

# Animal Disease Spread Model

Defining Disease



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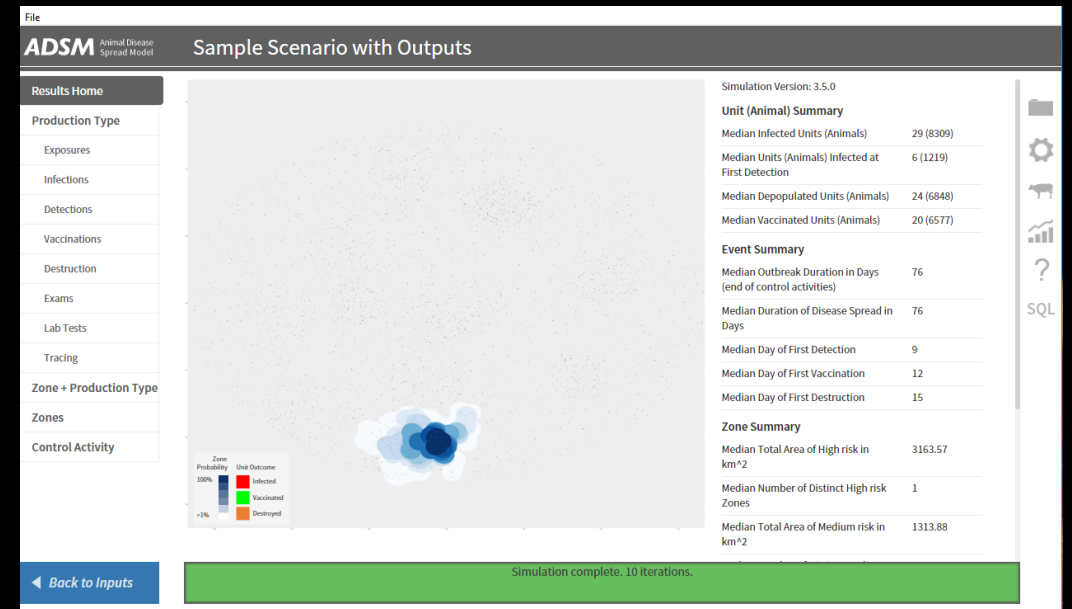
Disease Description

Disease Progression

Disease Spread

Review and Confirm

What's Next



# Document Conventions

The following conventions are used throughout the training modules:

**TRAINING MODULES** other than the one you are currently in will use all capital letters, bold face, italics and underline.

*Rhetorical questions* and *extra notes* will be in orange italics.

Conventions applying to the ADSM application are:

Navigation tabs on right and Admin panels on left are designated with an underline. Examples are Project Panel or Population Tab.

Items with an action on click, such as [Apply] Button or [Save As] icon are enclosed in square brackets.

*Parameter fields* (inputs) are in blue italics and *Variables* (outputs) are in green italics.

Navigation Tabs > *Parameter field* indicates to go to the given navigation tab to find the given field.

Hyperlinks appear in bright green type with underline <http://navadmc.github.io/ADSM/>

# Disease Description

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# Describing a disease in ADSM

