Agent-based models can predict appropriate risk-based setback distances for flooded fields

Summary

Flooding of produce fields can present a food safety risk, as flooding can transport and introduce bacterial hazards and facilitate bacterial growth. A standard setback distance from the edge of a flooding event is unlikely to always provide appropriate risk mitigation for harvest of adjacent fields as each flooding event is unique (e.g., in soil type, weather). There is a need for better tools and information that will allow growers to implement setback distances appropriate for a given flooding event. We address this need through (i) development of a model that can predict situation-appropriate setback distances to manage flooding-related food safety risk, as well as (ii) compilation of a dataset on growth, die-off, and dispersal of key bacterial food safety hazards after flooding.

Benefits to the Industry

Outcomes for this project will include (i) an agent-based model that will be available to industry (including instructions for use of the model) and (ii) a database and associated peer-reviewed publications reporting data and parameter estimates that can be used by others to independently assess setback distances after flooding events. These tools will help industry to apply improved risk-based approaches to managing food safety hazards after flooding events, which should replace one-size-fits-all setback distances and wait-periods with location and situation specific risk management approaches. Growers with flooding events that require food safety management decisions, and groups that develop guidance on food safety risk management (e.g., LGMA, state departments of agriculture) will benefit from this research.

Objectives

1. Develop an agent-based model (ABM) to model the dispersal and population dynamics of bacterial pathogens and to predict appropriate risk-based setback distances.
2. Perform mesocosm studies using different soil types and moisture levels to collect dispersion rates from flooded soil to unflooded soil for the ABM developed in Obj. 1.
3. Validate the ABM predictions through a simulated flooding event in a commercial scale field as well as published and unpublished data collected from natural and simulated flooding events.

Methods

An ABM will be developed to simulate the water movement between soil blocks in the produce field as well as microbial population dynamics to calculate a setback distance that represents an acceptable microbial risk. This model will be implemented in Python with the package "Mesa".

Mesocosm experiments that simulate flooding in fields with different soil types will help define key dispersal parameters for target pathogens (Enterohemorrhagic *Escherichia coli*, *Salmonella*, *L. monocytogenes*) in three different soil types. A simulated flooding event, using flood water inoculated with non-pathogenic surrogates, will produce data to (i) validate the ABM developed in Obj. 1 and to (ii) assess different testing approaches (e.g., microbiome compositions, total *Enterococcus* counts, generic *E. coli* counts) for their ability to validate model predictions.

Results to Date

The team has conducted a literature search and compiled a list of mathematical equations that describe water evapotranspiration from soil as well as vertical and horizontal water movement. A model framework (**Figure 1**) has been developed with key procedures for water movement implemented. The team initiated a literature review to identify and quantify risk factors for building the agent-based model (see **Figures 2** and **3** for search queries and screening process). Out of 1,383 research papers, screening yielded 199 papers for data extraction. The simulated flooding event is being coordinated; the team has gained permission from the appropriate parties and reserved a plot (**Figure 4**) at a research farm.

