A GIS Approach to Measuring Economic Costs of Integrated Pest Management Tools in Rice Processing Facilities

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Abstract

Methyl bromide is a commonly used fumigant for controlling insects in food processing facilities. However, it has been designated as an ozone depleter and is becoming less available and more costly. Integrated pest management (IPM) is an alternative, and may additionally reduce insecticide resistance, improve worker safety, and reduce environmental concerns and consumer concerns about pesticide residuals. However, little is known about the costs and efficacy of IPM in food processing facilities. Here, we consider several IPM approaches and measure both the treatment costs as well as the costs of failing to control insects for each approach. The results will provide managers economic information to choose a better insect control method in their goal of producing wholesome, pest-free and profitable products.

Key Words: insect control, integrated pest management, rice processing facilities, conventional fumigation

Introduction/Background

Rice consumption in the United States has increased dramatically over the last decade (Batres-marquez, Jensen, and Upton, 2009). As rice consumption increases, quality of the rice and wholesomeness (pest-free) are increasingly important in rice milling. Insect infestation during grain storage and processing has caused billions dollars of damage annually (Curperus and Krischik, 1995).

For many years, fumigants and residual insecticides have been used to control insects for grain products. Methyl bromide is the most important component of insect control management in rice mills and other processing facilities. But now, the fumigant methyl bromide is being phased out and restricted by regulations because it has been designated as an ozone depleter (Ristaino and Thomas, 1997). The loss of that fumigant, together with increased concerns about worker safety and insects developing resistance to insecticides, has led to an intensive search for alternatives, including IPM. Use of IPM could also increase consumer satisfaction and worker safety, reduce environmental concerns and insect resistance to pesticides. Two important elements of IPM are monitoring-based decision making and multiple control strategies (Campbell et al., 2004).

McKay et al. noted that an integrated approach to insect pest management that has been advocated for the wheat milling industry, combining the use of sanitation, aerosol insecticides, and residual surface treatments, can also be applied to rice mills. IPM approaches offer the potential to either completely eliminate the need to fumigate or to reduce the frequency of fumigation. However, there are few studies of the economic feasibility of IPM in rice processing facilities.

Objectives

The purpose of this paper is to determine the least cost combination of insect control methods that will achieve the desired level of insect control in rice processing facilities. Specifically, this study will compare the cost of conventional fumigation and IPM method. The costs include treatment cost, shutdown time cost and the cost of failing to control insects.

Conceptual Framework

A mill operator chooses insect control strategies to minimize expected costs, subject to a maximum amount of insects observed in insect traps at strategic locations within the mill.

$$\text{Min } \mathrm{E}(C) = TC + \mathrm{E}(SC) + \mathrm{E}(FC) \qquad (1)$$
$$\text{s.t. \# of insects}_{l,k,p} <= \mathrm{k}$$

where:
E(C) = expected total cost of a particular strategy;
TC = treatment cost of the strategy;
E(SC) = expected shutdown costs of the strategy;
E(FC) = expected “failure-to-control” costs of the strategy

Cost is minimized by choosing quantity of treatment b at location l in time t ($QTR_{b,l,t}$). The following graphs describe the relationship between Treatment Cost *(TC),*
Shut-down cost *E(SC), and* Failure-to-control” cost E*(FC),* and Quantity of Treatment ($QTR_{b,l,t}$).

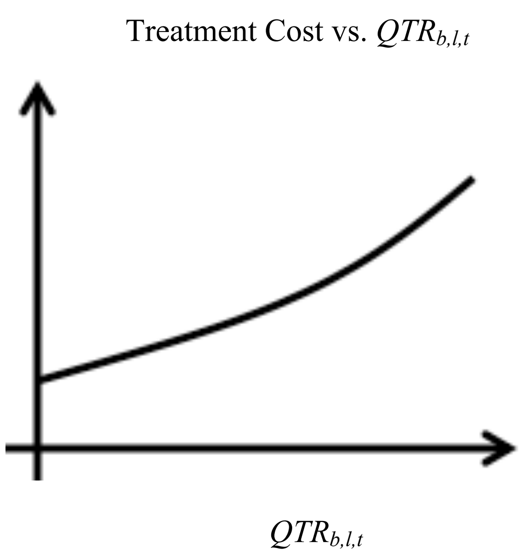
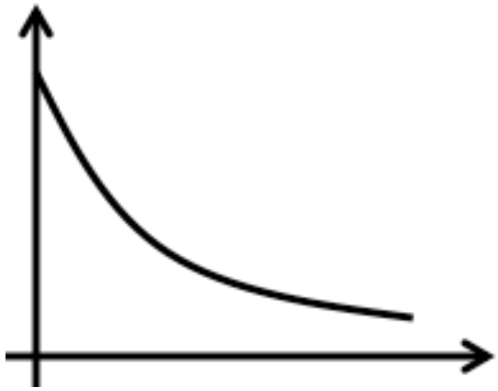


Figure 1. Treatment Cost vs. $QTR_{b,l,t}$

Figure 1 shows that as quantity of treatments increases, treatment cost increases. Figure 2 shows that as quantity of treatments increase, cost of failure to control insects decreases, since presumably increased quantity of treatments kills a greater number of insects.



