Animal Disease Spread Model

Defining Disease

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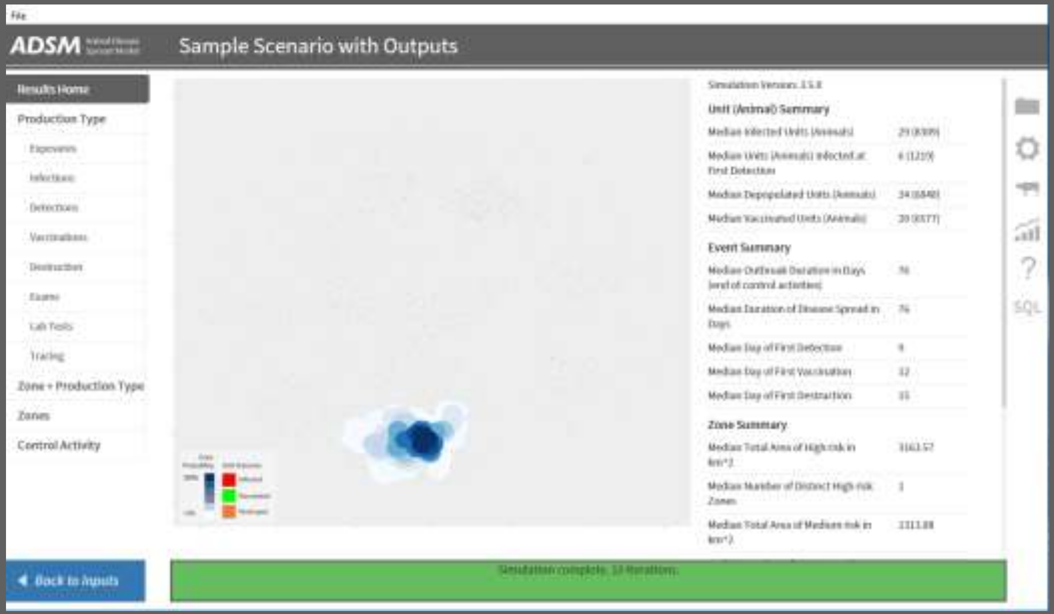
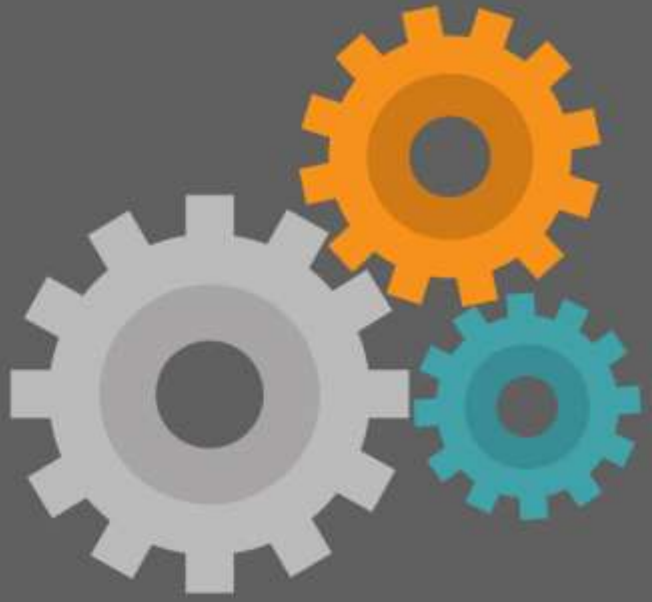


Disease Description



Describing a disease in ADSM

ADSM is very flexible for simulating highly infectious diseases. Because many users may create models for a number of diseases, it is important that a name is provided to accurately describe the disease of interest.

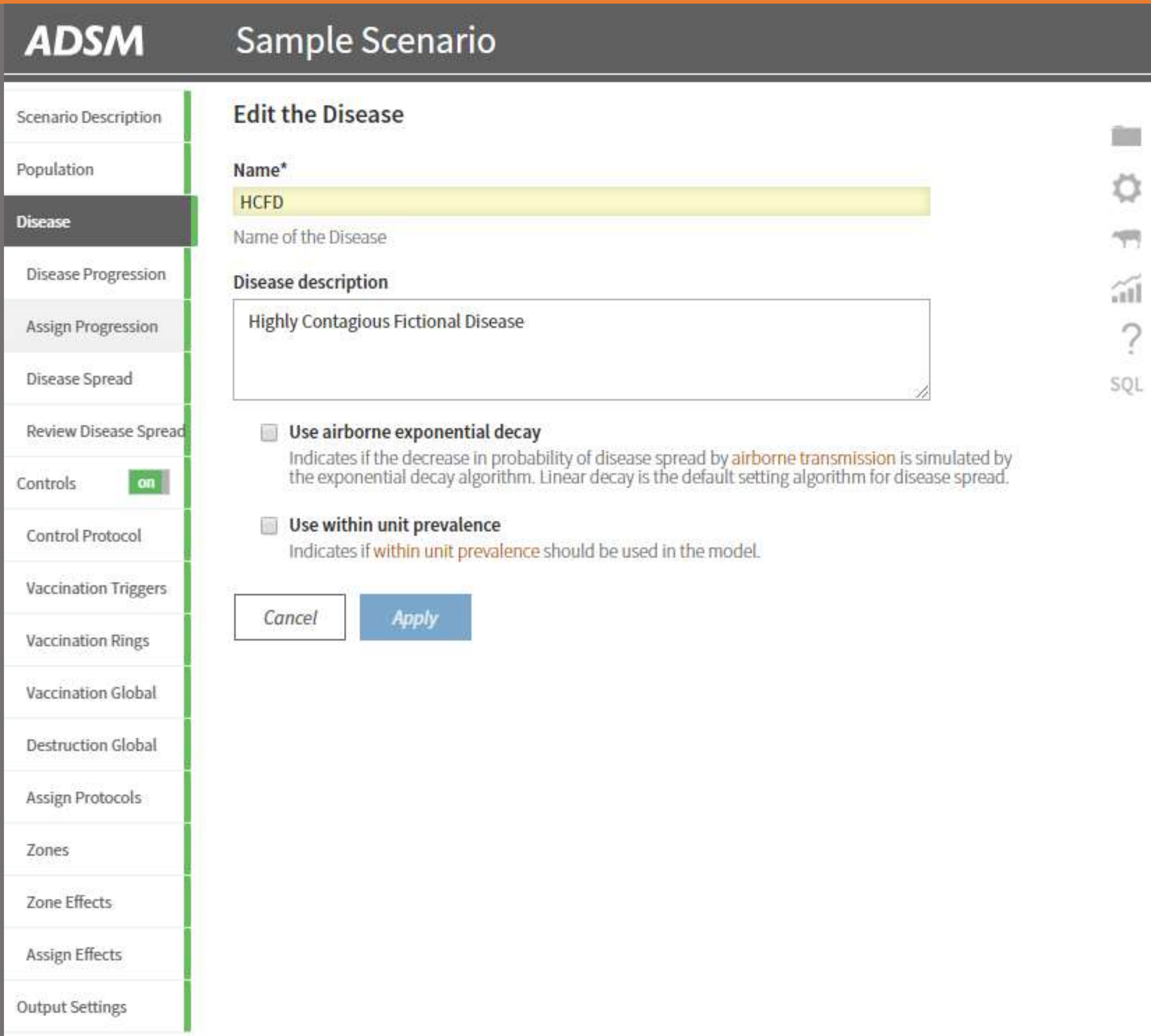
On the Disease tab, the name field must be completed to proceed to the next sections, as noted by the yellow highlight. It may also be helpful to provide a short description of the disease.

Airborne Spread

When a disease can be spread by tiny particles carried in air currents or aerosolized respiratory droplets, it is considered an **airborne transmitted disease**. The default setting in ADSM is a linear decay, which requires entry of a parameter of the max distance of spread. As appropriate, you can select the option that airborne exponential decay will be simulated instead.

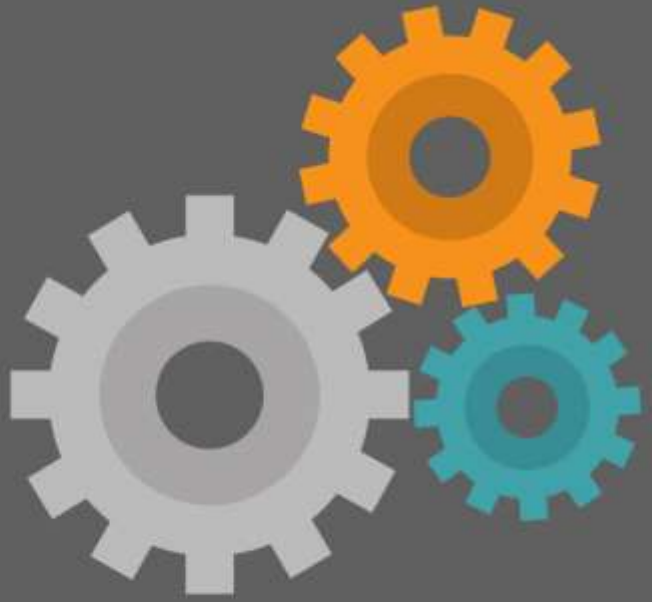
Within Unit Prevalence

You may prefer utilizing within unit prevalence, which is the average daily prevalence within a single unit. Within unit prevalence requires adding a prevalence parameter by production type on the Disease Progression tab. If this option is left unselected, ADSM uses the infection probability at the production type level on the Disease Spread tab.



