When and Where Does Reducing Food Loss Make Sense? A Dynamic Supply Chain Analysis

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Abstract

It is often asserted that reducing food losses is unambiguously beneficial to supply chain actors (often with a focus on the benefits to farmers) and to the environment. However, these assumptions may not accurately reflect the responses of supply chain actors when losses are reduced, nor do they indicate *where* in the supply chain the reductions will occur. We describe a dynamic model representing multiple interacting supply chain decision-makers (farm, wholesalers, and retailers) using leafy greens as an example of a perishable food product. Our analyses make explicit the assumptions about the location, extent and costs of reducing food loss, and consider alternative behavioral responses throughout the supply chain. We find that the dynamic impacts on prices and profits for supply chain actors and the cumulative environmental impacts depend on the behavior of supply chain actors—the degree and speed of adjustment to a new stream of orders and the magnitude of any cost changes for reducing loss, the degree of coordination among supply chain actors, and the location in the supply chain where the reduction occurs. A dynamic systems model of the leafy greens supply chain suggests that common assumptions about the benefits of food loss reduction may be unwarranted.

Key words: Food loss, supply chain, environmental impacts, leafy greens

1 Introduction and Objectives

Food loss and waste1 have been an issue of importance for the past two decades, and the available (but admittedly incomplete) empirical estimates suggest that their volume may have continued to increase (UN Environment Programme, 2024) due to larger global populations—even if per capita loss and waste has not increased. Although much of the international research community has focused on quantifying food losses in lower-income countries (e.g., Sheahan and Barrett, 2017), such losses are also large in higher-income countries like the US (Sun et al. 2022). Many researchers have examined the causes of food losses and waste, and some have proposed potential interventions to address them, such as 'redistribution' of fruits and vegetables through alternatives to conventional marketing channels (such as 'gleaning' or food recovery for distribution to local food banks; Alptekinoğlu et al., 2026)

It is often asserted that reducing food loss is unambiguously beneficial to supply chain actors (especially farmers) and to the environment. For example, a report published in 2019 by the World Resources Institute (WRI, 2019) stated that:

> *Tackling the issue of food loss and waste can generate a "triple win." Reductions can save money for farmers, companies, and households. Wasting less food means we can feed more people. And reductions can alleviate pressure on climate, as well as on water and land.*

Most of these assertions seem to be based on the assumption that a) if less food is lost, all of the former losses will be made available for sale (thus increasing food availability and lowering prices but with limited environmental impacts) or b) if less food is lost then less will be produced, thus lowering environmental impacts and not affecting food availability or prices. However, these assumptions may not accurately reflect the responses of supply chain actors when losses are reduced, and only rarely is the location in the supply chain specified where the reductions will occur. There often also seems to be an implicit assumption that reducing food

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[1] The distinction between these terms can be somewhat arbitrary. We follow the definition from (Lipinski et al., 2013) that indicates: *'Food loss' refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. 'Food waste' refers to food that is of good quality and for human consumption but that does not get consumed because it is discarded—the result of negligence or a conscious decision to throw food away.*

losses incurs no additional costs, or that any costs for reducing losses will be recouped by other cost savings (such as reduction in production costs or inventory holding costs).

A few economic critiques of the issue (e.g., Rutten, 2013; Koester, 2015) have argued against a universal goal of reducing food loss waste or noted the economic and policy challenges (Cattaneo et al., 2021). Most previous studies of environmental impacts do not specify the mechanisms by which food loss and waste will be reduced (e.g., Muth et al., 2019), and studies of specific methods for loss reduction usually address only the changes in food loss and waste (e.g., Leichti et al., 2025), not financial or environmental impacts. Previous literature on strategies to reduce food loss does provide case examples where costs increased, or environmental outcomes worsened due to interventions designed to reduce losses. For example, Eriksson et al. (2014) examined a strategy of lowering temperatures in retail store coolers to reduce returns of beverage milk due to spoilage. They found that reductions in loss were feasible but that costs and greenhouse gas emissions increased. This example highlights the potential for counterintuitive results of actions to reduce food loss and waste although it may not be broadly representative .

However, there is a very limited literature examining the impacts of strategies to reduce food loss from a dynamic supply chain perspective, based on decision rules commonly used by food supply chain actors. An intuitive example would be that if a retail store employed a strategy to reduce in-store losses for perishable food products, the retailer could then order less of those products from suppliers. Depending on the degree of supply chain coordination, this would affect upstream production and marketing decisions, including those by farmers. The impacts on those upstream suppliers would depend on whether and how quickly they responded to the changes by the retailer. Thus, the impacts of reducing food loss can be better understood using a dynamic model that represents multiple interacting supply chain decision-makers and makes explicit assumptions about the location, extent and costs of reducing food loss, and considers alternative behavioral responses throughout the supply chain.

Our objective is to examine the dynamic impacts on supply chain actors and stylized environmental outcomes of reductions in food losses of perishable products, using leafy greens as a product case example. We consider the location in which the reduction is losses is assumed to occur (farm, wholesale retail), the costs associated with achieving the reduction, and the degree to which other supply chain actors modify their decisions. We acknowledge that this analysis is stylized, so a principal motivation is to demonstrate that a) worsening of economic and(or) environmental outcomes is possible from strategies to reduce loss and waste, and b) highlight that the location in the supply chain and the degree of coordination will affect these outcomes. A future comparative study of leafy greens supply chains in the US and Kenya is described in the discussion to address the limitations of this current stylized modeling approach.

2 Model Structure and Assumptions

Our analysis modifies the supply chain model described in Nicholson and Gómez (2022) to assess the implications of reducing food losses for leafy greens. This model links farmers, wholesalers, retailers and consumers based on the supply chain model structure described in Sterman (2000; Figure 1). The model represents a supply chain for leafy greens for a localized area in which prices and profits—rather than contractual commitments[2]—determine supply chain actor behavior. We assume that farmers, wholesalers, and retailers adjust prices based on inventory coverage as a goal, increasing prices when inventories are low relative to a reference coverage value and decreasing them when inventories are larger than a reference coverage value. The model assumes constant unit costs for production, product held in inventory, and the "acquisition cost" (price including transportation costs) for the next stage downstream in the supply chain. These unit costs apply to product that arrives at each stage of the supply chain (whether sold or part of 'losses'), and revenues are received only for product actually provided to the next stage of the supply chain or customers. Profits for each supply chain actors are calculated given prices, production, orders, sales and costs. Expected Profits are calculated using a first-order smooth of current profits. Consumers are defined as the end users, and the quantity they demand of leafy greens is determined by prices, incomes, and knowledge of the healthfulness of leafy greens. To represent food loss, we assume proportional losses from inventory at each stage of the supply chain. We do not specify the specific actions that are

[2] These assumptions reflect the main characteristics of a wholesale produce market such as the one at Hunt's Point, New York, which is served by producers from throughout the US and provides produce to food retailers throughout the New York City metropolitan area.

possible to reduce losses but assume that the loss can be reduced at some additional cost to the supply chain actor undertaking the reduction.

We also explore the implications of alternative behavioral responses to the reduction of food losses. In the initial decision-making formulation, production decisions by farmers are based on a reference land area and the impact of expected profits relative to reference profits on planting decisions. Similarly, for the wholesaler and retailer, ordering decisions (to the farmer and wholesaler, respectively) are based on a reference ordering quantity adjusted for the impact of expected profits to reference profits. In this formulation, the reference production and order values are not adjusted over time in response to changes in the supply chain other than profits. We refer to these as "No Adjustment" scenarios. An alternative decision-making structure assumes that farmers, wholesalers and retailers use a "stock management structure" (SMS) formulation in which production and ordering decisions are based on a first-order smooth of the current "loss rate" (sales to wholesalers, retailers and consumers), but also adjusted for the effects of expected profits relative to a reference margin. These are referred to as "With Adjustment" scenarios.

