# Estimating the Value of Area Wide Disease Management: A Bioeconomic Model of Western X-Disease in Cherry Orchards

**Khashi Ghorbani[1], Shady S. Atallah[1], Scott Harper[2], R. Karina Gallardo[3]**

**1. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, 2.Department of Plant Pathology, Washington State University, 3. School of Economic Sciences, Washington State University**

## MOTIVATION

Western X-disease caused lost revenues valued at $65 million and generated re-establishment costs estimated at $115 million during 2015-2020 epidemic in Washington and Oregon states (DuPont et al., 2021; Molnar et al., 2022).

Photos credit to treefruit.wsu.edu

- Cherry trees cannot be cured once infected (Molnar et al., 2022).
- Removing infected trees is the primary control measure to restrict further disease spread (Adaskaveg et al., 2009; Molnar et al., 2022).
- Van Steenwyk et al. (1995) shows that removing infected trees reduced the infection rate across orchards by 65%.

However, growers tend to keep the infected trees longer to obtain extra cherry harvest at the cost of increased disease spread and damages in future seasons.
Due to high mobility of X-disease vector, collaborative efforts of growers are highly recommended to coordinate their management actions across orchard boundaries to manage the disease and its vectors (J. H. Vreysen Rui Pereira, Marc J. B., 2020).

## CONTRIBUTION

While previous studies highlighted the overall gains and potential behavioral adoption barriers of area-wide management, there is fewer research on the private incentives of farmers to control the disease within their orchard, which is a major determinant of the incentives to participate in area-wide management and a major step in determining the control level that would be required by individual farmers in an area-wide management program.
We contribute to previous studies by answering two major questions:

1. What is the optimal private level of disease control by removing and replanting individual trees?
2. What is the impact of area-wide managing on farm-level profits?

## METHOD

We propose a bioeconomic model that integrates X-disease dynamics, crop growth, with a grower profit-maximization model of optimal tree removal and replanting decision.

$$NPV = \sum_t^T \sum_i^I \sum_j^J p y_{t,i,j} d\left(E(s_{t,i,j})\right) - c_{t,i,j}$$

Where $p$ is the constant price of marketable product, $y_{t,i,j}$ and $c_{t,i,j}$ are stepwise yield functions that depend on the age of tree at location $(i,j)$ and time $t$, and $d(E(s_{t,i,j}))$ is a damage function which maps expected health states of tree at location $(i,j)$ and time $t$ to a corresponding yield reducing factor.

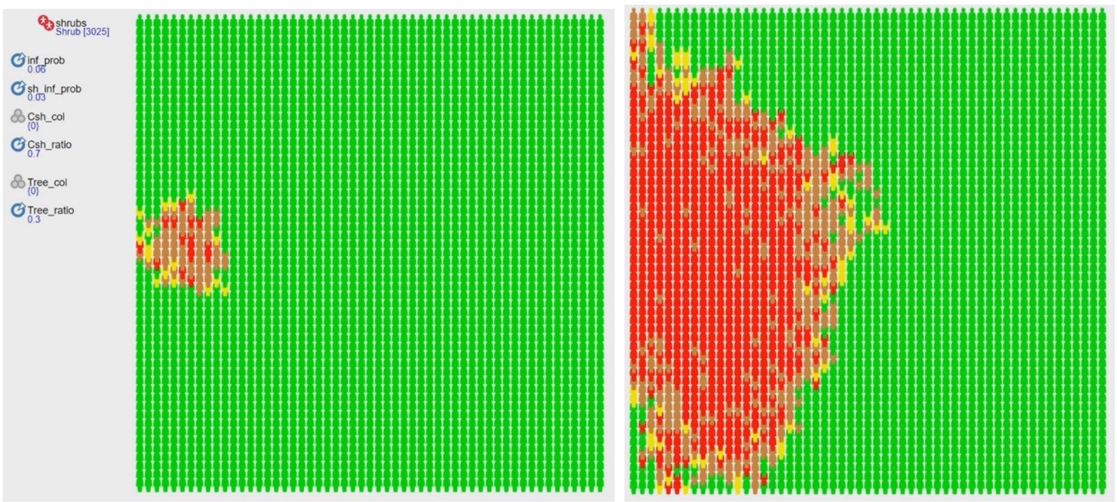
We model the health status of each tree using first order stochastic Markov processes where health status of each tree at time $t$ depends on a) the health status of the same tree at $t-1$ , and b) the probability of transitioning between states.

$$E(s_{t,i,j}) = \gamma^T s_{t-1,i,j}$$

Where $E(s_{t,i,j})$ is a probability vector of staying in the health state at $t-1$ given the probability matrix of transitioning between states $\gamma$.

$$\gamma = \begin{pmatrix} 1-vt & vt & 0 & 0 & 0 \\ 0 & 1-inf & inf & 0 & 0 \\ 0 & 0 & 1-vb & vb & 0 \\ 0 & 0 & 0 & 1-lo & lo \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

The diagonal elements of $\gamma$ matrix are the probability of staying in the current state and off-diagonal elements are the transition probabilities to other infection state.