Be sure to select *Apply* to save the changes.

Disease Progression



Disease States Used in ADSM

Susceptible: A disease state characterized by the capacity of a unit to become infected. Units in this disease state are neither infected, naturally immune, nor vaccine immune.

Latent: A disease state characterized by the period of time that elapses between exposure to a disease agent and onset of infectiousness (shedding of disease agent).

Sub-clinically infectious: A disease state in which there is an absence of clinical signs but in which the disease agent is being shed.

Clinically infectious: A disease state characterized by the presence of clinical signs and shedding of the disease agent.

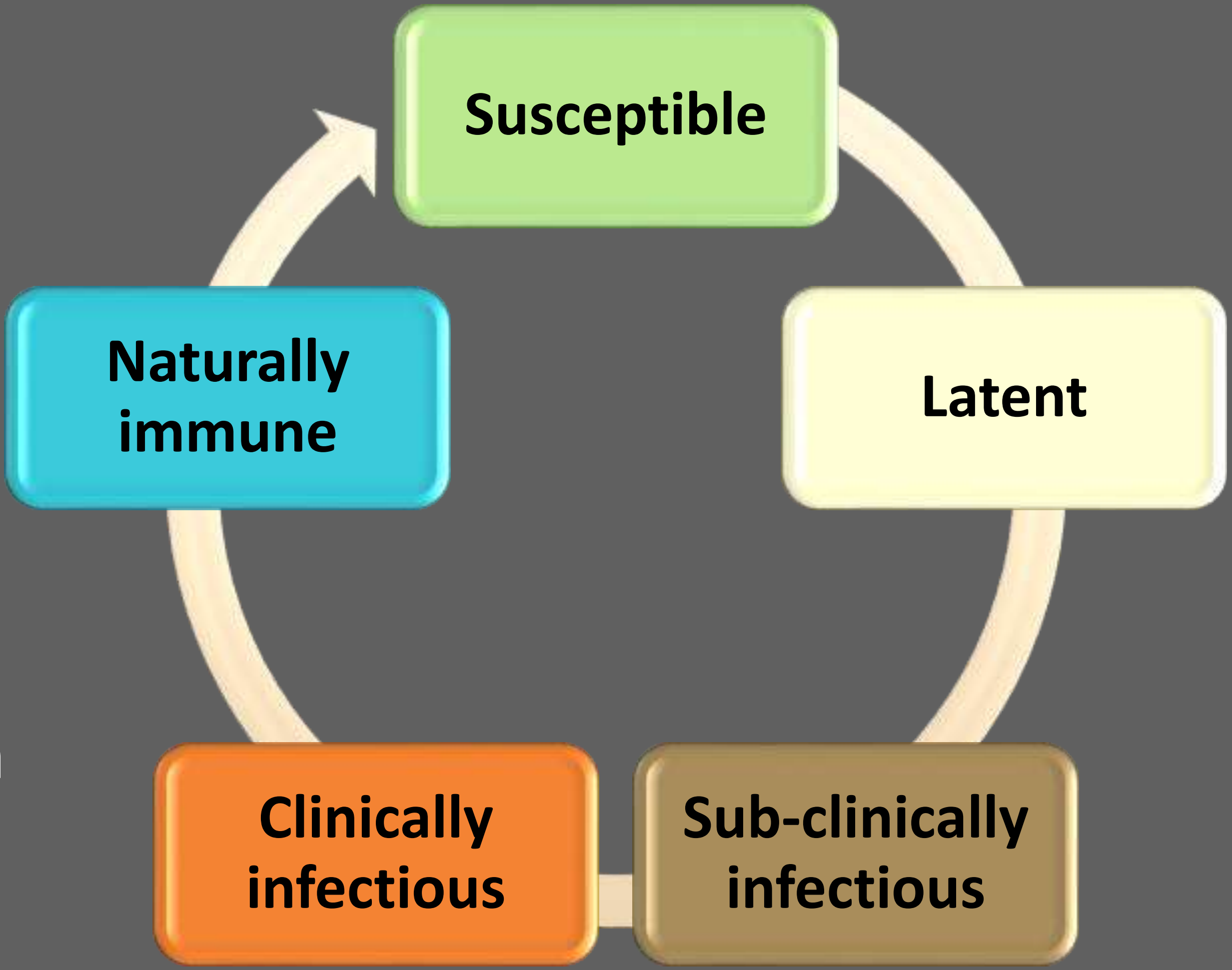
Immune: A disease state in which units are immune due to natural progression through the disease states (i.e. previous exposure to the pathogen) or vaccination.

All disease states in ADSM are considered at the farm or unit level.

Disease Progression - Describing Disease States in ADSM

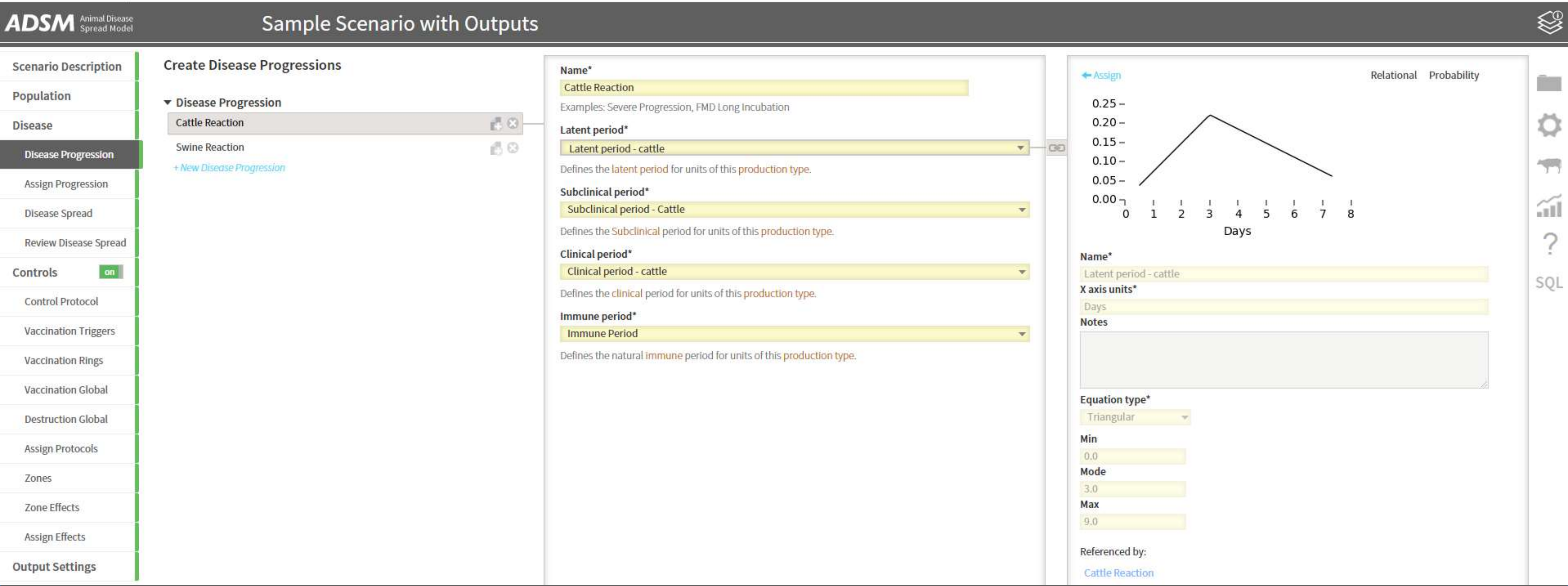
As described in the population file, units (individual farms) are initially defined as susceptible, latent, sub-clinical, clinical, naturally immune, vaccine immune or destroyed.

Probability density functions characterize the length of the time period for each disease state. The value for the length of the disease state is then selected stochastically for each new infection from the range of possible values within the function.



Herd immunity

Herd immunity can be defined as the resistance to the spread of a contagious disease within a population that results if a sufficiently high proportion of individuals are immune to the disease. Herd immunity decreases the risk of disease in a population. The risk of infection in susceptible individuals is greatly reduced by surrounding them with immune individuals. In ADSM, immunity at the unit level can be achieved either by natural exposure or through vaccination.