To assess the potential environmental impacts of food loss reduction, we calculate a stylized environmental impact indicator based on the amount of leafy greens that moves through each stage of the supply chain, accounting for production, transportation and storage. The amounts produced, transported and inventory are multiplied by weights representing the proportion of the environmental impact of each of these activities for leafy greens based on calculations by Nicholson et al. (2023) about carbon emissions at each stage of the supply chain. The largest proportional environmental impact (60%) is assigned to the production of the leafy greens. This indicator can only be used to compare relative outcomes and is summed over the time period after which interventions are implemented to reduce food loss.

Model parameters are adapted from Nicholson and Monterrosa (2023). The model is programmed in Vensim® Professional software (https://vensim.com) and is initialized in a dynamic equilibrium. Changes to product loss rates, associated costs are implemented as step changes at time t=10 (i.e., assuming full, simultaneous implementation by supply chain actors at that time) and outcomes such as prices, profits, inventories and environmental outcomes are simulated for a total of 104 weeks (2 years) to allow for sufficient time after an intervention for system adjustments to occur. We use a computation interval (the 'time step' for the model of 0.125 weeks) and assume that each of the interventions to reduce losses is implemented at 10 weeks. We will examine the pattern of behaviors for the key variables for each of the interventions and its average value during weeks 10 to 104. Additional details about the model structure and assumptions are provided in the Appendix.

3 Scenarios Analyzed

We analyze three sets of scenarios to highlight how assumptions about the stage where food loss reductions are implemented and the behavioral responses of supply chain actors affect outcomes. For illustration, all scenarios assume a 25% reduction in the proportional rate of food loss from inventory (Table 1), and most scenarios assume that this results in a 10% increase in the unit cost at the implementing stage of the supply chain. We assume that reduction interventions can be implemented instantaneously at time t=10 with concomitant changes in costs, which will underestimate the time and challenges of implementing specific reduction strategies, and assume no financial assistance is provided by governments or non-profit organizations.

We first assess the impacts on farmers of implementing food loss reduction independent of other supply chain actors, without and with adjustment of reference values for production to account for the losses. We also include one scenario in which the costs to implement food loss reduction are higher, 25% rather than 10%. A second set of scenarios explores the implications of supply chain coordination in the reduction of food losses. We assume that the reductions are implemented by the wholesaler and examine outcomes when farmers and retailers adjust behaviors to account for the reduction in losses (e.g., decisions based on a SMS) and when they do not. Finally, a third set of scenarios examines the implications of where in the supply chain the food loss reductions are implemented, but assuming that all supply chain actors account for the reductions (again, base decisions on an SMS).

Table 1. Sets of Food Loss Reduction Scenarios Analyzed

Set, Scenarios	Implementor of Reduction Strategy	Famer Behavior Assumed	Wholesaler Behavior Assumed	Retailer Behavior Assumed	Reduction in Proportional Loss Rate	Change in Unit Costs
First Set						
Farmer Reduction No Adjustment	Farmer	Without Adjustment	Without Adjustment	Without Adjustment	25%	10%
Farmer Reduction With Adjustment	Farmer	With Adjustment (SMS)	Without Adjustment	Without Adjustment	25%	10%
Farmer Reduction With Adjustment Higher Costs	Farmer	With Adjustment (SMS)	Without Adjustment	Without Adjustment	25%	25%
Second Set						
Wholesaler Reduction All Adjustment	Wholesaler	With Adjustment (SMS)	With Adjustment (SMS)	With Adjustment (SMS)	25%	10%
Wholesaler Reduction Only Wholesaler Adjustment	Wholesaler	Without Adjustment	With Adjustment (SMS)	Without Adjustment	25%	10%
Third Set						
Farm Reduction All Adjustment	Farmer	With Adjustment (SMS)	With Adjustment (SMS)	With Adjustment (SMS)	25%	10%
Wholesaler Reduction All Adjustment	Wholesaler	With Adjustment (SMS)	With Adjustment (SMS)	With Adjustment (SMS)	25%	10%
Retailer Reduction All Adjustment	Retailer	With Adjustment (SMS)	With Adjustment (SMS)	With Adjustment (SMS)	25%	25%

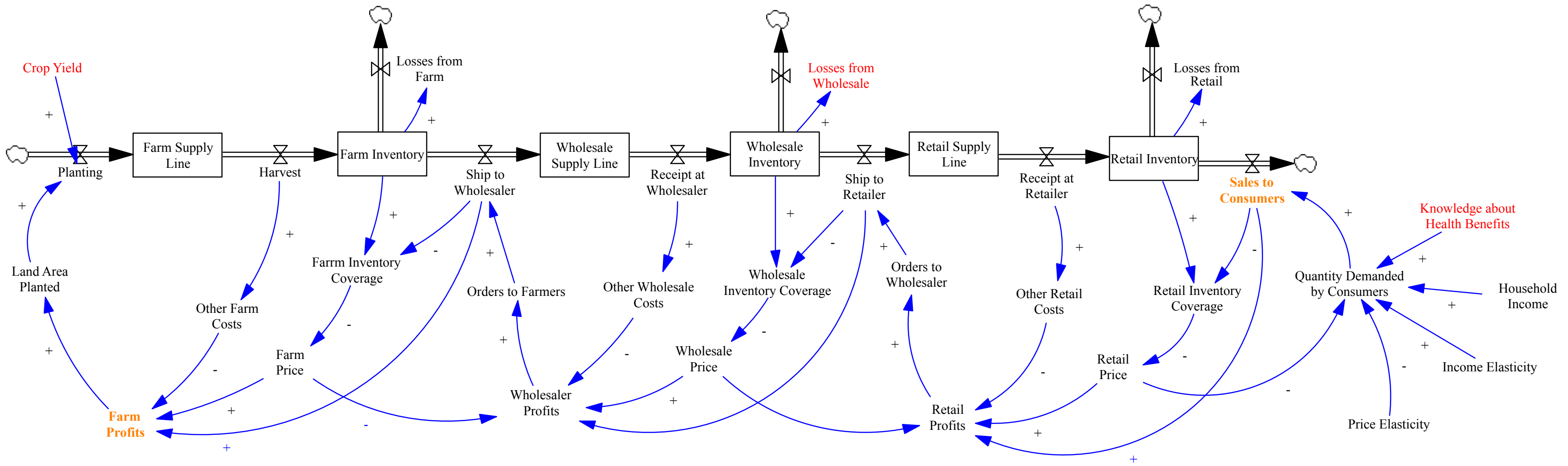


Figure 1. Conceptual SD Model of a Vegetable Supply Chain with Farmers, Wholesalers, Retailers and Consumers.

NOTE: This is a simplified version of the model structure to highlight the linkages. The specific model structure used fo the analysis is provided in Appendix Figures.