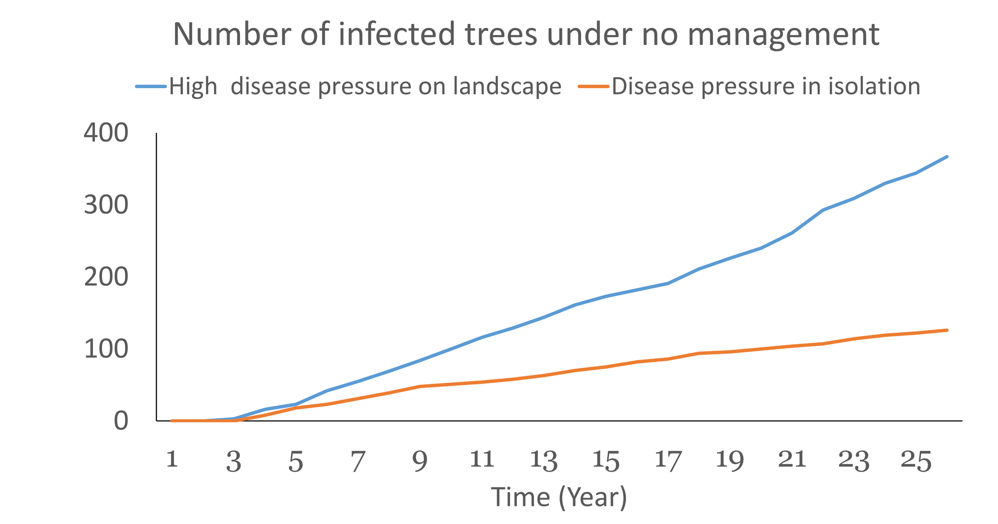


Disease diffusion over time (left t=5, right t=12)

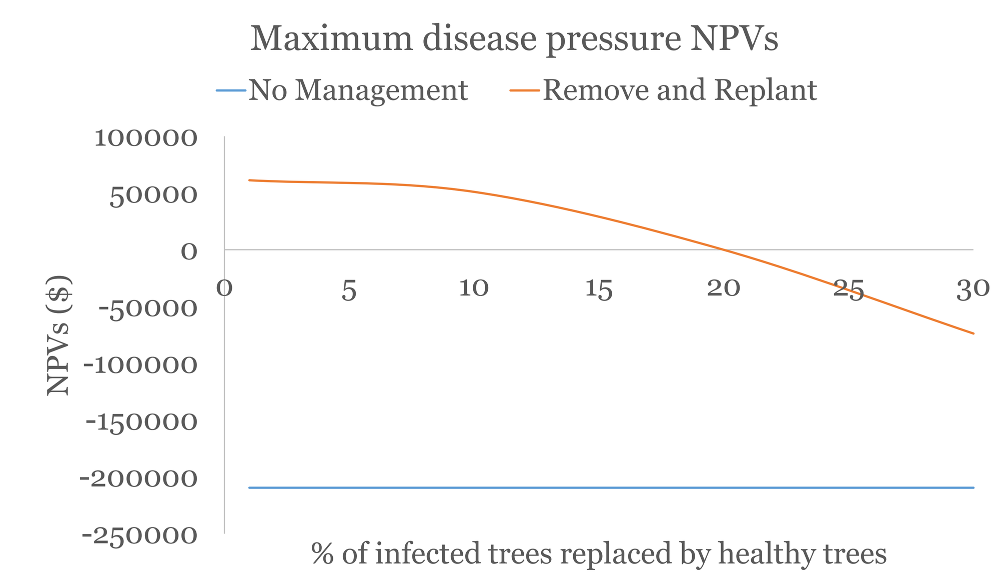
Lastly, the impact of area-wide management on individual growers is modeled through a function which maps the rate of participation in the program by neighboring farmers to changes in on-farm infection rates $(\gamma R^{-1}(\alpha))$. Where $\alpha$ is the participation rate and $R(\alpha) > 0 \; \forall \; 0 < \alpha < 1$.