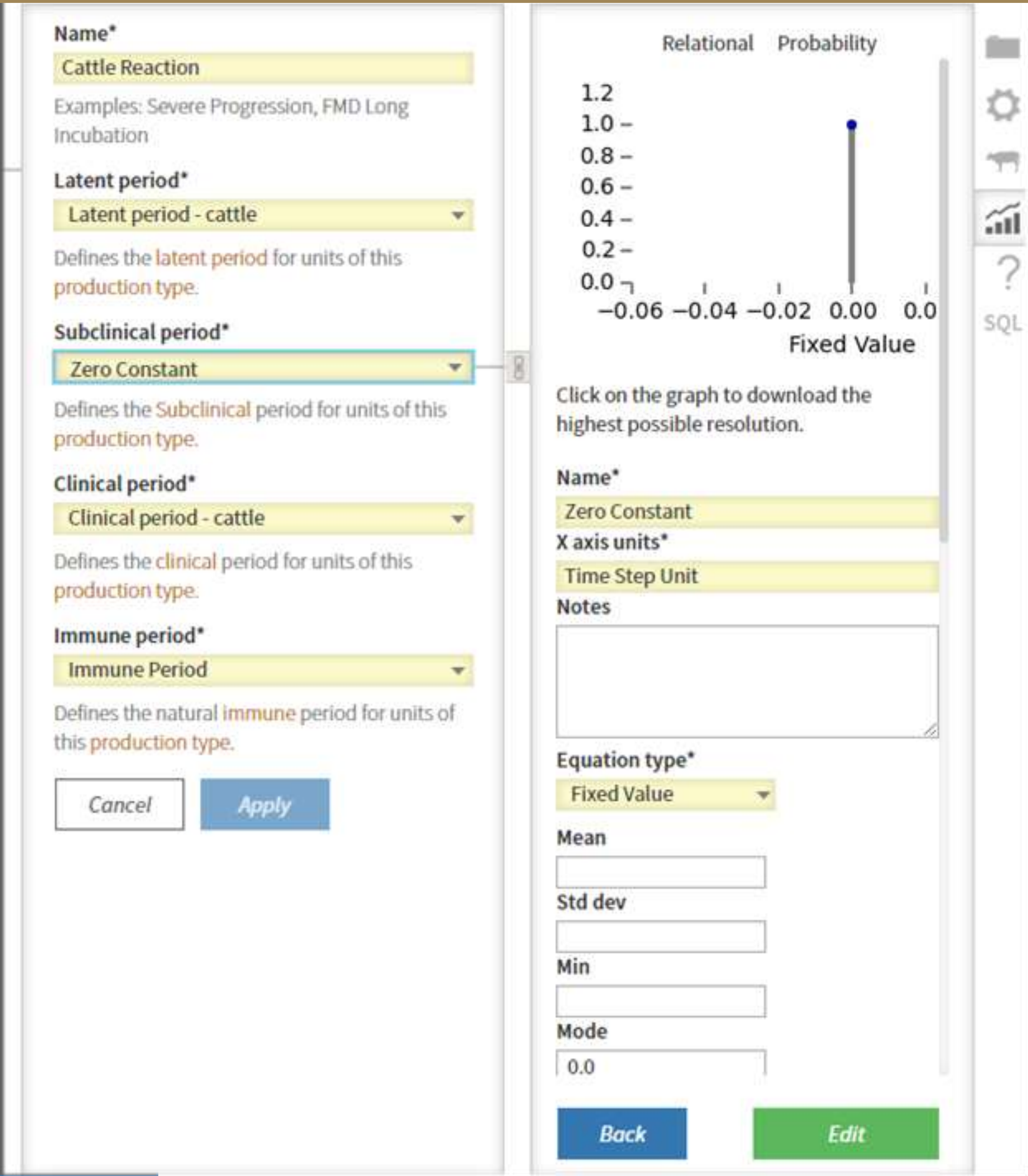


Defining each stage of disease progression is required to fully capture the entire process of infection within a unit. Within each disease state, a unique probability density functions can be used to describe the range of possible values. The user-named probability density functions are then assigned to each state to mimic biological disease progression.

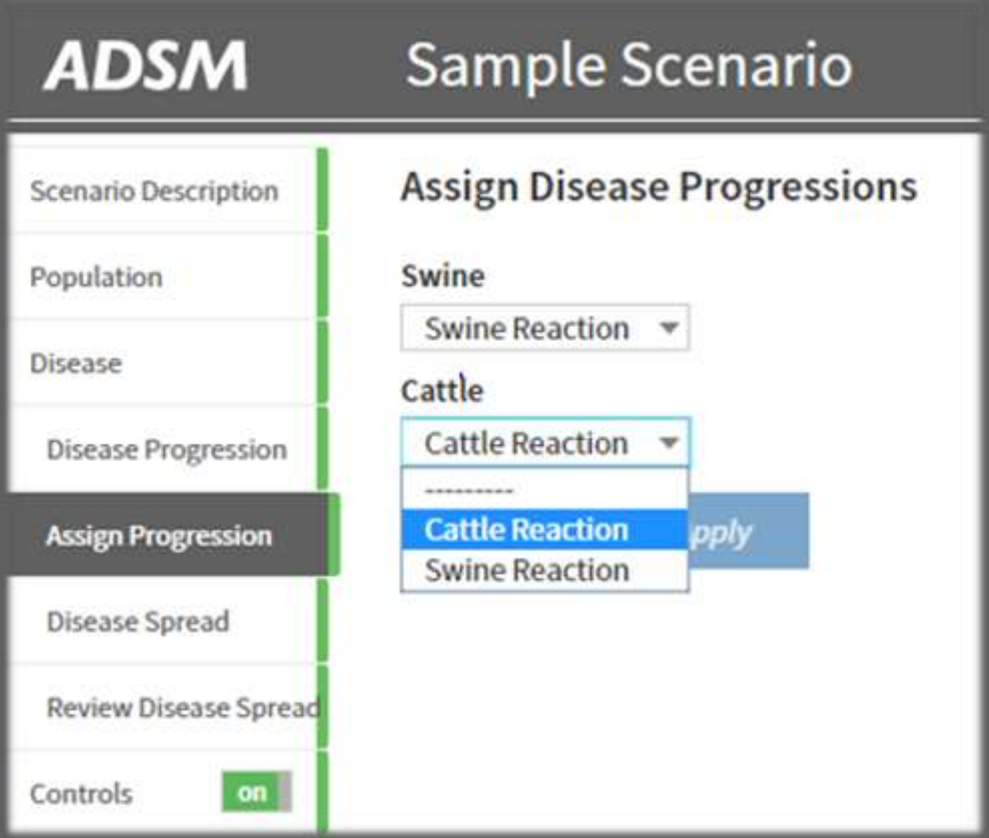
With adequate time and survival, infected units will progress into the immune state unless they are destroyed.

A specific disease state may be bypassed to the subsequent state by setting its duration to 0 days.

In this example, the Subclinical period parameter is set to a Fixed Value of 0.

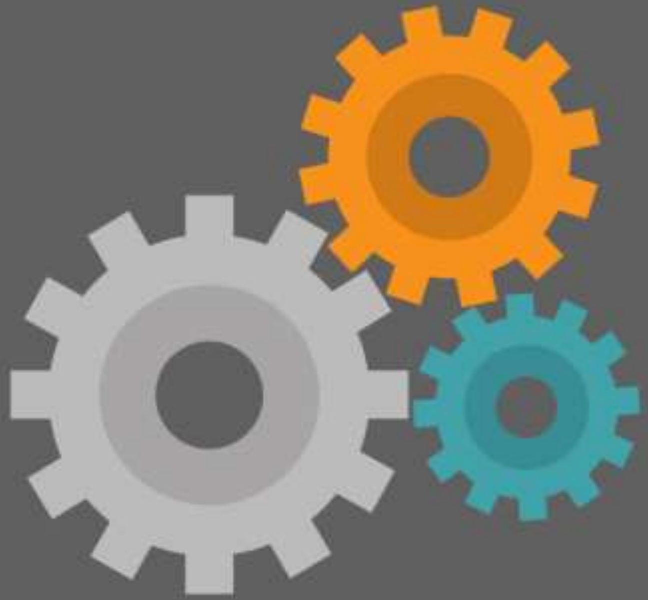


Use the drop-down tabs to assign the specific progression function to each disease state for each production type.



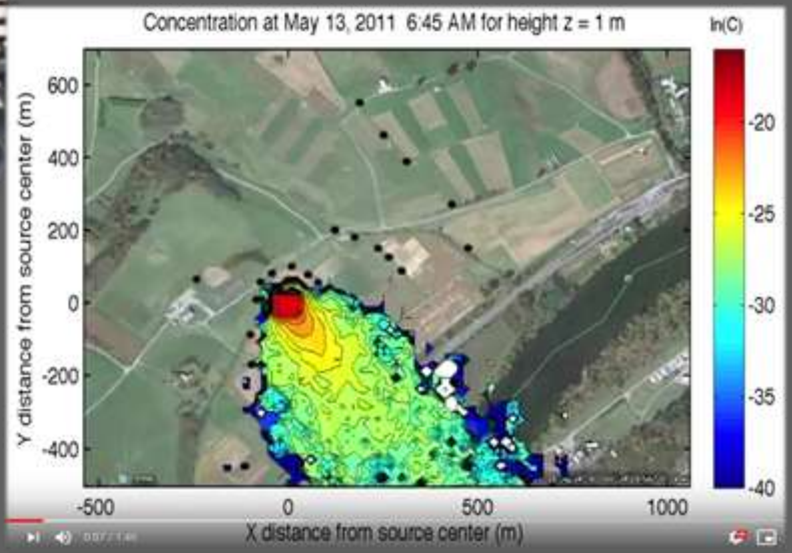
Be sure to select *Apply* to save the changes.