4.3 Results

4.3.1 Results for Farmer Implementation Scenarios

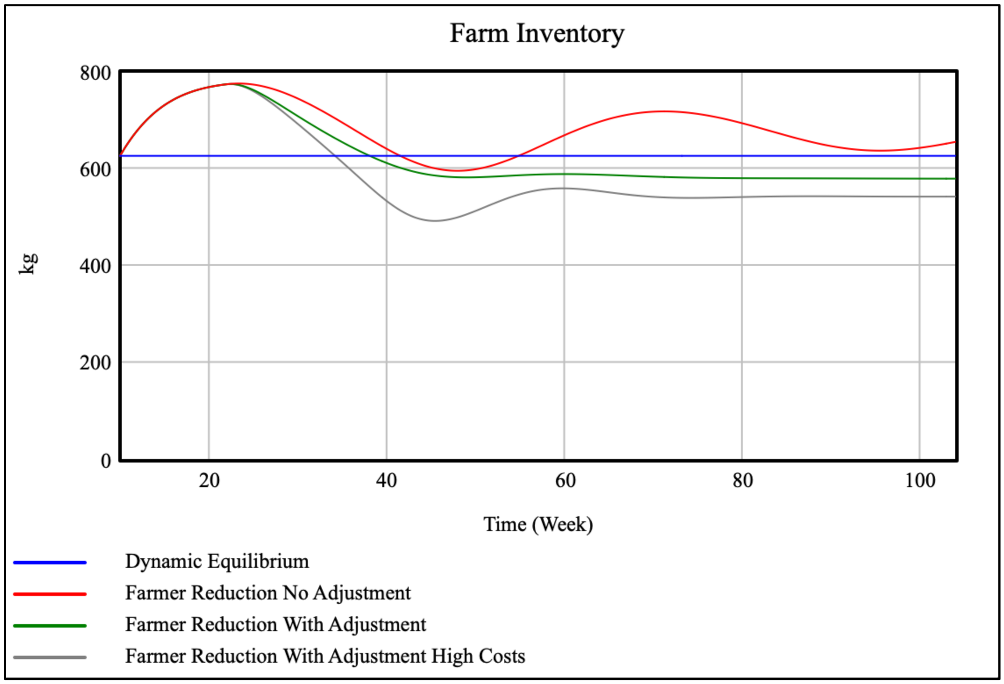
The first set of scenarios assesses the impacts on farms if they act unilaterally to reduce (post-harvest) losses of leafy greens, with alternative assumptions about behavioral responses and costs. For the two scenarios in this set, assuming a 10% increase in unit costs to reduce food losses, the average farm price, the average amount harvested (acres planted), and average weekly farmer profits decrease (Table 2). The average wholesale and retail prices decrease (as a result of the lower farm price), but wholesaler and retailer average weekly profits increase. These results occur primarily due to the dynamic response of inventories to the reduction of food losses (Figure 3). When food losses are reduced and the farmer does not adjust reference quantities to account for this, average inventories increase compared to the Baseline without the reduction of food losses, and farm prices fall (Figure 4), resulting in much lower farm profits (Figure 5). (Oscillatory behavior occurs because of delays in adjusting expected profits and production delays embedded in a balancing feedback loop.) Lower farm prices are reflected in lower wholesale and retail prices, increasing consumption of leafy greens (Table 2). If farms are assumed to make a behavioral adjustment, inventories adjust more quickly to the average lower amounts required to service wholesalers, with farm prices and profits returning to close to Baseline levels in about 30 weeks. The lower farmer profits in this case are temporary, reflecting transition costs to reduce food losses. With higher costs assumed to reduce food losses, but assuming modified behavior by farmers, larger adjustments to inventory occur (Figure 3) and farm, wholesale and retail prices increase compared to the Baseline. This lowers the consumption of leafy greens, and profits decrease for all supply chain actors. The environmental impacts depend on the extent to which the reduction in food losses affects production, inventory holding throughout the supply chain and whether consumption is increased or decreased. When farmers don't adjust reference values, larger inventory holdings, smaller reductions in production and lower prices that increase consumption result in a higher environmental impact. Environmental impact is decreased when farmers make adjustments, and particularly when costs for reductions are higher because this reduces demand for leafy greens throughout the supply chain.

Although this set of scenarios focuses on farm interventions, it highlights a number of key points not consistent with conventional wisdom:

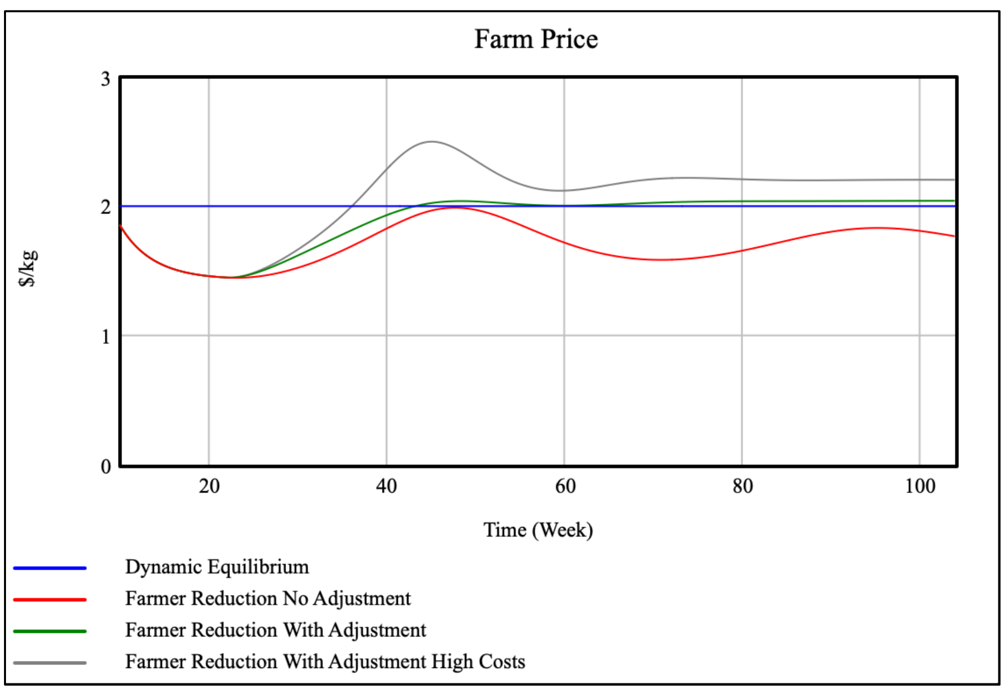
- Reduction of food loss (by farmers) may not be financially beneficial to farmers. In each of the scenarios, average weekly farm profits were decreased, although this decrease is temporary when there is behavioral adjustment;
- Reduction of food loss (by farmers) may not result in the improvement of environmental outcomes, particularly given complex interactions among supply chain actors;
- Reduction of food loss has the potential to redistribute income in the supply chain. In this case, actions by farmers to reduce losses resulted in lower profits for them and higher profits for wholesalers and retailers, particularly when the farmer's behavior did not account for the change in losses;
- The impacts on the supply chain depend on behavioral assumptions and how strategies to reduce food loss affect unit costs.

Table 2. Simulated Outcomes of the First Set of Food Loss Reduction Scenarios, Compared to Baseline, Weeks 10 to 104