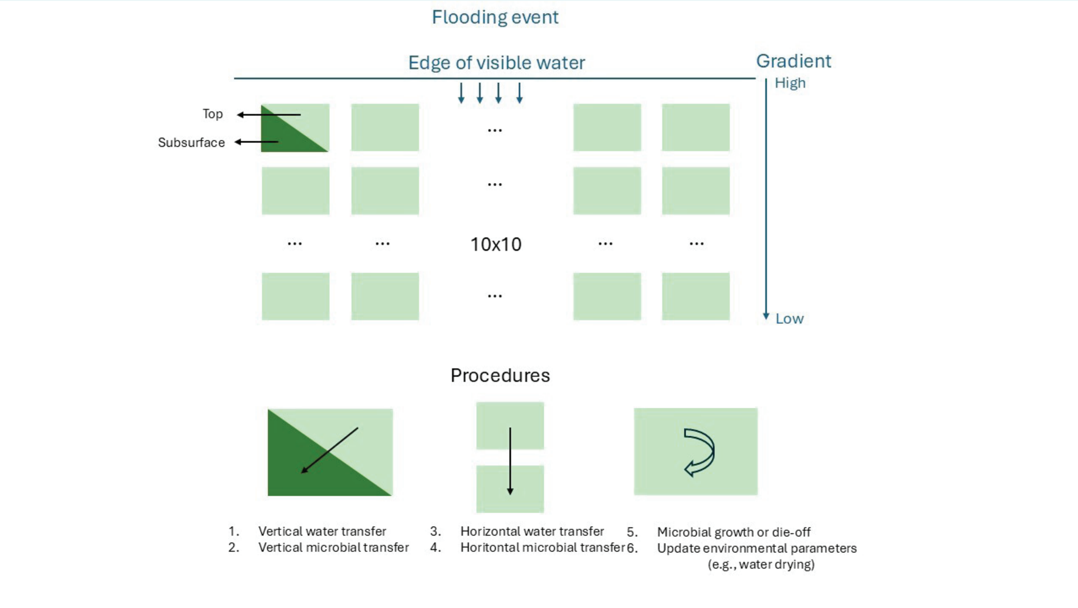

Figure 1:
Agent-based model layout with key procedures describing water movement and microbial population dynamics. The model consists of a total of 200 agents that represent soil blocks (10 in each row X 10 in each column X 2 depths). The light and dark green areas show, for each soil block, two agents representing top and sub-surface soil, respectively. The water moves from high gradient to low gradient, with the high gradient representing close proximity to the edge of visible flooding water above soil.

#	Query
1	ALL=("Salmonella" OR "STEC" OR "E. coli" OR "Escherichia coli" OR "EHEC" OR "Listeria" OR "Enterococcus" OR "pathogen")
2	ALL=("Transport" OR "horizontal movement" OR "spread" OR "survival" OR "survive" OR "grow" OR "die off" OR "persistence" OR "risk")
3	ALL=("Soil" OR "porous media")
4	ALL=("Flooding" OR "saturation" OR "water" OR "floodwater" OR "hydrological" OR "hydrologic"))
5	ALL=("Produce" OR "vegetables" OR "leafy greens" OR "agriculture" OR "Foodborne" OR "soil amendment" OR "biological soil amendment" OR "manure" OR "compost" OR "poultry litter")
6	ALL=("plant pathogen" OR "plant growth promoting"))
7	#1 AND #2 AND #3 AND #4 AND #5 NOT #6

Figure 2:
A list of queries used for the literature search, with row #7 representing the final query.