Disease Spread



ADSM simulates three types of contact that may spread disease:

Direct Contact
Indirect Contact
Airborne Contact



• Dr. Danelle Bickett-Weddle

Definitions Related to Disease Spread

- **Direct contact:** The movement of animals within units (premises, section, pen) or from one unit to another unit with animals.
- **Indirect contact:** The movement of people, vehicles, equipment, etc. from one premises to another premises with animals.
- **Direct transmission:** The transfer of a disease agent by direct or close contact.
- **Indirect transmission:** The transfer of disease agent via movement of personnel, vehicles, equipment, etc.
- **Airborne transmission:** The distribution of microbial aerosols consisting partially or completely of microorganisms which can be drawn into lung alveoli. This type of transmission includes transmission by droplet nuclei and dust.
- **Fomites:** Inanimate objects that when contaminated with infectious agents can transfer disease to a new host.
- **Vectors:** Any organism (vertebrate or invertebrate) that functions as a carrier of an infectious agent between organisms of a different species.
- **Mechanical vs biological transmission:** In mechanical transmission, the disease agent does not replicate or develop in/on the vector but in biological transmission, the agent replicates and/or develops in it.

Additional considerations regarding disease spread…

- Latent cases can be a source of infection in direct disease spread.
- Simulation results are achieved at the herd level, not in individual level.
- Production types differ in their susceptibility to disease and can greatly influence the results of a simulation.

Direct Spread

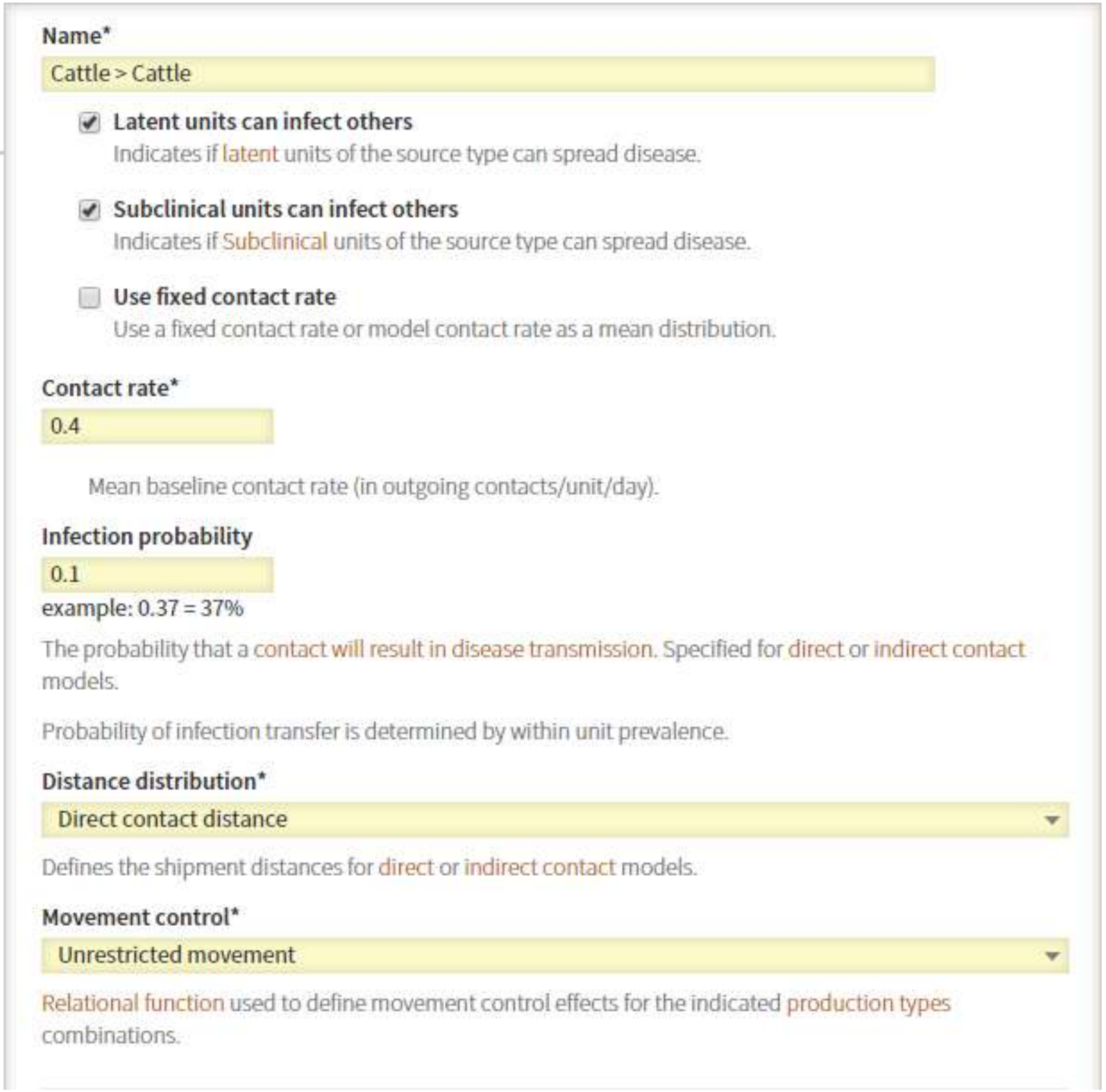
Within ADSM, parameters associated with direct spread of disease includes the contact rate, infection probability, and distance distribution. These direct contact measures consider different production types and movement control.

Direct contact measures the movement of one or more animals from one herd to another. These are assigned within ADSM by selecting a production type to be the source of the animal movement, and one or more production types to be the recipient of the animal movement.

Direct Spread

To begin, create a name to accurately describe the production type-to-production type spread. In this example, we are considering cattle-to-cattle direct spread.

With these production types and the disease of interest in mind, you would then determine if latent and/or subclinical units can infect other susceptible units and check the boxes as appropriate.



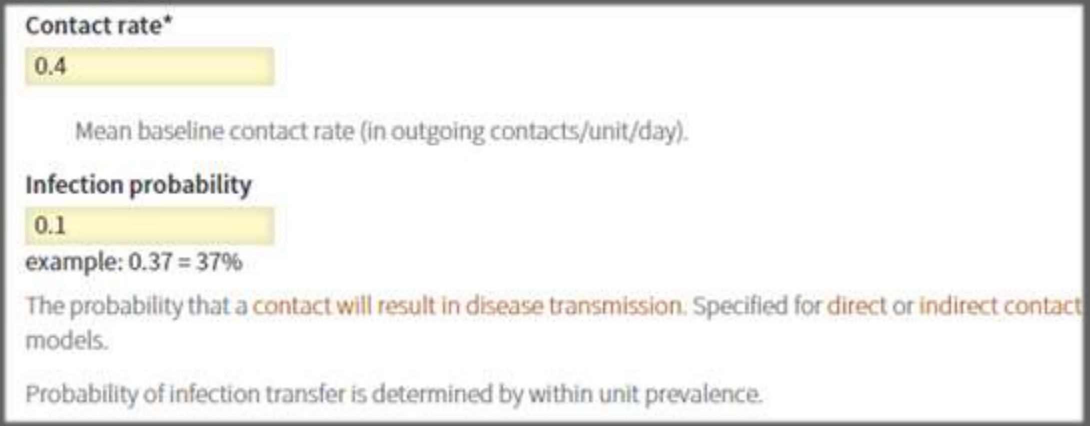
Contact rate

Disease is spread from one unit to another in one of 2 ways:

- If within unit prevalence is used, the function selected generates the infection probability.
- Alternately, contact rate and the probability of infection transmission, which are set for each pair of production types.

A contact rate is used to indicate the average number of contacts (shipments of animals in the case of direct contact, or movements of people, equipment, etc., for indirect contact) that are generated by each unit on each day.

For each unit that can infect others, the model simulates a number of outgoing shipments. A distance in chosen for each shipment from a probability density function of movement distances.


Contact rate*

0.4

Mean baseline contact rate (in outgoing contacts/unit/day).