## RESULTS

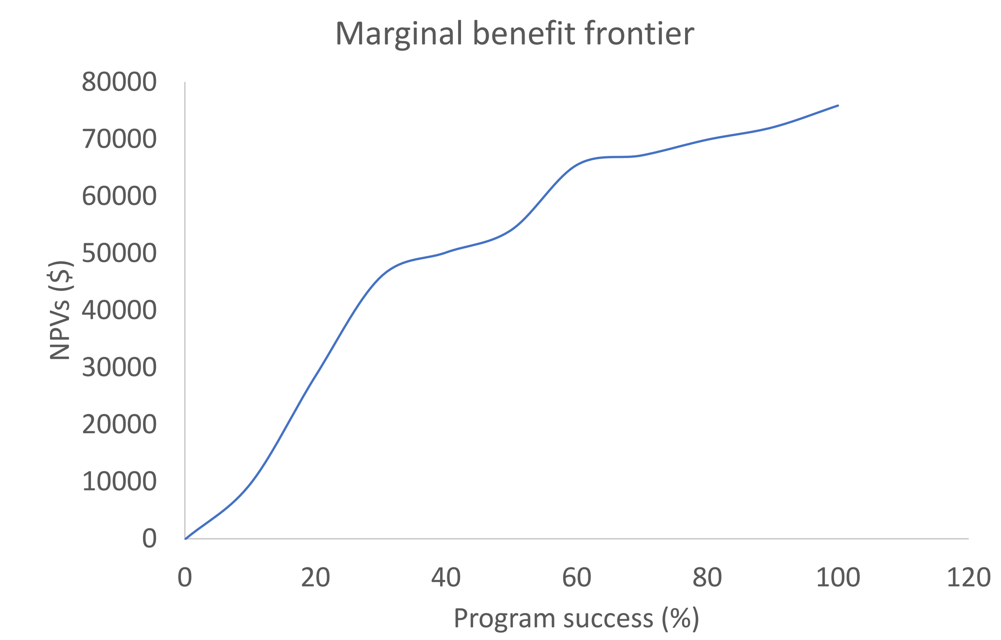
We show that there is a significant difference in the number of infected trees under no management scenario, when there is high disease pressure on the landscape level compared to the situation where disease dynamic is modeled for an isolated orchard.




We find that initiating removal and replanting of all symptomatic trees at the first onset of symptoms is optimal. Once the number of infected trees is beyond 20% of the total trees in the orchard, the optimal action is to remove and replant all trees.




We evaluate farmer returns to decreased pressure of superspreader leafhoppers that would result from an area-wide program. An area-wide program that is moderately successful, e.g., decreases the pressure of superspreader leafhoppers by 60%, increases farmers NPV by $65,000/acre over 25 years. Our result indicates that private gain of cherry growers has decreasing returns to scale of area-wide management success.




## Discussion

Our study emphasizes the coordination among cherry growers to manage the spread X-disease. The identified threshold of 20% infection level where the NPV is zero provides a critical decision point for growers. This threshold represents a tipping point; beyond this, the costs of removing and replanting trees overshadow the benefits, rendering continued management economically unviable.

Our findings underscore the effectiveness of area-wide management in controlling disease pressure. A high participation rate in area-wide program leads to not only significantly reduced spread of X-disease but also enhances the overall economic returns for participating growers, as shown by the increase in NPV.

The diminishing returns to scale observed in our study indicate that while area-wide programs offer substantial initial benefits in terms of reducing disease pressure and improving NPV, the marginal benefits decrease as the success rate of program increases. This suggests that there might be an optimal level of area-wide management success beyond which the cost of additional management may not justify the marginal gains in NPV. This finding is crucial for designing cost-effective programs that are compatible with private grower incentives.

The findings of our study have significant policy implications for the management of X-disease among cherry growers. Policymakers should focus on promoting and facilitating area-wide management programs that encourage high participation rates among growers. Additionally, policy should emphasize the establishment of monitoring and support systems to help growers maintain infection levels below the identified 20% threshold. By doing so, the economic burden of tree removal and replanting can be minimized, ensuring that the benefits of disease management outweigh the costs. This targeted approach will help maximize the NPV for growers, ensuring the sustainability and profitability of cherry orchards in the long term.

## ACKNOWLEDGEMENTS

This material was made possible, in part, by a Cooperative Agreement from the United States Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). It may not necessarily express APHIS' views.

ILLINOIS