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



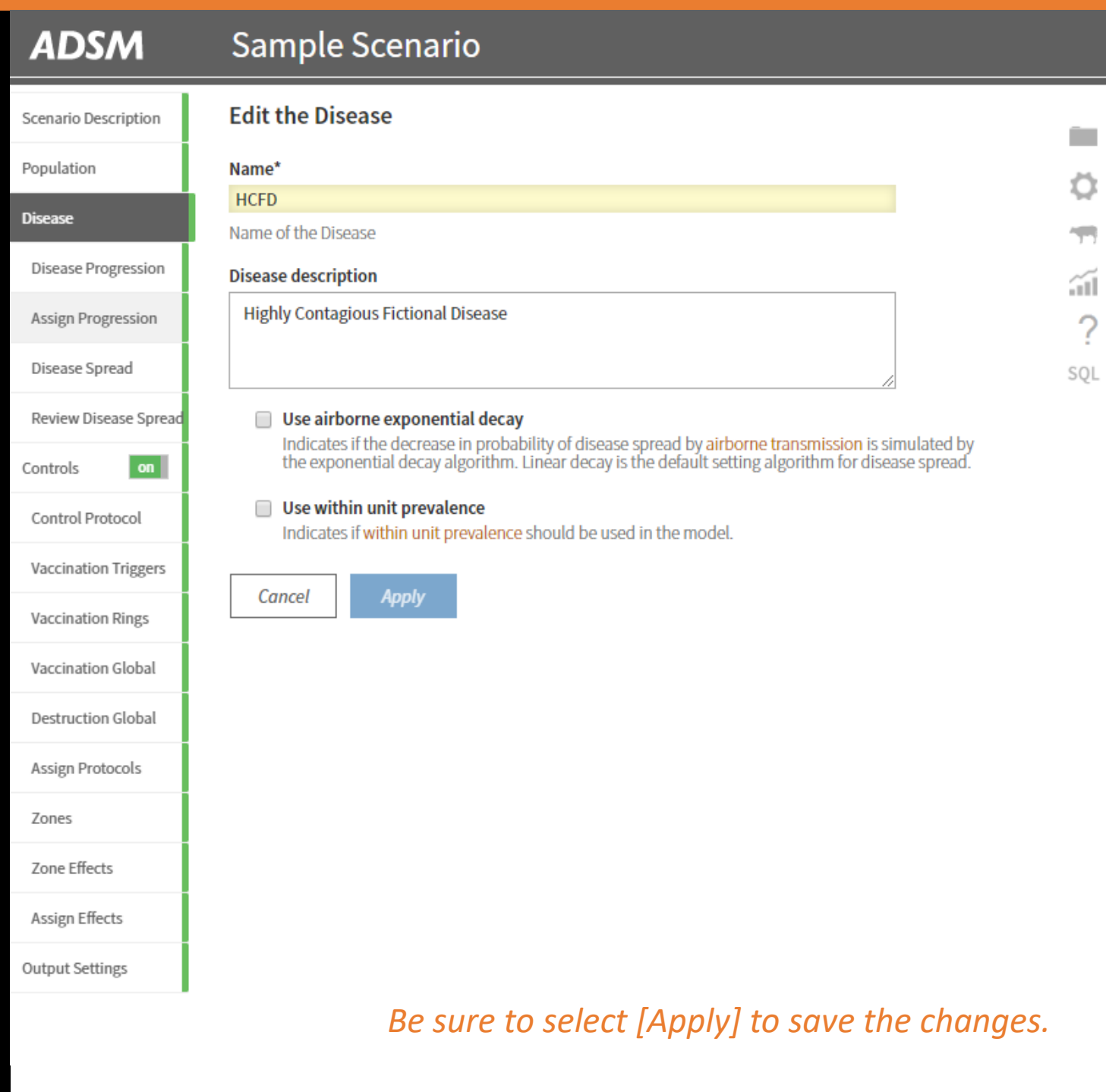
On the Disease tab, the name field must be completed to proceed to the next sections, as noted by the yellow highlight. It may also be helpful to provide a short description of the disease.

### 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 maximum distance of spread. As appropriate, you can select the option *airborne exponential decay* to be simulated instead.

### Within Unit Prevalence

You may prefer using *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.



**ADSM** Sample Scenario

Scenario Description

Population

**Disease**

Disease Progression

Assign Progression

Disease Spread

Review Disease Spread

Controls **on**

Control Protocol

Vaccination Triggers

Vaccination Rings

Vaccination Global

Destruction Global

Assign Protocols

Zones

Zone Effects

Assign Effects

Output Settings

### Edit the Disease

**Name\***

HCFD

Name of the Disease

**Disease description**

Highly Contagious Fictional Disease

Use airborne exponential decay  
Indicates if the decrease in probability of disease spread by airborne transmission is simulated by the exponential decay algorithm. Linear decay is the default setting algorithm for disease spread.

Use within unit prevalence  
Indicates if within unit prevalence should be used in the model.

Cancel Apply

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

# Disease Progression

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# 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 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 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.