$QTR_{b,l,t}$

Figure 2. "Failure-to-Control" Cost vs. $QTR_{b,l,t}$

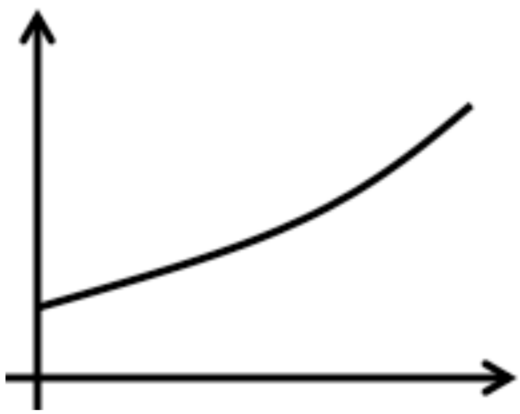
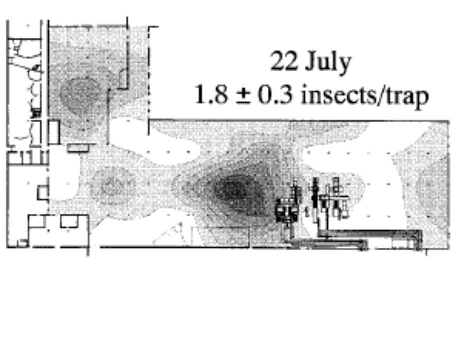


Figure 3. Shut-down cost vs. $QTR_{b,l,t}$

Figure 3 shows that as quantity of treatments increases, the cost of shutting down the mill increases – this is especially true if the treatment is fumigation, and to some extent with application of aerosols.

The observations and the predicted number of insects can be displayed in a GIS contour map.



Yearly Treatment Costs

$$TC = FMC + \sum_b \sum_l \sum_t QTR_{b,l,t} * TRC_{b,l}$$

where:
FMC is the fixed insect monitoring cost, if IPM is used. It includes the costs of traps and the installation costs of the traps
b = treatment
t = weeks 1 to 52
l = location of each trap
$QTR_{b,l,t}$ is quantity of treatment b at location l and time t.
$TRC_{b,l}$ is treatment b's cost per unit at location l (b could represent insect monitoring, aerosols, space spray, structure modification, sanitation, cooling, extreme temperature treatments, surface pesticide treatments, fumigation, etc.)

Shutdown Time Costs

$$\mathrm{E}(SC) = \sum_b \sum_l \sum_t DTR_{b,l,t} * SCD_{b,l}$$

where $DTR_{b,l,t} = f(QTR_{b,l,t})$ = # of days of shutdown required for treatment b at location l & time t.
$SCD_{b,l}$ = shutdown cost per day with treatment b at location l (opportunity cost).

Failure-to-control Costs

$$\mathrm{E}(FC) = \sum_l \sum_t \sum_k h\{Y_{l,t,k}\}$$

$$h\{Y_{l,t,k}) = g(QTR_{b,l,t}) = PP\ (Xl,t,k\ \ ) \quad \sum_l \sum_t \sum_k h\{Y_{l,t,k}\}$$

$$\boldsymbol{Y_{i,t,k}} = \mathrm{g}(QTRb,l,t,k) = \mathrm{PP}(l,t,k) - \textstyle\sum_b (QTR_{\ \ b,l,t,k} * EFF_{\ \ b,l,t,k})$$

At time t, by monitoring the traps we can estimate the number of type k insects caught by the trap at location l and time t. is the predicted population of insect k without any treatment at time $t+n$. is the predicted population of insect with treatment at time $t+n$ based on
k here stands for the type of insect.(such as k=1 refer to red flour beetle)

$$
\begin{aligned}
\boldsymbol{h}\{\boldsymbol{Y}_{\boldsymbol{l,t,k}}\} = \ & \boldsymbol{h}_{\boldsymbol{a}}\{\boldsymbol{Y}_{\boldsymbol{l,t,k}}\} \ \forall_{l} \in \boldsymbol{A} \\
& + \boldsymbol{h}_{\boldsymbol{b}}\{\boldsymbol{Y}_{\boldsymbol{l,t,k}}\} \ \forall_{l} \in \boldsymbol{B} \\
& + \boldsymbol{h}_{\boldsymbol{c}}\{\boldsymbol{Y}_{\boldsymbol{l,t,k}}\} \ \forall_{l} \in \boldsymbol{C}
\end{aligned}
$$

The expected failure-to-control cost is a function of estimated number of insects remaining from each treatment; this function varies by location.

Methods

The work will be done in three steps. The first step is to estimate the cost of each component of every insect control method in rice processing facilities using an economic-engineering approach. The second step is to estimate the benefits as a negative cost of the insect control methods. Third and last one is to determine the least cost combination method.