Infection probability

0.1

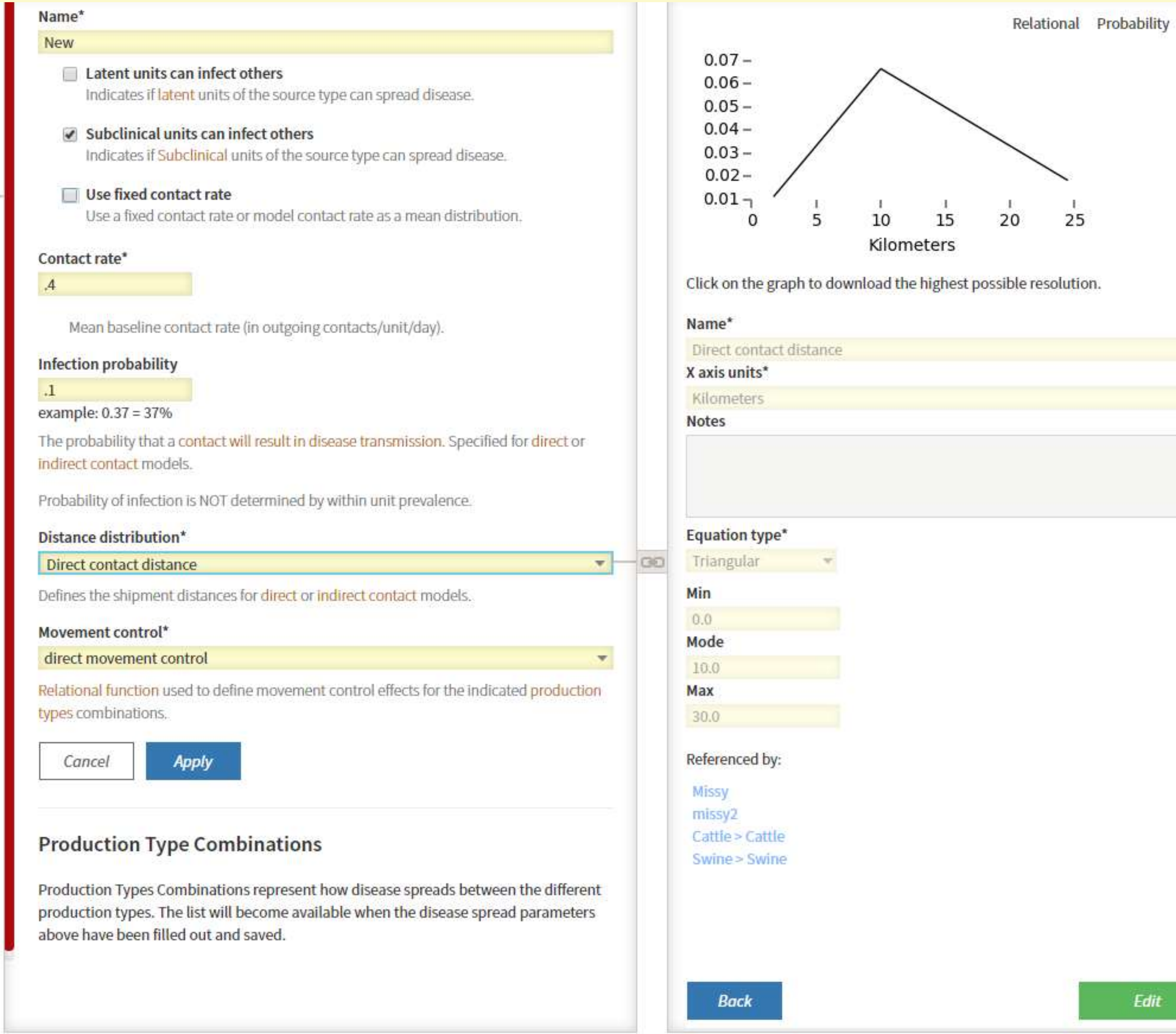
example: 0.37 = 37%

The probability that a contact will result in disease transmission. Specified for direct or indirect contact models.

Probability of infection transfer is determined by within unit prevalence.

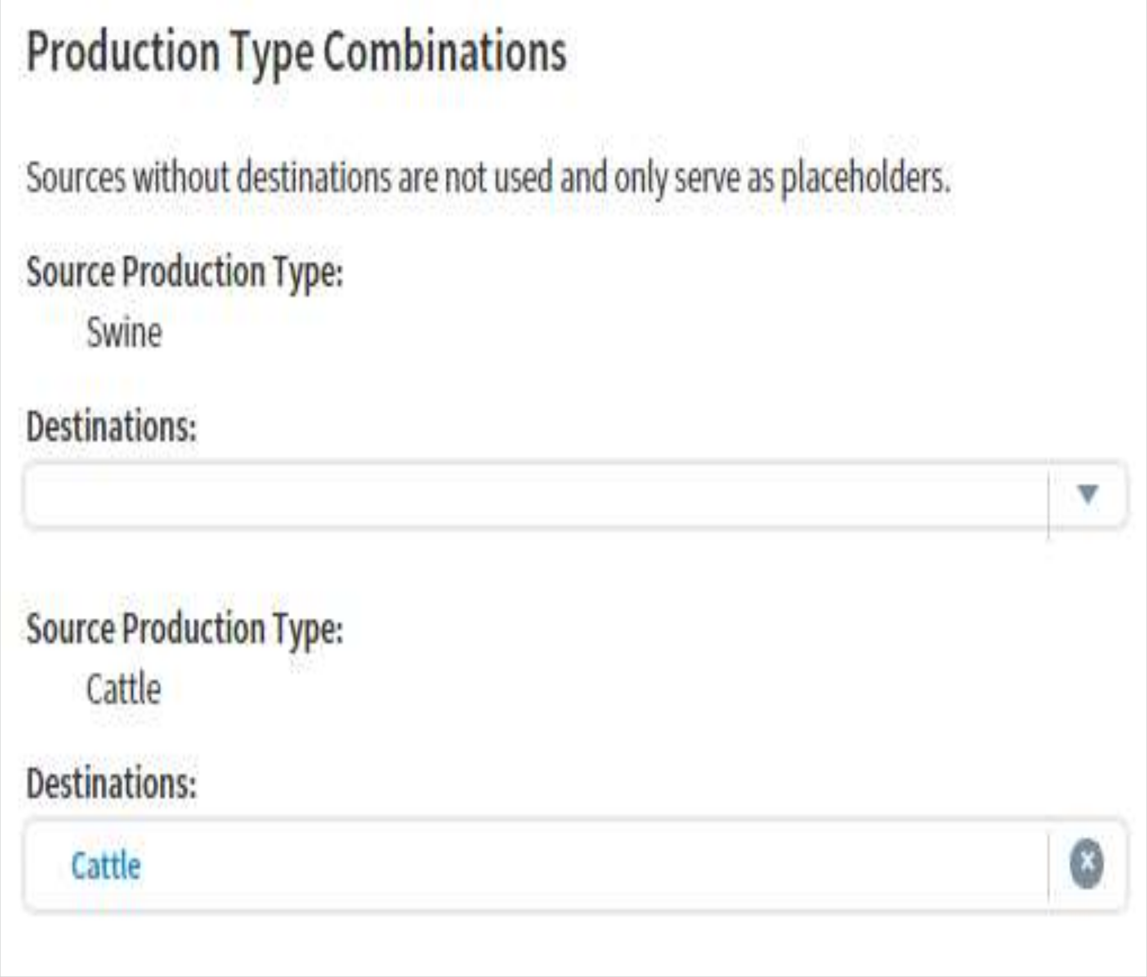
The Distance distribution uses a probability density function. ADSM supports 22 general types of probability density functions (pdf).

Some distributions are more suitable to certain applications than others, but all are provided to ensure maximum flexibility to model users.



- Open the spread after you have saved. Be sure that you are selecting source and destinations. Even though the name already has this specified, the name is only labeling it, not assigning it.
- You can add multiple destinations to each production type.
- These selections *Apply* automatically to save the changes.

Cattle > Cattle Example



Swine is not a source in this spread from cattle to cattle, therefore it is empty.

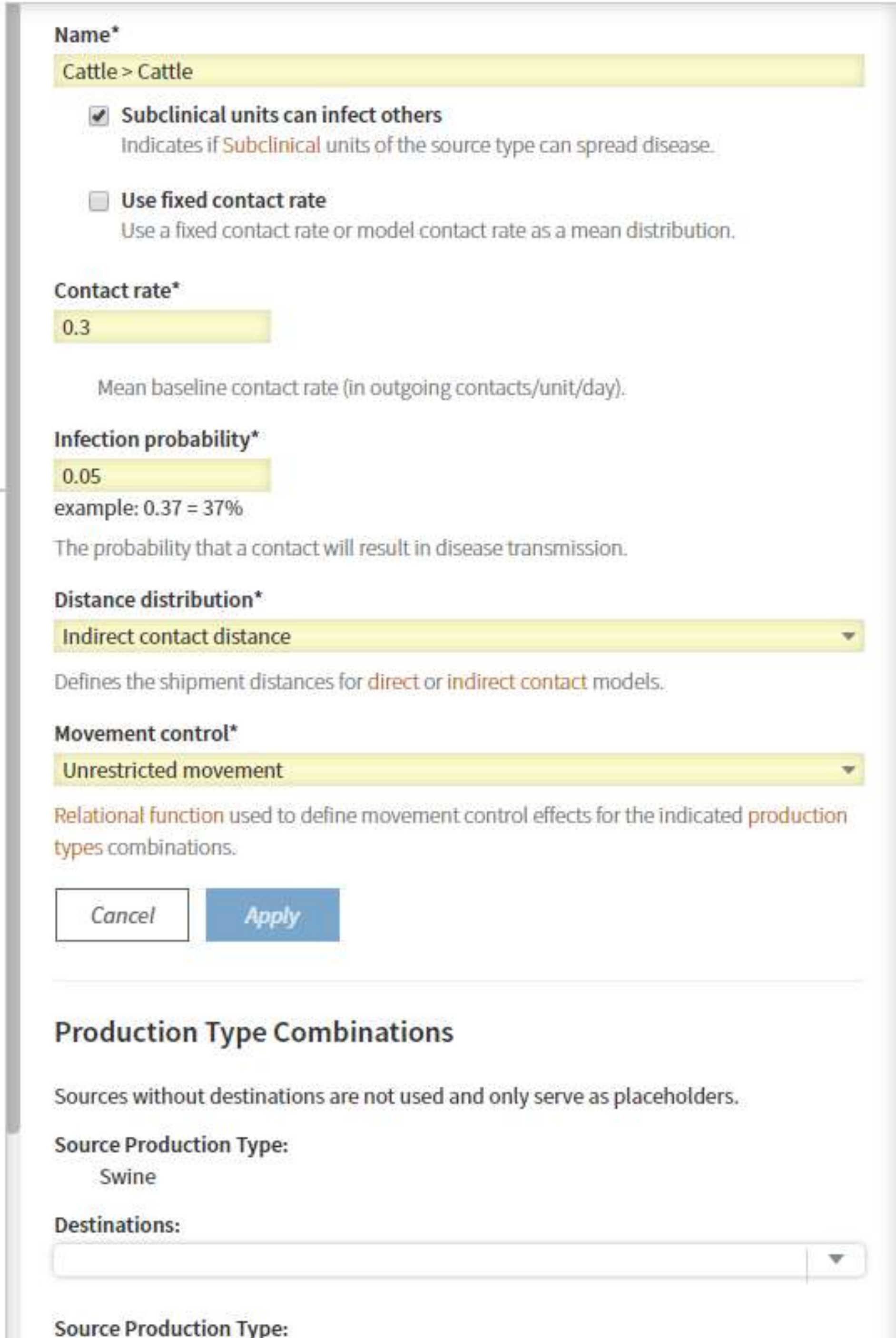
Indirect Spread

Disease can indirectly spread in many ways. Disease agents can spread by movement of animals, people, farm equipment, and vehicles. Within ADSM, indirect spread is modeled similar to direct spread, considering the same potential parameters of contact rate, infection probability, distance, and movement control.