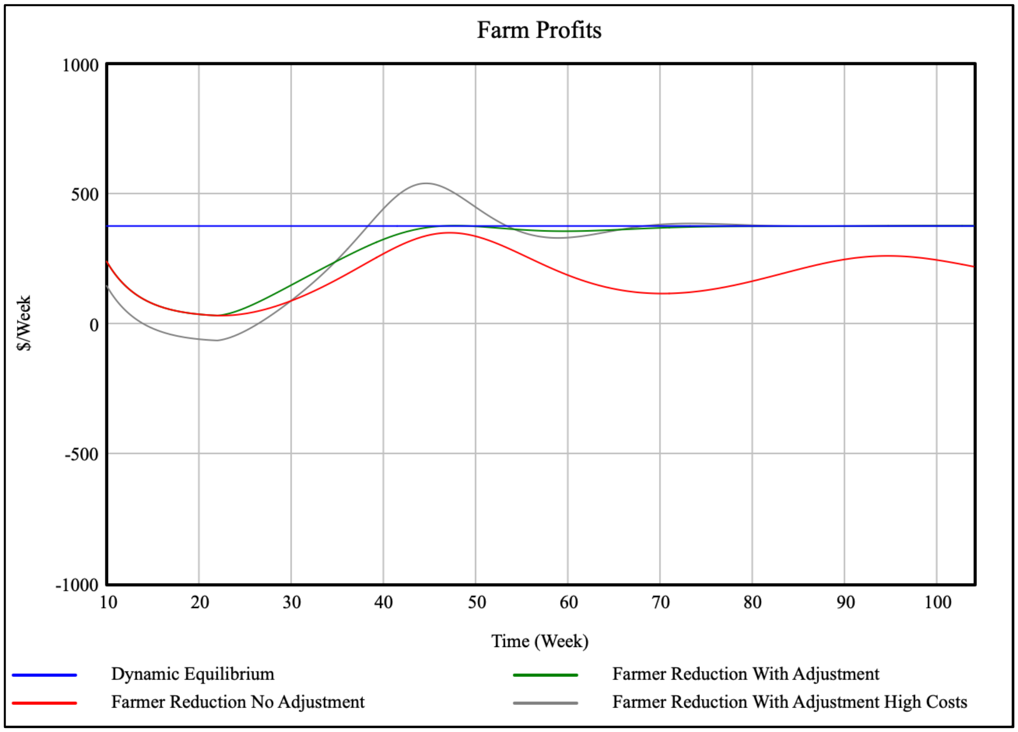
Supply Chain Position, Simulated Outcome	Baseline No Reduction	Farmer Reduction No Adjustment	Farmer Reduction With Adjustment	Farmer Reduction With Adjustment and Higher Costs
Farm Outcomes				
Price, $/kg	2.00	-14.9%	-5.2%	2.8%
Inventory,000 kg	625	8.7%	-0.4%	-6.2%
Harvested, 000 kg/week	625	-2.9%	-4.8%	-6.2%
Sales to Wholesaler, 000 kg/week	500	0.8%	0.3%	-0.2%
Profits, $000/week	375	-50.9%	-21.7%	-22.1%
Wholesaler Outcomes				
Price, $/kg	4.00	-2.9%	-1.1%	0.6%
Inventory,000 kg	500	3.0%	1.2%	-0.5%
Sales to Retailer, 000 kg/week	400	0.5%	0.2%	-0.1%
Profits, $000/week	400	24.4%	8.2%	-4.2%
Retailer Outcomes				
Price, $/kg	7.50	-0.3%	-0.1%	0.1%
Inventory, 000 kg	400	0.6%	0.3%	-0.1%
Sales to Consumer, 000 kg/week	320	0.4%	0.2%	-0.1%
Profits, $000/week	400	10.0%	3.9%	-1.8%
Environmental Indicator	80,464	1.9%	-2.5%	-5.5%



- **Figure 2. Farm Inventory with Farm Loss Reduction, Without and With Adjustment to New Loss Rate and with Higher Costs for Loss Reduction**



- **Figure 3. Farm Price with Farm Loss Reduction, Without and With Adjustment to New Loss Rate and with Higher Costs for Loss Reduction**



- **Figure 4. Farm Profits with Farm Loss Reduction, Without and With Adjustment to New Loss Rate and with Higher Costs for Loss Reduction**

4.3.2 Results for Supply Chain Coordination Scenarios

A second set of scenarios assumes reductions in food loss are implemented by the wholesaler and examines the effect of behavioral responses by other food supply chain actors. When the wholesaler acts unilaterally and farmers and retailers do not adjust reference production and order quantities to the reduction in losses, supply chain instability is less and outcomes differ more from their baseline values (Table 3). Similar to the previous set of scenarios, if farms (and retailers) don’t adjust to the reduced losses, farm inventory is increased (Figure 5) and prices and profits reduced by more compared to the Baseline outcomes. Assumptions about coordination affect the wholesaler also, so that when all supply chain actors adjust to the reduced losses, the wholesaler has lower inventories (Figure 6), smaller price decreases, and larger sales increases to the retailer. Wholesale profits are not much different with and without adjustments given the complex interaction with supply chain partners upstream (farmers) and downstream (retailers). Similar to the previous example, behavioral assumptions about supply chain coordination in response to reductions in food losses are important because they determine the rate at which supply chain actors adjust to the change, which affects prices, profits and environmental impacts.

Table 3. Simulated Outcomes of the Second Set of Scenarios with Wholesaler Food Loss Reduction With and Without Supply Chain Coordination, Compared to Baseline, Weeks 10 to 104

Supply Chain Position, Simulated Outcome	Baseline No Reduction	Wholesaler Reduction All Adjustment	Wholesaler Reduction No Farm or Retailer Adjustment
Farm Outcomes			
Price, $/kg	2.00	-4.7%	-7.3%
Inventory,000 kg	625	1.2%	4.1%
Harvested, 000 kg/week	625	-2.1%	-1.0%
Sales to Wholesaler, 000 kg/week	500	-2.9%	-2.4%
Profits, $000/week	375	-17.1%	-24.4%
Wholesaler Outcomes			
Price, $/kg	4.00	-2.9%	-6.7%
Inventory,000 kg	500	-0.8%	0.5%
Sales to Retailer, 000 kg/week	400	2.8%	1.0%
Profits, $000/week	400	-8.8%	-8.7%
Retailer Outcomes			
Price, $/kg	7.50	-1.7%	-2.0%
Inventory,000 kg	400	4.0%	4.6%
Sales to Consumer, 000 kg/week	320	2.5%	2.9%
Profits, $000/week	400	1.9%	3.1%
Environmental Indicator	80,464	-0.6%	1.5%

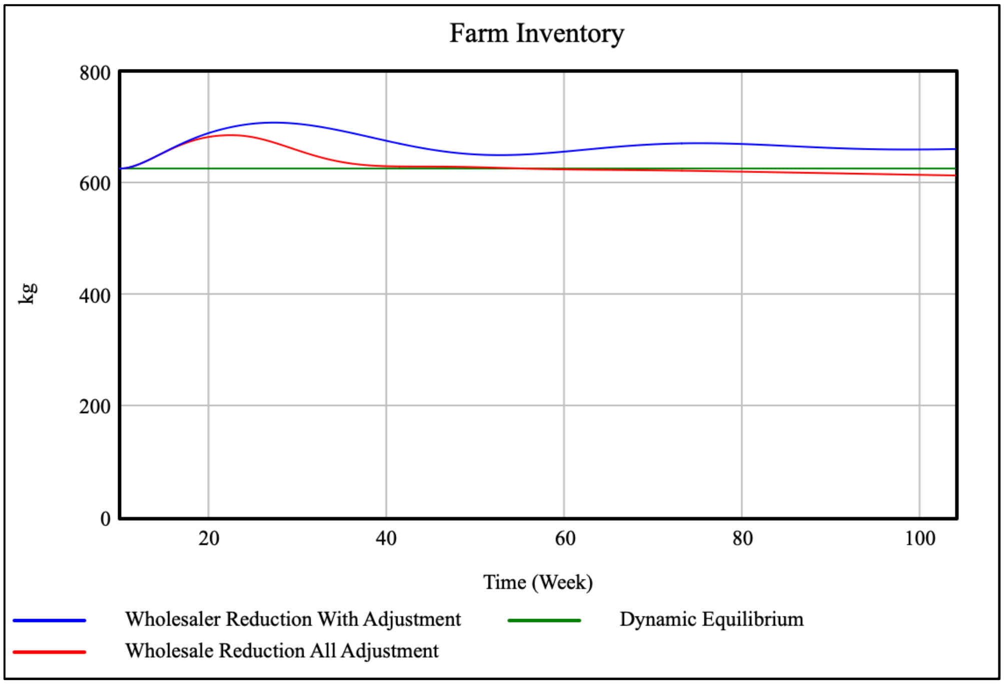


Figure 5. Farm Inventory with Wholesaler Loss Reduction, Without and With Farm Adjustment to New Loss Rate