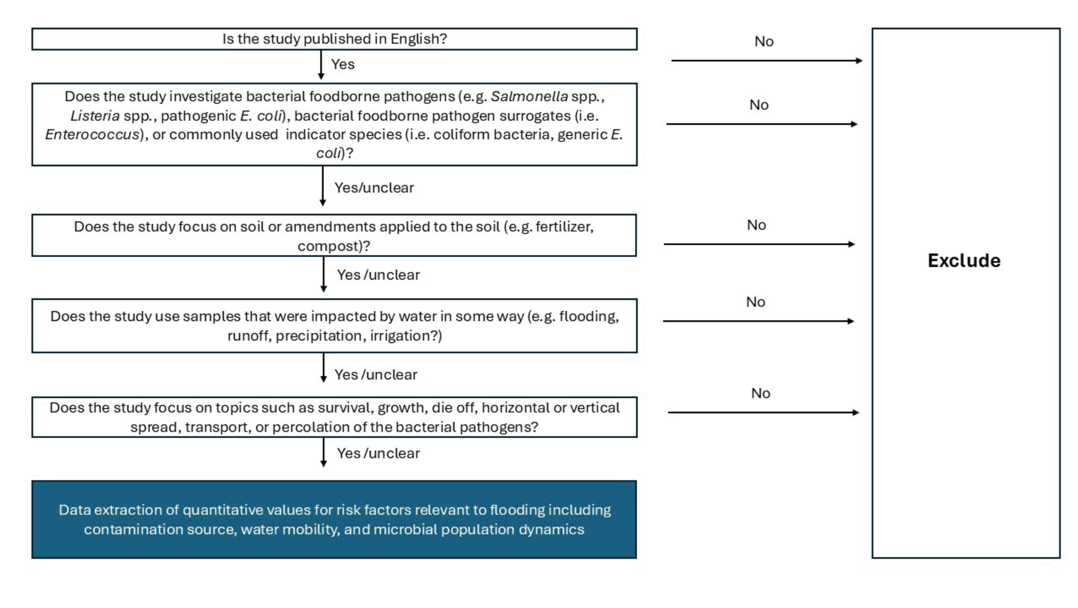

Figure 3:
The screening process and exclusion criteria for the selected publications from the initial search query.

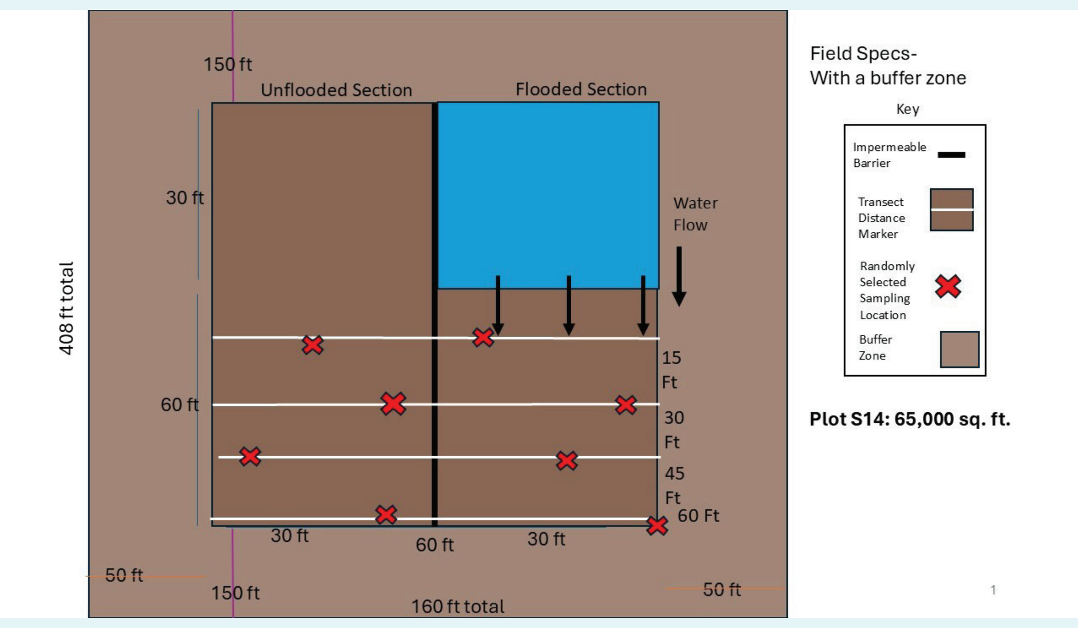

Figure 4:
Diagram of flooded field and sampling setup. The sample collection area will be situated in the inner area of the plot (as indicated by the dark brown square, with a small blue square in the upper right part in the figure), surrounded by a buffer zone (indicated by the light brown area). Within the sample collection area, there will be a flooded section and unflooded section. The unflooded section will serve as the unflooded control and is separated from the flooded section by an impermeable barrier (shown in the diagram by a thick black line.) The flooded section will have a 30 x 30 ft. area flooded (as represented by the blue square) and will have an impermeable barrier surrounding it except for one side, which will have a small barrier, such as a small soil dam or barricade that will allow for water flow in the soil subsurface, allowing for assessment of microbial spread into the "adjacent unflooded area". Sampling will take place at different distances in the adjacent unflooded area (as indicated by red Xs, which are examples of sampling sites, but do not represent all potential sampling sites).

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