Contact rates between production types can be calculated for each time unit (e.g., daily), or they can use a fixed contact rate throughout the disease simulation period.

When applying values to these parameters, you consider the likelihood of indirect contacts from production type-to-production type.

For each susceptible unit, ADSM stochastically calculates a number of outgoing shipments using a pdf.



Infection probability in *ADSM*

You must set the probability of infection within indirect disease spread. This is the probability that a contact will result in disease transmission. This can also be thought of as the likelihood of an effective contact.

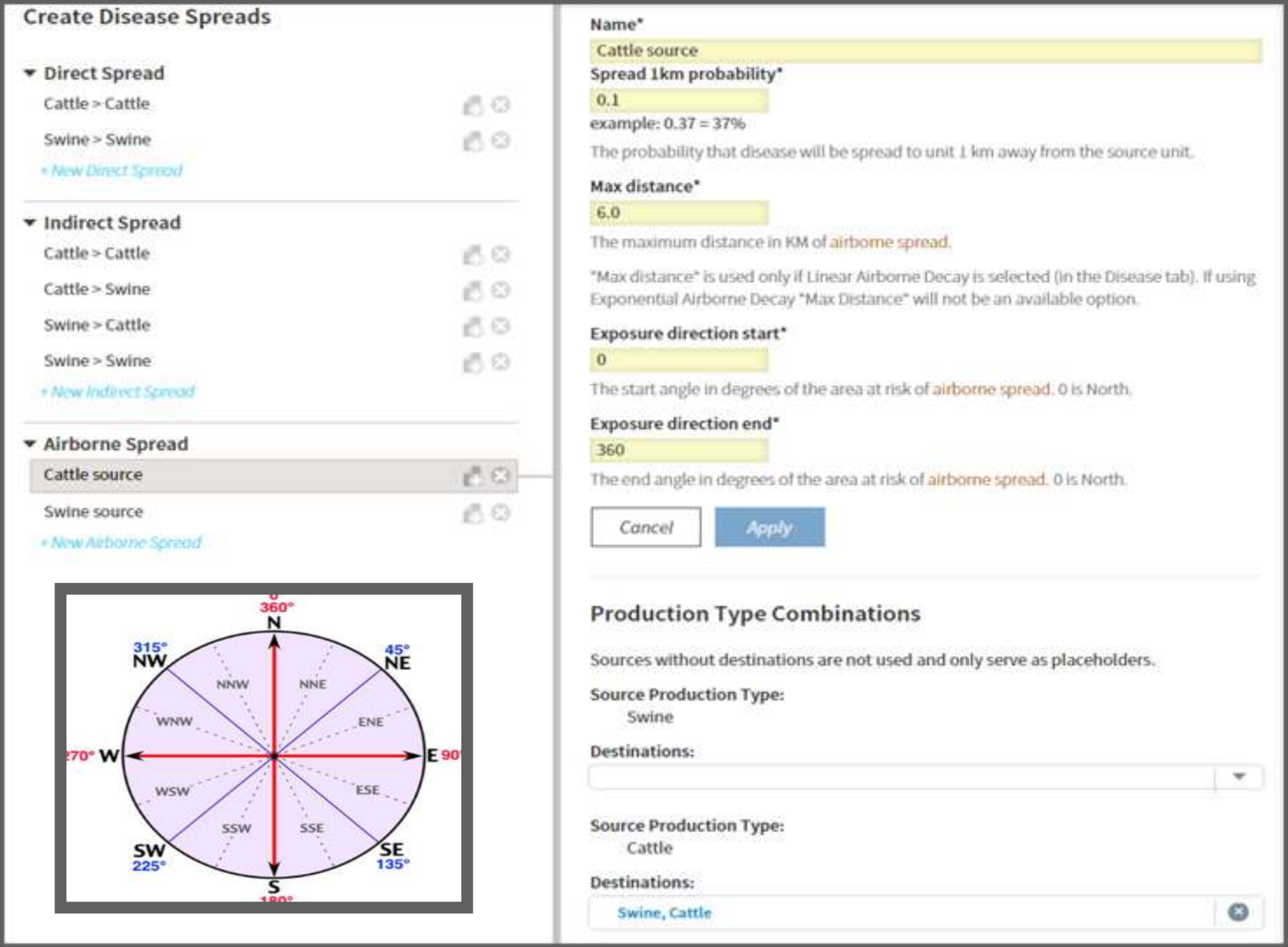
Airborne spread is the process of spreading a disease agent through the air.

If appropriate for the disease agent you want to model, ADSM can simulate airborne disease spread. Susceptible animals can become infected through inhalation of airborne biological droplets.

All species may pose varying likelihoods for emitting virus in the form of aerosols. Additionally, susceptibility to air droplets also differs by production types.

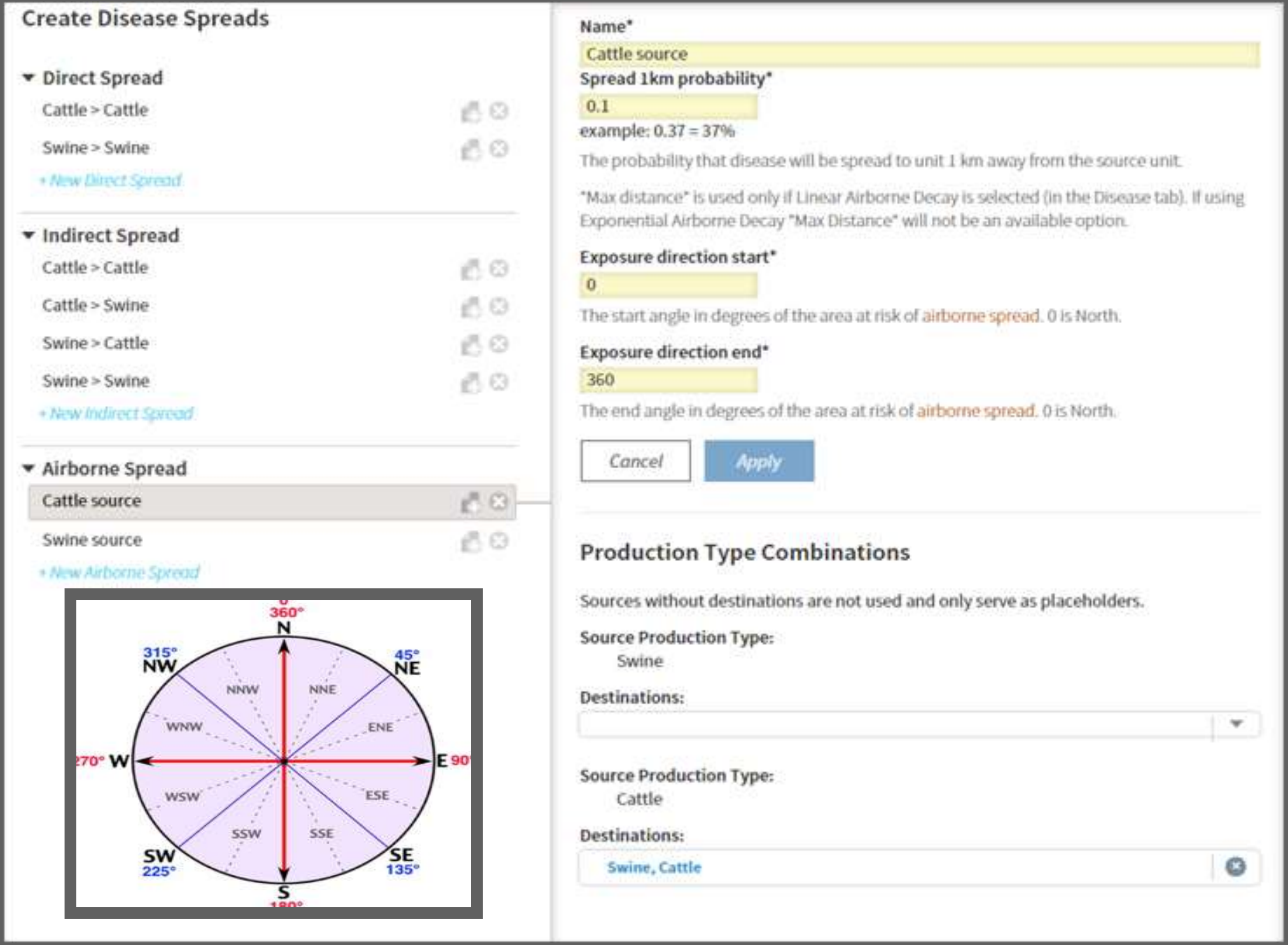
ADSM uses exponential or linear algorithms to simulate airborne disease spread.