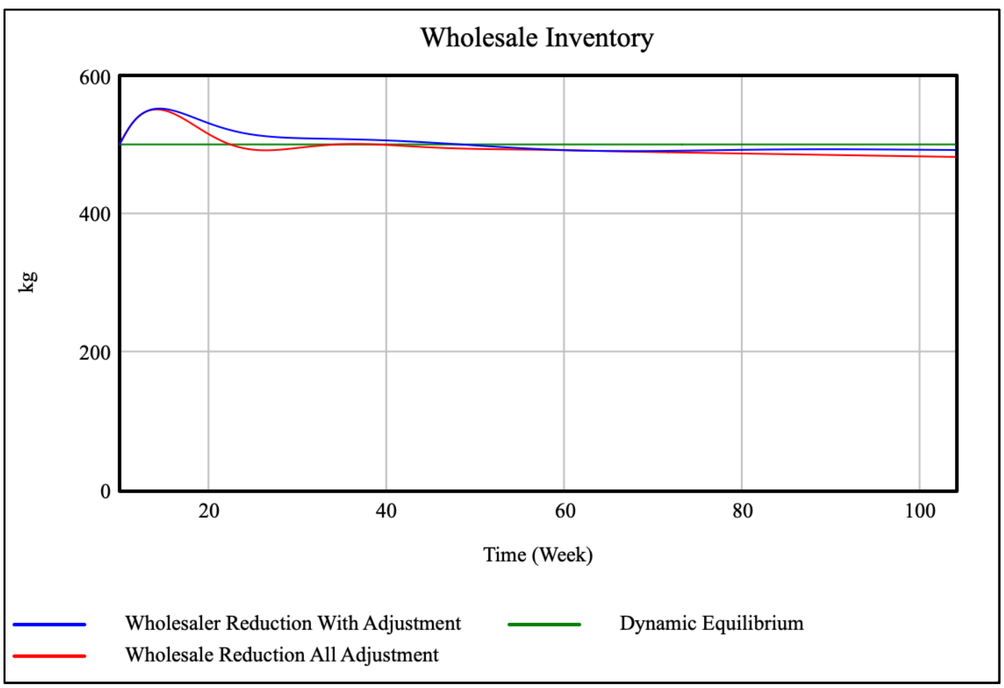


Figure 6. Wholesale Inventory with Wholesaler Loss Reduction, Without and With Farm Adjustment to New Loss Rate

4.3.3 Results for Supply Chain Loss Reduction Location Scenarios

Our third set of scenarios assesses the impacts of where in the supply chain the reductions are assumed to occur. Although in principle, strategies to reduce food losses could be implemented at multiple supply chain stages simultaneously, here we assume implementation each of the three supply chain stages separately. We assume that all actors adjust to reference production and ordering decisions to the reduction in losses and assume equal proportional reductions and cost increases for each of the three stages. The supply chain location at which reductions are implemented affects outcomes throughout the leafy greens supply chain (Table 4). In general, reductions implemented at the farm stage result in smaller negative impacts on farm profits (Figure 7), larger positive impacts on wholesaler and retailer profits (Figures 8 and 9) and larger decreases in environmental impacts (Figure 10). However, variation in supply chain outcomes is larger when food loss reduction strategies are implemented at the farm stage. In addition, when loss reduction is implemented at the retailer, the upstream effects on wholesalers and farmers tend to be larger, which is consistent with the idea of the "bullwhip effect" in supply chains.

Table 4. Simulated Wholesaler Food Loss Reduction Scenarios With Reductions at Different Supply Chain Locations, Compared to Baseline, Weeks 10 to 104

Supply Chain Position, Simulated Outcome	Baseline No Reduction	Farm Reduction All Adjustment	Wholesaler Reduction All Adjustment	Retailer Reduction All Adjustment
Farm Outcomes				
Price, $/kg	2.00	-4.0%	-4.7%	-6.0%
Inventory,000 kg	625	0.0%	1.2%	2.0%
Harvested, 000 kg/week	625	-3.6%	-2.1%	-2.2%
Sales to Wholesaler, 000 kg/week	500	1.8%	-2.9%	-3.2%
Profits, $000/week	375	-16.6%	-17.1%	-21.1%
Wholesaler Outcomes				
Price, $/kg	4.00	-1.6%	-2.9%	-4.9%
Inventory,000 kg	500	2.9%	-0.8%	0.2%
Sales to Retailer, 000 kg/week	400	1.5%	2.8%	-3.9%
Profits, $000/week	400	3.8%	-8.8%	-11.2%
Retailer Outcomes				
Price, $/kg	7.50	-0.9%	-1.7%	-1.3%
Inventory,000 kg	400	2.1%	4.0%	-3.0%
Sales to Consumer, 000 kg/week	320	1.3%	2.5%	2.0%
Profits, $000/week	400	1.9%	3.1%	3.1%
Environmental Indicator	80,464	-1.6%	-0.6%	-0.6%

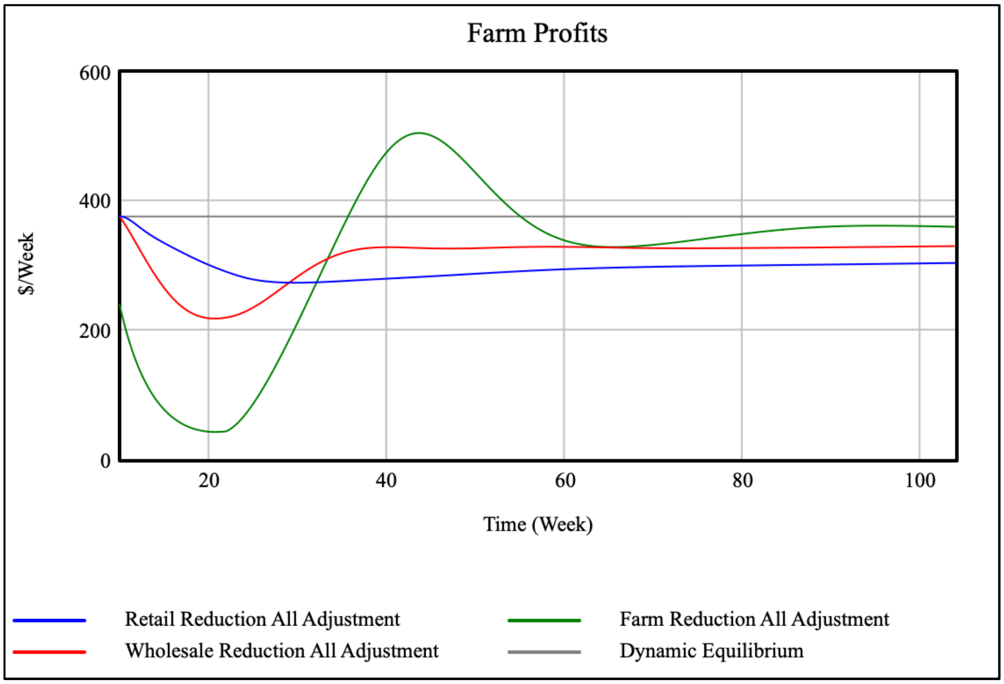


Figure 7. Farm Profits with Loss Reduction by Different Points in the Supply Chain, With Adjustment for All to New Loss Rate

