total negative changes by adding together the added costs and reduced revenues for each season. Finally, we calculate the net effects by subtracting the total negative changes from the total positive changes. If the net change is positive for a treatment, this indicates the treatment is more profitable than the control. The treatment with the highest net effects is the optimal treatment.

Table 2 lists the results of partial budget analysis for Florida tomato nematode control in 2018. (Note: we gathered and applied partial budget analysis to three years' [six seasons'] data between August 2018 and December 2020, but Table 2 is intended as an example rather than a comprehensive review of all of the data and therefore provides only the 2018 results.) In spring 2018, the treatment of combining fumigation and nematicides yielded the highest net effect ($2145/acre), followed by the fumigation only group ($285/acre) and the nematicides only group ($−122/acre). We therefore concluded that the combination of fumigation and nematicides was the most cost-effective treatment during spring 2018. We reached the same conclusion for fall 2018. Thus, we can conclude that a combination of fumigation and nematicides treatment was consistently the optimal choice for nematode control in 2018.

Additionally, we made a spreadsheet for the step-by-step calculation of partial budget analysis: https://fred.ifas.ufl.edu/media/fredifasufledu/gradsyll/spring2025/Case-Study-of-Nematode-Mgmt-spreadsheet-final.xlsx. Users could use this file as a template. This template has five parts regarding the calculation: yield, average price, revenue, cost change relative to control, and partial budget analysis. For each part, we provide make-up numbers and calculation formulas in the notes, so users can use the make-up numbers and formulas to calculate the net effects of each treatment. The "make-up numbers" are hypothetical or illustrative values used to help users apply the provided formulas to their own data or scenarios.

Discussion and Conclusion

This publication provides a step-by-step guide for conducting partial budget analysis to identify the most cost-effective treatment against nematodes in Florida's tomato production. Partial budget analysis assesses a treatment's net impact by comparing its benefits and costs with those of a control group. Four steps are outlined to evaluate the cost-effectiveness of pest-management strategies, including experimental setup, determining revenue and cost changes, and calculating the net effects. In this case analysis, we conclude that the combination of fumigation and nematicides was the most cost-effective treatment against nematodes in 2018.

The principles of partial budget analysis can be applied to a range of pest-management strategies, such as resistance management, biological control, and grafting, as long as relevant data are available. This approach is adaptable for any in-season management tactic, providing a robust tool for economic decision-making in agricultural practices.

This publication illustrates how economic analysis is done at the farm level. It highlights the importance of using partial budgeting for agricultural professionals to assess cost-effectiveness in pest-management decisions. By using this approach, farmers and agricultural managers can make informed, economically sound choices that optimize both productivity and profitability. In our next publication, we will focus on the environmental concerns of pest management, which often extend beyond the farm level, highlighting the importance of integrating farm-level decision-making with the assessment of social benefits and costs to promote sustainable pest-management practices.

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Table 1. Example of partial budgeting for nematode management in tomato production.

Partial Budget Analysis			
A	**B**	**C**	**D**
Added revenues ($/acre)	**Reduced costs ($/acre)**	**Added costs ($/acre)**	**Reduced revenues ($/acre)**
Value of increased tomato yield: difference in gross revenues due to treatment	Reductions in costs: labor costs, machinery costs, material costs, harvest costs, and marketing costs associated with reduced yields	Additional costs: labor costs, machinery costs, material costs, harvest costs, and marketing costs associated with increased yields	Value of decreased tomato yield: difference in gross revenues due to treatment
Total positive changes ($/acre) = Added revenues + Reduced costs		Total negative changes ($/acre) = Added costs + Reduced revenues	
Net effects ($/acre) = Total positive changes – Total negative changes			

Table 2. Partial budget analysis results for nematode management in Florida tomato production in 2018.

Season	Treatment	Added revenues ($/acre)	Reduced costs ($/acre)	Total positive changes($/acre)	Added costs ($/acre)	Reduced revenues ($/acre)	Total negative changes ($/acre)	Net effects ($/acre)
Spring	FuOnly	1,836	0	1,836	1,551	0	1,551	285
	NeOnly	709	0	709	831	0	831	–122
	FuNe	4,527	0	4,527	2,381	0	2,381	2,145
Fall	FuOnly	2,651	0	2,651	1,551	0	1,551	1,100
	NeOnly	0	0	0	831	3,593	4,423	–4,423
	FuNe	4,301	0	4,301	2,381	0	2,381	1,920

Note: The control presents tomato production without adopting any fumigant or nematicides; FuOnly denotes the sole adoption of fumigation; NeOnly signifies the exclusive use of nematicides; and FuNe means a combination adoption of fumigation and nematicides.