Airborne Disease Spread – Linear Decay



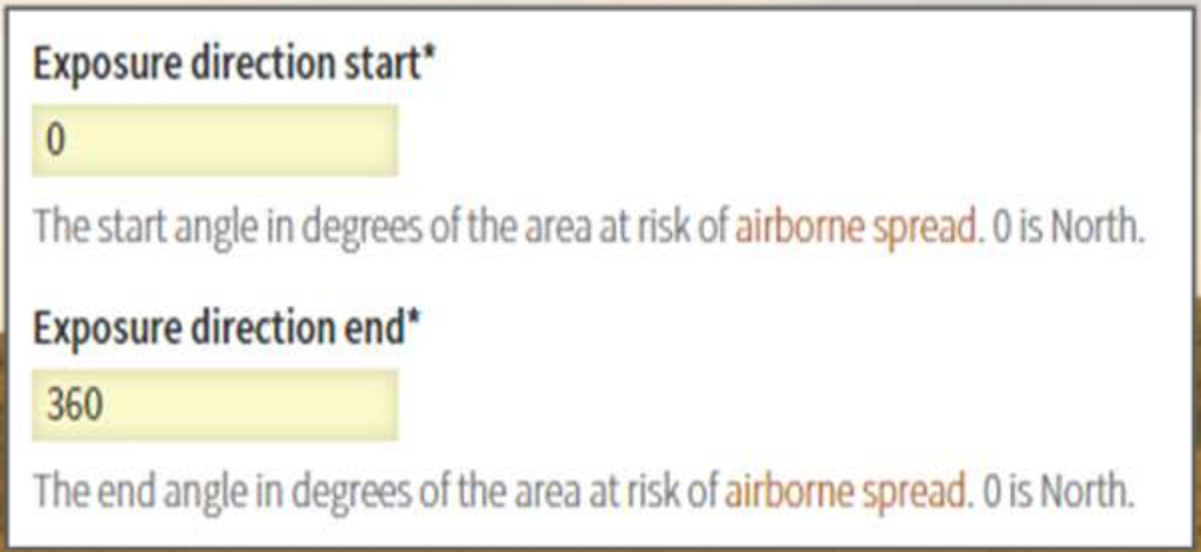
- The probability of airborne disease spread is calculated within a 1km area of the farm, with a maximum distance indicated.
- As in direct and indirect disease spread, the user determines the source and destination for disease spread (e.g., Swine > All).
- To set the spread at a constant probability within a certain area, select "all probable production types" in the Destinations field.

Airborne Disease Spread – Exponential Decay



- The probability of airborne disease spread is calculated within a 1km area of the farm.
- As in direct and indirect disease spread, the user determines the source and destination for disease spread (i.e. Swine > All).
- To set the spread at a constant probability within a certain area, select “all probable production types” in the Destinations field.

Airborne Disease Spread – Wind Direction



Exposure direction start*

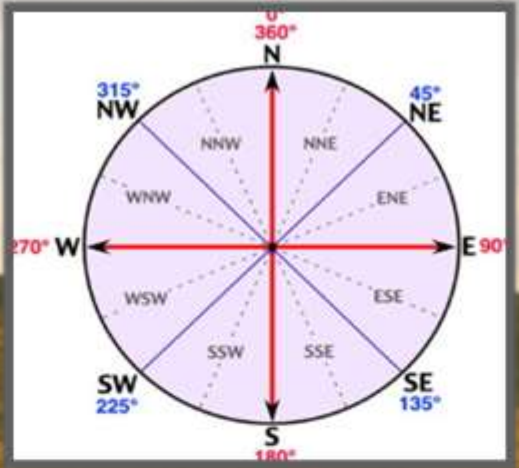
0

The start angle in degrees of the area at risk of airborne spread. 0 is North.

Exposure direction end*

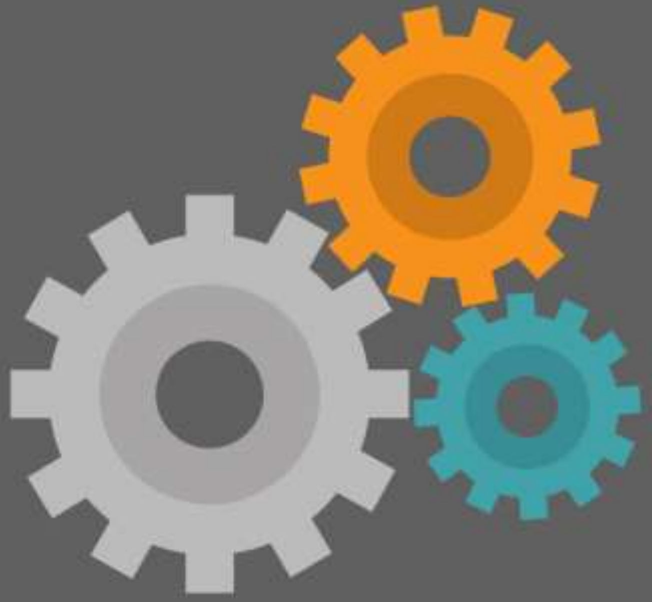
360

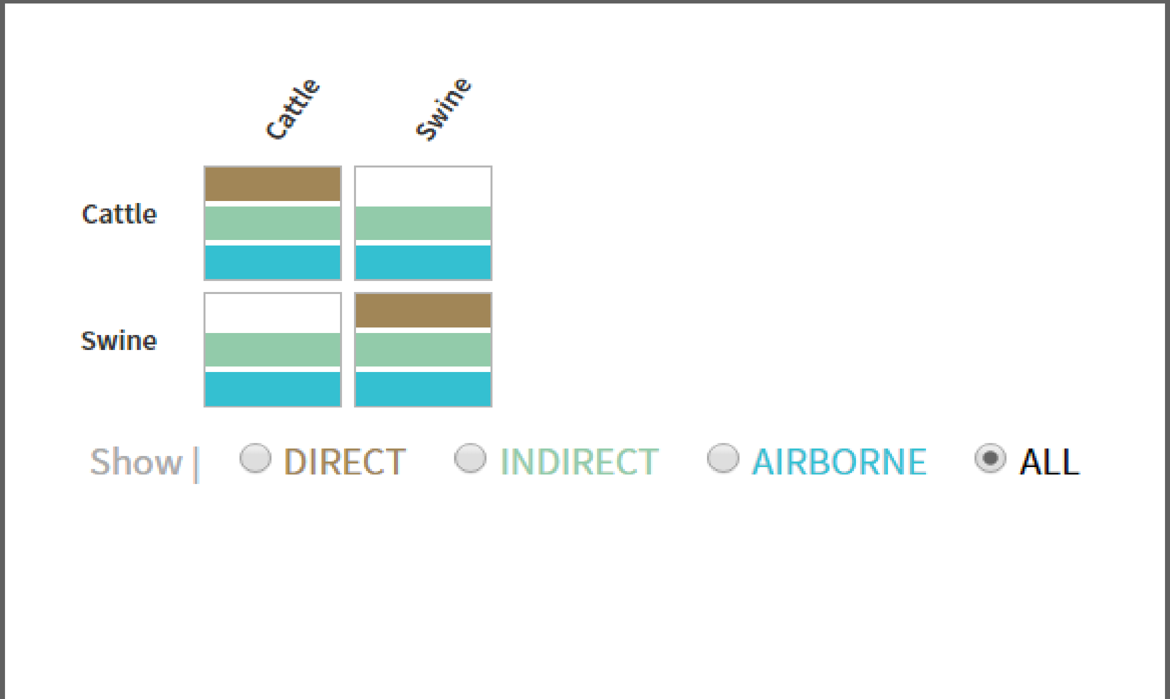
The end angle in degrees of the area at risk of airborne spread. 0 is North.



To adequately describe airborne transmission, ADSM allows you to enter the directionality of the spread. In this image, we have set our exposure direction to begin at 0 degrees (North) and to end at 360 degrees. This allows a full rotational effect to mimic local area spread. If a directional wind is more appropriate, this can be applied as well.

Review and Confirm





ADSM provides a review step for easy visualization of the methods of contact and disease spread between production types.

You can use the contact method matrix to see a summary of the connections between production types that were parameterized in the model.

How many possible spread options are there?

Number of production types (2)

x

Number of production types (2)

x

Spread methods (3)

=

12 possible spread options for a simple example!