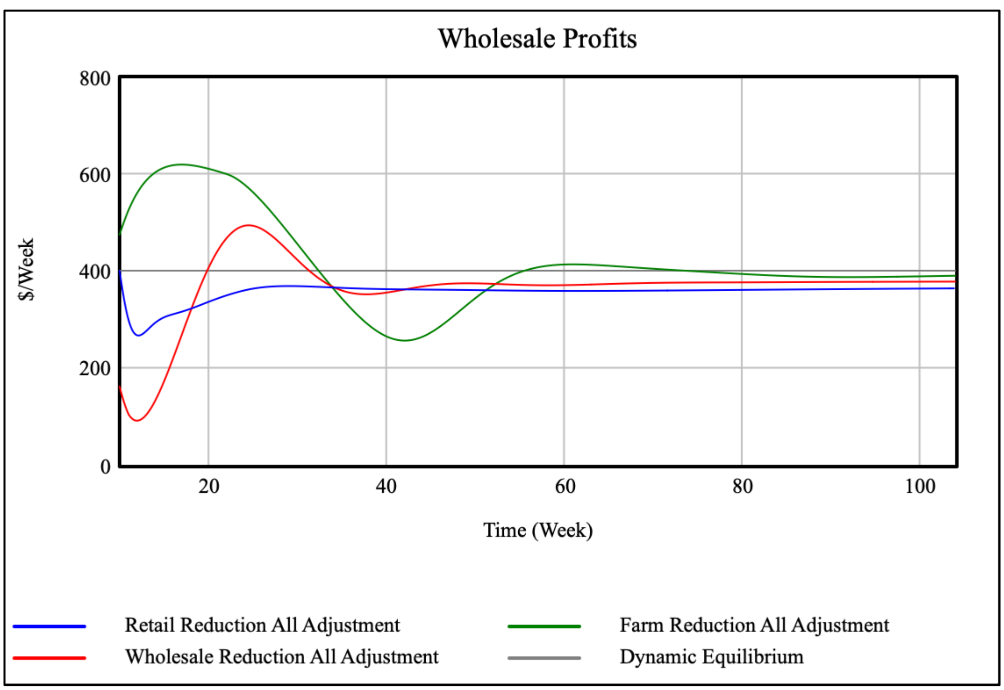


Figure 8. Wholesaler Profits with Loss Reduction by Different Points in the Supply Chain, With Adjustment for All to New Loss Rate

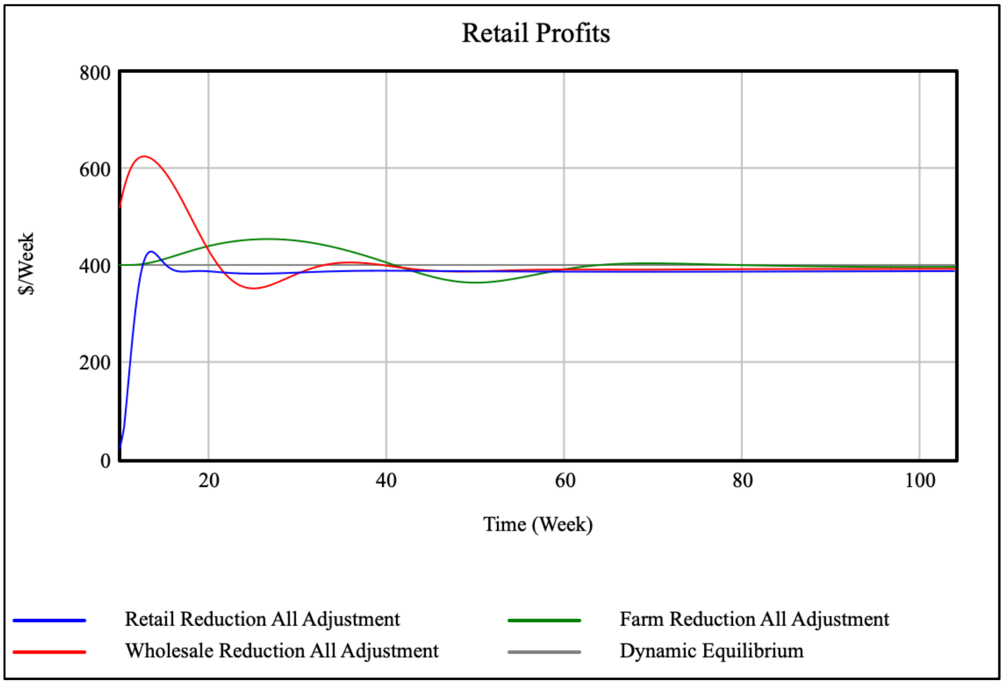


Figure 9. Retailer Profits with Loss Reduction by Different Points in the Supply Chain, With Adjustment for All to New Loss Rate

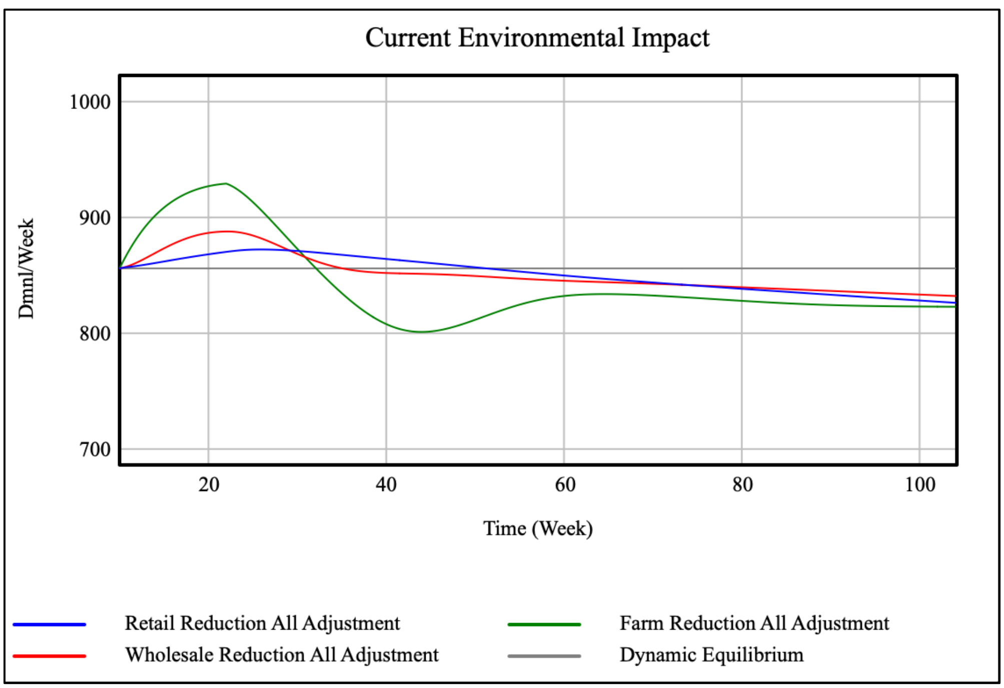


Figure 10. Environmental Impact with Loss Reduction by Different Points in the Supply Chain, With Adjustment for All to New Loss Rate

5 Discussion and Conclusions

Our analyses suggest the possibility that many of the assumptions about the impacts of reducing food loss (i.e., the 'triple win') may not be accurate given supply chain decision structures. Moreover, the costs of reducing food loss, the location in the supply chain where losses are assumed to be reduced and behavioral assumptions about responses of supply chain actors to reductions (including the degree of coordination) will influence outcomes such as prices, profits, consumption of the product and environmental outcomes. It is also worth noting that even when environmental outcomes are improved, the proportional reductions tend to be small compared to the assumed proportional reduction in food loss (e.g., a 5% reduction in food loss implemented by the wholesaler results in a 0.6% reduction in the stylized environmental impact). We also note relevant economic and environmental tradeoffs: higher costs to reduce food loss decrease environmental impacts in part through higher prices and lower product consumption.

Although our findings provide a relevant perspective on food loss impacts in a supply chain, our study could be extended in several ways. First, although based on parameter estimates from previous work on a specific supply chain (Nicholson and Monterrosa, 2023), our analysis is for a highly perishable, minimally processed product (leafy greens) and is rather stylized, particularly for the environmental impacts. A more detailed empirical representation of other specific supply chains, including more specific environmental indicators, would provide additional insights into impacts and approaches to food loss. Second, we assume that the strategies to reduce food loss are feasible and implementable in a very short time frame at all locations in the leafy green supply chain without explicit consideration of the financial incentives to actors to reduce food loss. This is unlikely to be the case in many settings, especially in low- and middle-income countries. Our analyses also do not account for the possibility of close coordination of the supply chain to reduce food loss and waste, which might include joint planning for food loss reductions or financial support (incentives) from one component of the supply chain to another. This is consistent with our conceptualization of the leafy green supply chain as serving a wholesale producer market for which contracts are relatively unimportant, although this will not be the case for all food products. Fourth, we assume that reductions in food loss do not affect consumption decisions, that is, the impact of improved environmental outcomes does not affect consumer purchasing decisions. Previous work on leafy greens (Krasovskaia et al., 2025) suggests that consumer valuation for leafy greens and purchase decisions can be affected by environmental outcomes. Finally, we do not assess situations in which reducing food loss decreases unit costs for production and marketing. Future work could usefully address these considerations, although we consider it unlikely this would result in a marked impact on our basic conclusions about the impacts of food loss and waste.