We have to estimate the costs of three methods of pest control: 1) Fumigation with Methyl Bromide. 2) Fumigation with Sulfuryl Fluoride (ProFume). 3) IPM approaches including sampling and monitoring red flour beetles, aeration, sanitation and treatment of residual insecticides or with aerosols. (For now the IPM approaches still has not been decided yet, we have to estimate every treatment cost). Treatment cost for each strategy was estimated using an economic-engineering approach. Cost components include equipment, labor, chemicals, electricity, rice weight lost, downtime cost and safety training. An Arkansas rice mill with 3 floors and 4,000 ft^2 about 30,000m^3, is assumed.

These three strategies must achieve the desired level of pest control in rice processing facilities The data determined are: labor needed for fumigation, wages paid for labor, training needed for workers, differences in power use, equipment fee and shutdown loss. Table 2-4 show cost estimates of components of typical treatment.The strategy which has the smallest $E(C_j)$ will be the optimal insect control methods.

Table 2. Economic-engineering costs of fumigating insects in rice processing facilities with Methyl Bromide. ($/year)

Fumigation cost components	Rate	$/year
Fixed		
Liability insurance		
Fumigation training		
(training hours/employee) * # employee *labor cost + training fee		
Fumigation equipment		
($3800 amortized at 10% over 10 yrs + insurance + maintenance)		
	Twice a year	
Labor		
2 people , 3 h per 10,000 m^3 @$16/h		
	Twice a year	
Fumigant		
(120 tablets/27.19 m^3) *$0.043/tablet		
Grain lost in turning		
0.25% * annual grain output ($)		
	Twice a year	
Turning electricity		
$0.10/kWh * 250kWh/10,000 m^3 (3h * 83kW/h)		
	Twice a year	
Shut down cost		
Revenue daily loss ($)* # days shutdown		
Total cost (30,000 m^3)		

Table 3. Economic-engineering costs of fumigating insects in rice processing facilities with Sulfuryl Fluoride. ($/year)

Fumigation cost components	Rate	$/year
Fixed		
Liability insurance		
Fumigation training		
(training hours/employee) * # employee *labor cost + training fee		
Fumigation equipment		
($3500 amortized at 10% over 10 yrs + insurance + maintenance)		
Labor		
2 people , 3 h per 10,000 m^3 @$17/h		
Fumigant		
(90 tablets/85.62 m^3) *$0.059/tablet		
Grain lost in turning		
0.23% * grain price (135$/ m^3)		
Turning electricity		
$0.10/kWh * 210kWh/10,000 m^3 (3h * 70kW/h)		
Shut down cost		
Revenue daily loss ($)* # days shutdown		
Subtotal cost (30,000 m^3)		

Table 4

Economic-engineering costs of IPM methods for insects in rice processing facilities. ($/year)

Sampling and monitoring cost components
Labor involved in sampling traps and recording data + equipment
Sanitation
Labor + equipment + electricity
Aeration
Labor + equipment + electricity
treatment of residual insecticides or with aerosols

Subtotal cost

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On the benefits side, it will focus on the IPM approach. This strategy has 3 advantages: 1) less pesticide residual and less effect on environmental; 2) protect worker safety; 3) avoid insect resistant. We have to find the number that the consumers are willing to pay more for products under a reduced chemical usage management plan.

The strategy which has the smallest $E(C_j)$ will be the optimal insect control methods.

Data and Procedure

The data is collected from several rice mills in Arkansas, Texas, and Louisiana. Cost of traps and their installation in strategic locations within a facility and the costs of monitoring those traps and counting insects, costs of surface pesticide treatments, sanitation, aeration, sealing structure, aerosols and space sprays are key parts of the data. Economic engineering costs of these tools will be estimated for several intensities of insect management, following procedures by Mah 2004 and Su 2011. Red flour beetle is the target insect because of the significant damage it causes in rice (McKay et al. 2010).

Costs of failing to control insects may vary by location within the processing facility; for example, insects in locations closer to processing stages near the final product may cause greater costs than insects near earlier stages of processing. A Geographic Information Systems (GIS) model that considers the proximity of insects to sensitive areas and the costs of infestation in those areas will be used to measure the costs of failing to control insects for each of several insect control methods. For example, darker areas in the contour map at the right (from Campbell et al. 2004) show increased levels of insect activity. Contours such as these will be paired with economic data to model economic pressure and measure cost of failing to control insects.

Results and Discussion

An IPM approach such as that modeled here may have higher costs of implementation and require significant expertise in evaluating trap counts. However, while whole-plant methyl bromide fumigation are often effective, they typically involve significant shutdown costs in the form of lost revenue. As methyl bromide becomes less available, though, and more costly, it will be even more important that IPM approaches are used as effectively as possible. Little information exists on costs of IPM in processing facilities. The results will provide critical information for managers in determining the kinds and intensities of insect control methods they will need. The GIS approach should prove very helpful in similar applications in other processing industries, because of the heterogeneous nature of insect growth environments, along with the high costs of insect infestation in especially sensitive areas within processing facilities.

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