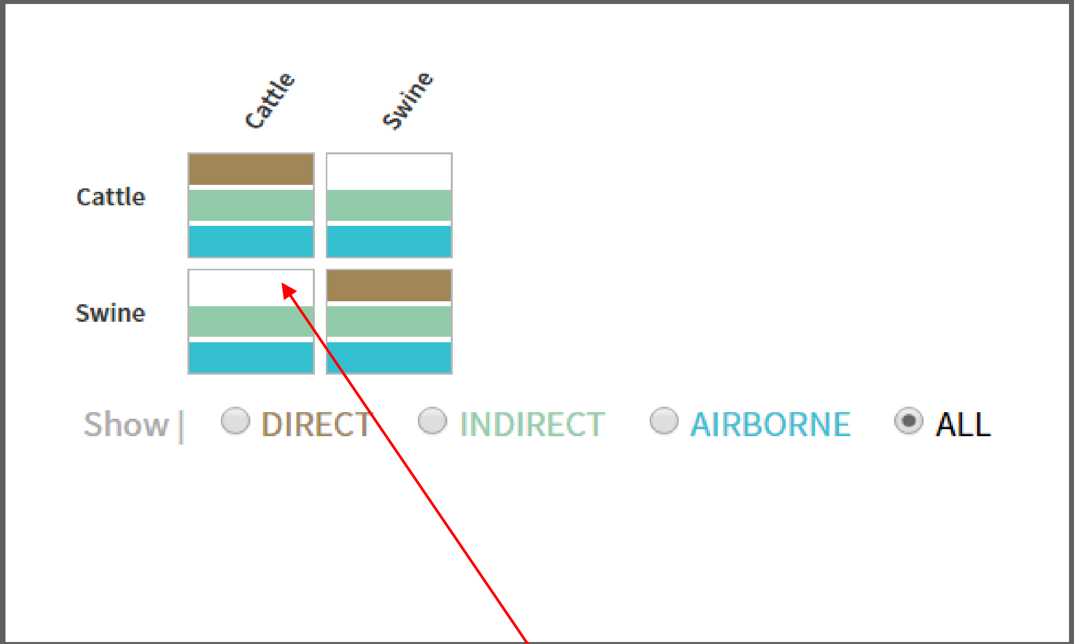
Review Disease Spread

Brown represents direct contact

Green represents indirect contact

Blue represents airborne spread

White indicates that no spread has been assigned



Every row is a source and every column is a destination.

If a correction is needed, you can return to a specific parameter block by clicking on it.

With more production types, the interaction become much more complex. Here is a complex example.

Number of production types (12)

X

Number of production types (12)

X

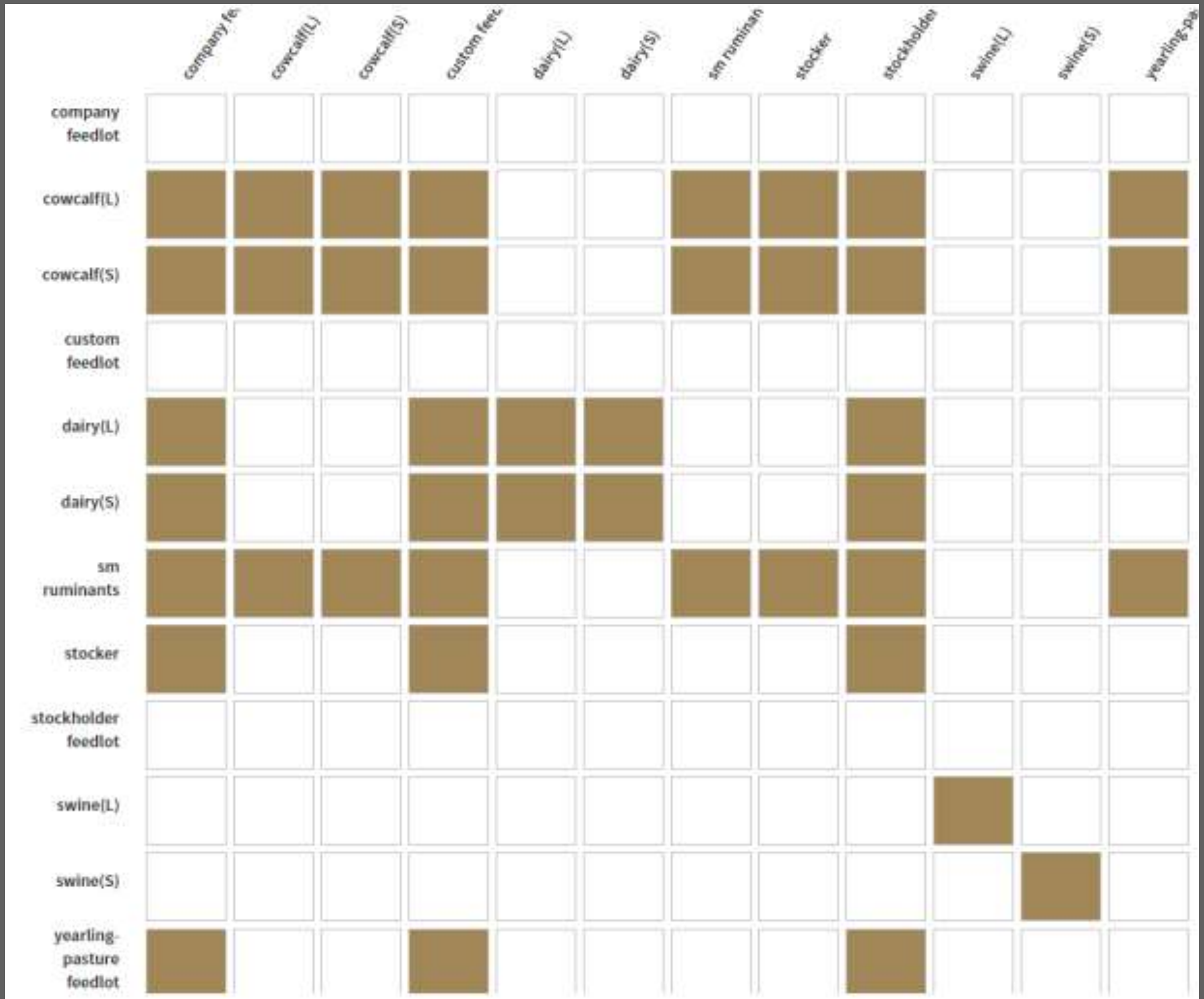
Spread methods (3)

=

432 possible spread possibilities

In this view, only direct spread is showing.

The white space allows you to see if you have failed to select a Production Type Combination in the Disease Spread tab.



Review Disease Spread

If any disease contact combinations are missing……

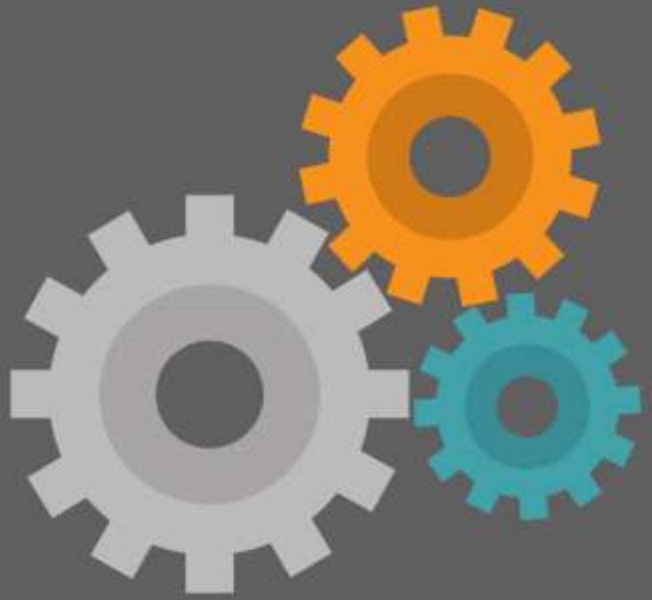
Go back to the individual disease spread option and add it in with the probability of disease spread for that combination.

Summary

In this training we have covered Production type specific disease and transmission parameters. This training also included the definition of how one production type (source) is connected to another production type (destination).

NAHMS Archives – Judy Rodriguez

What’s Next



Parameters related to control measures will be covered in the next training.

Join the flock!
Learn more about ADSM or try an example

ADSM is currently available at https://github.com/NAVADMC/ADSM/releases/latest

Try the sample scenario
https://github.com/NAVADMC/ADSM/wiki/A-Quick-Start-Guide:-Running-the-sample-scenario

Read the wiki pages link
https://github.com/NAVADMC/ADSM/wiki

What's Next?

Addition training materials will be posted at
http://navadmc.github.io/ADSM/

Training will include:

- **Overview**
- **Populations and Production Types**
- **Getting Started**
- **Disease Parameters**
- **Control Parameters**
- **Output settings and Run**
- **Results**
- **Verification and Validation**
- **Vaccination Strategy**
- **Administration**

The outcome of an ADSM simulation (as with any computer simulation model) depends heavily on the quality of the scenario input parameters; the assumptions of the modeler who created the scenario; and the capabilities and limitations of the model framework itself. The utility of disease models like those created with ADSM critically depends on input and interpretation of experts familiar with the behavior of disease within populations, and with the limitations, assumptions, and output of the model. While ADSM is available as a service to animal health communities, the ADSM team does not necessarily endorse results obtained with the ADSM application or any conclusions drawn from such results. Note that the parameters provided in the Sample Scenario are simple examples to clarify concepts in the application. These parameters do not represent any real population or disease event.

Pinecroft Farms

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Photo credits

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