Our team is now working on further development of this type of dynamic analysis for a comparative case study of interventions to reduce food loss and waste for leafy greens in the U.S. and Kenya. This will build on previous empirical work (e.g., Nicholson et al., 2023; Nicholson and Monterrosa, 2023) and highlight how different supply chain structures and incentives in the two locations may affect the outcomes of specific interventions. These future analyses will develop more specific representations of supply chain actors and their decision-making processes (including coordination strategies), more specific cost and margin estimates for supply chain stages, and identify and assess the impacts and costs of specific food loss and waste reduction strategies. We will also assess what will be more realistic the implementation timelines and the potential role of financial assistance provided by governments or non-profit organizations. We believe these will make the stylized findings from this study more explicit and provide insights about how to undertake relevant analyses of specific interventions to reduce food loss and waste.

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APPENDIX

Detailed Supply Chain Model Description

The supply model is modified based on a commodity supply chain model discussed at length in Sterman (2000). The model's key assumptions are:

- Farms, wholesalers, retailers and consumers are the key decision makers.
- Farms, wholesalers, retailers and consumers each are aggregations of multiple actors, e.g., production occurs on numerous farms that do not (directly) coordinate their production. Similar assumptions apply to wholesalers, retailers and consumers. Thus, this is an aggregated supply chain, not one for a particular retailer and decisions are not coordinated in advance (as in some manufacturing supply chains).
- The key stock to be managed is inventory of product at the farm, wholesale and retail levels.
- Inventory is sold to customers (e.g., wholesalers ship product to retailers) and replenished from suppliers (e.g., farms supply to wholesalers).
- Inventory coverage (the number of weeks of inventory available given current rates of sales and spoilage) affects prices for farms, wholesalers and retailers. If inventories are higher than the desired number of weeks, price is reduced. If inventories are less than the desired number of weeks, prices are increased. This assumes price-setting ability is equal among the actors in the supply chain.
- A proportion of inventory is assumed as "loss" due to spoilage at the farm, wholesale and retail levels. No allowance is made for loss during use by consumers.
- The price received by the supplier is the same as the cost paid by the buyer, e.g., the price paid to farmers is the cost to wholesalers, and this includes relevant transportation costs from seller to buyer.
- Profits drive production decisions for farms and ordering decisions for wholesalers and retailers. Each actor expands activities when expected profits (a smoothing of previous values of current profits) are higher than an initial (reference) level and decreases activities when profits are lower than the initial level.

- For behavioral assumptions that include the stock management structure (SMS), decision makers adjust orders to align with expected loss rates (a smooth of sales to customers and food losses).
- Profits for farms, wholesalers and retailers equal revenues less costs. Revenues equal sales time selling price. Costs equal (constant) other costs per unit acquired plus the price paid to the supplier. Note that: there are no economies of scale (lower other costs per unit) assumed for larger volumes and the quantity sold is less than the quantity purchased due to spoilage of product in inventory.
- There are time delays between planting and harvest for farmers, and between the placement and receipt of quantities ordered by wholesalers and suppliers. These delays are represented by the "supply lines" for each actor.
- Consumer decisions about the quantity to purchase depend on expected prices (a smooth of previously-observed prices), current income and current knowledge about the healthfulness of vegetables. The impacts of each are modeled as "constant elasticity" (nonlinear) functions of these variable relative to an initial (reference) value.

Retail and Consumer Sector

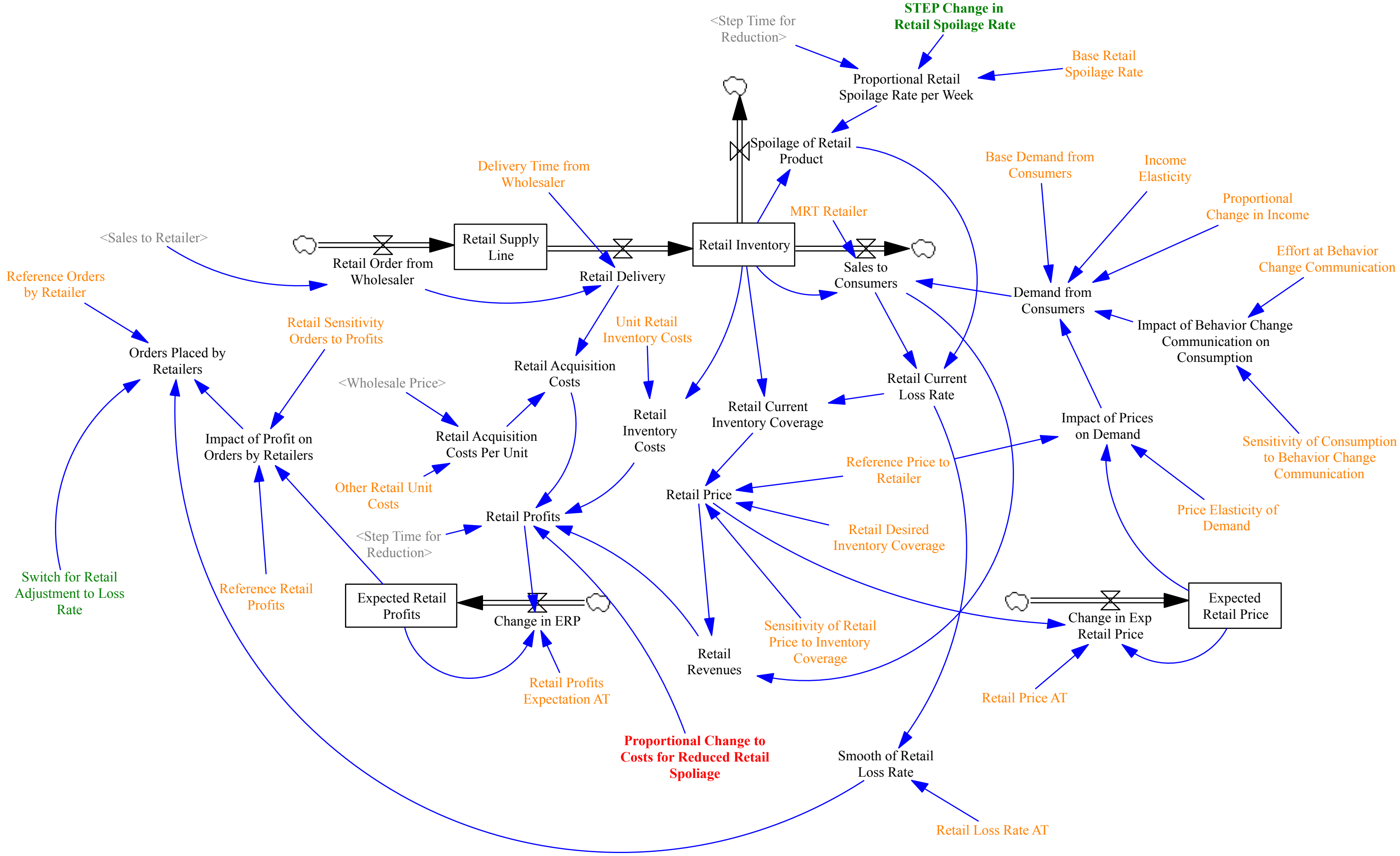
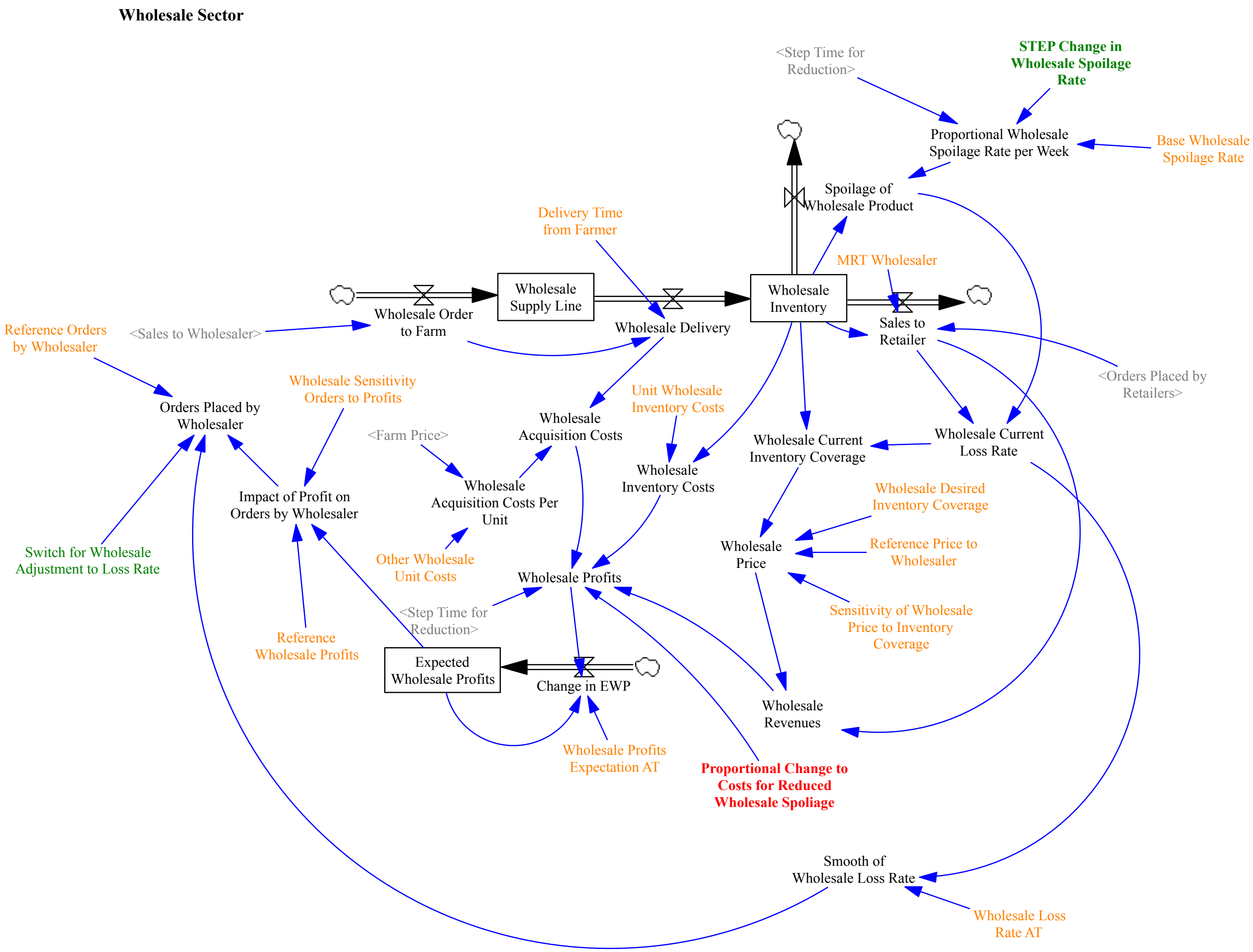


Figure A1. Detailed Quantitative Model Diagram for Retailers and Consumers



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31 **Figure A2. Detailed Quantitative Model Diagram for Wholesalers**

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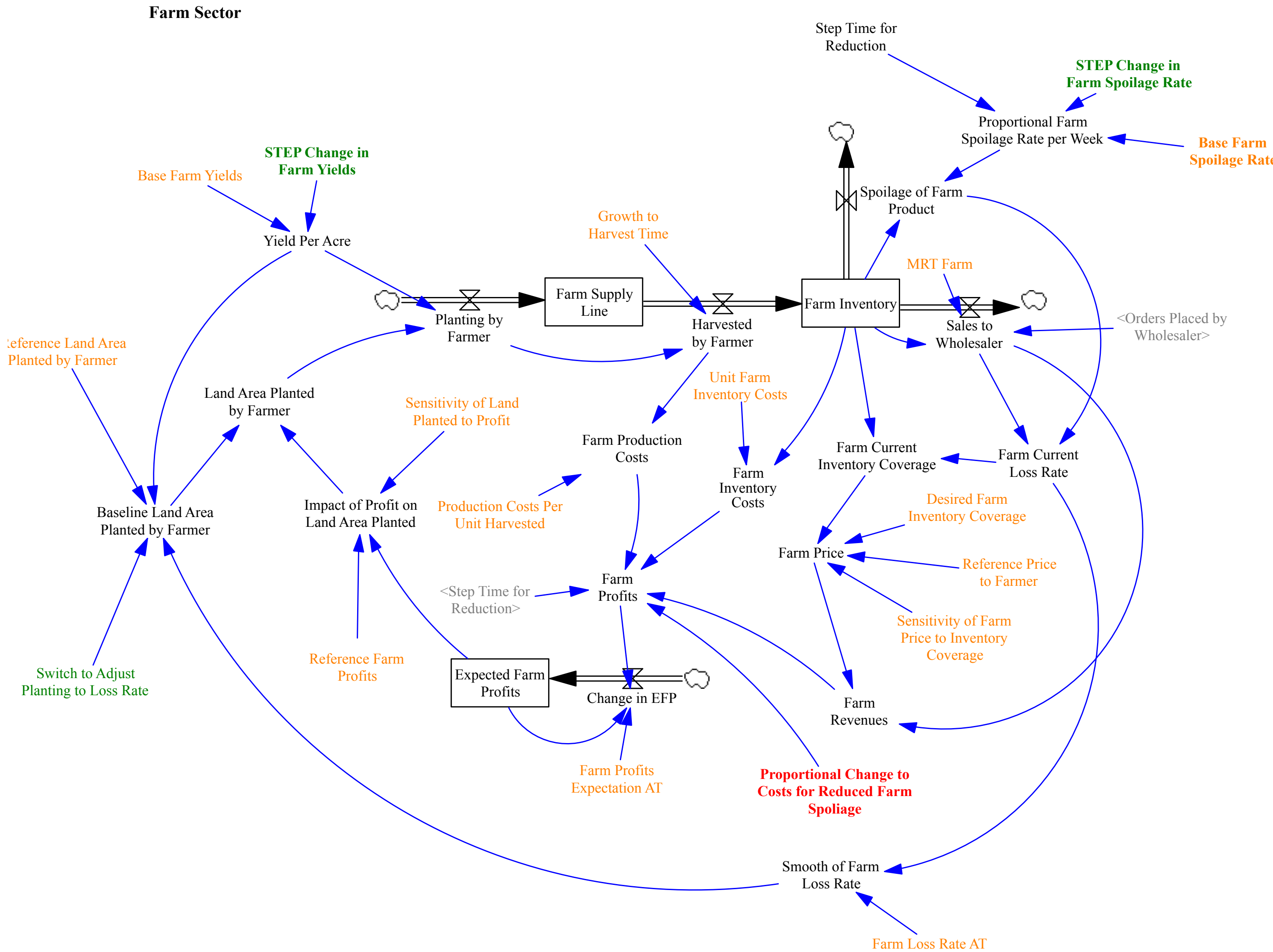

Figure A3. Detailed Quantitative Model Diagram for Farmers