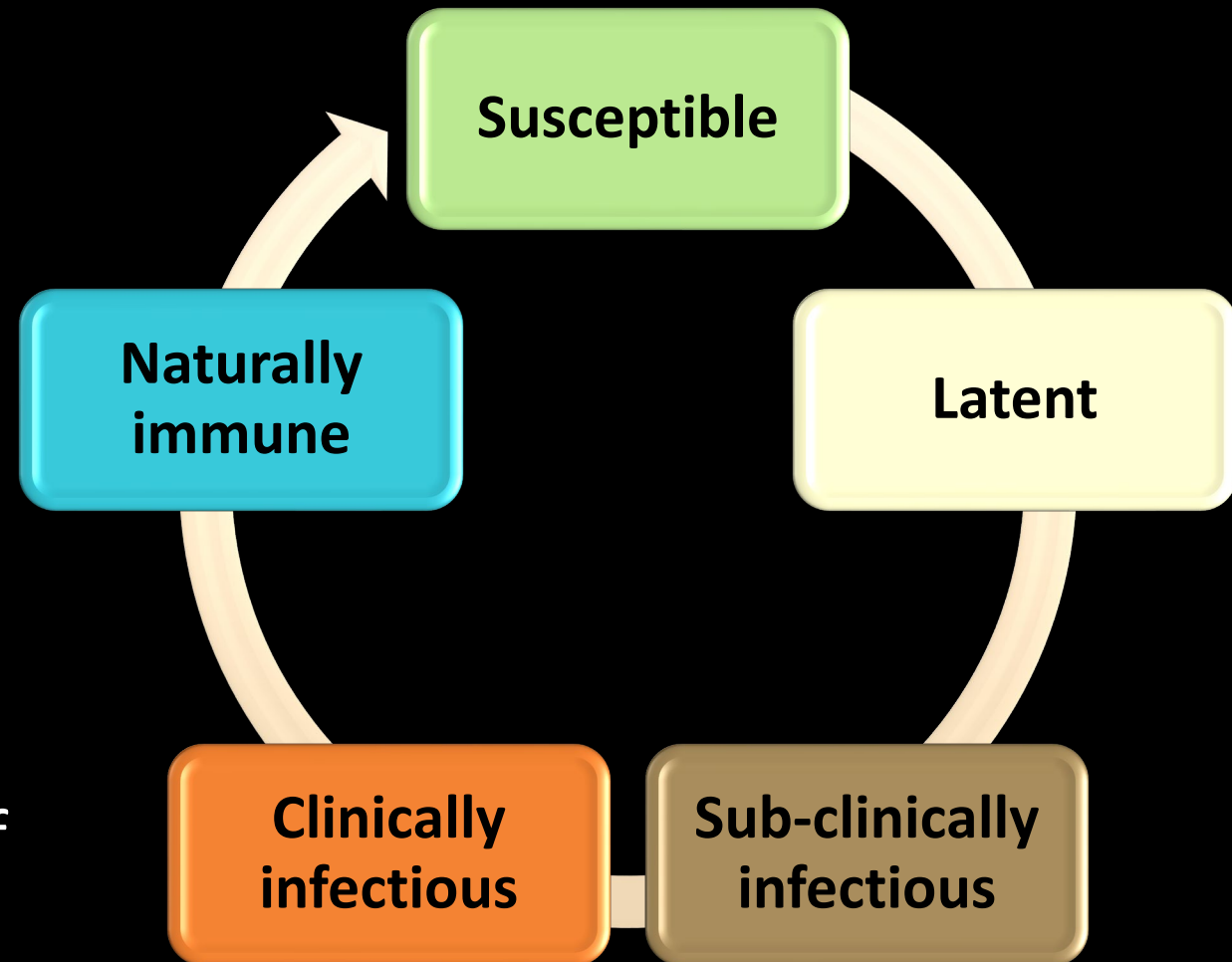
*All disease states in ADSM are considered at the farm or unit level.*



# 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 time period for each disease state. The number of days for the disease state is selected randomly for each new infection from the range of possible values within the function.



# Herd immunity

We define herd immunity 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.



- Scenario Description
- Population
- Disease
- Disease Progression**
- Assign Progression
- Disease Spread
- Review Disease Spread
- Controls on
- Control Protocol
- Vaccination Triggers
- Vaccination Rings
- Vaccination Global
- Destruction Global
- Assign Protocols
- Zones
- Zone Effects
- Assign Effects
- Output Settings

### Create Disease Progressions

▼ Disease Progression

- Cattle Reaction + ×
- Swine Reaction + ×
- [+ New Disease Progression](#)

**Name\***  
Cattle Reaction

Examples: Severe Progression, FMD Long Incubation

**Latent period\***  
Latent period - cattle

Defines the latent period for units of this production type.

**Subclinical period\***  
Subclinical period - Cattle

Defines the Subclinical period for units of this production type.

**Clinical period\***  
Clinical period - cattle

Defines the clinical period for units of this production type.

**Immune period\***  
Immune Period

Defines the natural immune period for units of this production type.

← Assign Relational Probability

**Name\***  
Latent period - cattle

**X axis units\***  
Days

**Notes**

**Equation type\***  
Triangular

**Min**  
0.0

**Mode**  
3.0

**Max**  
9.0

**Referenced by:**  
[Cattle Reaction](#)

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- 
- 
- 
- 
- SQL

ADSM requires you to define each stage of disease progression to fully capture the entire process of infection within a unit. Within each disease state, you may use unique probability density functions 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, infected units will progress into the immune state unless they are destroyed.

You may bypass a specific disease state and progress 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.

Name\*  
Cattle Reaction

Examples: Severe Progression, FMD Long Incubation

Latent period\*  
Latent period - cattle

Defines the latent period for units of this production type.

Subclinical period\*  
Zero Constant

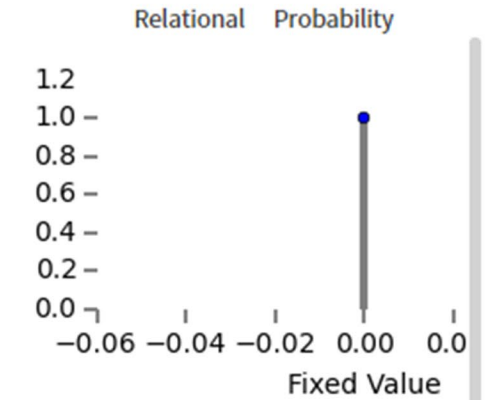
Defines the Subclinical period for units of this production type.

Clinical period\*  
Clinical period - cattle

Defines the clinical period for units of this production type.

Immune period\*  
Immune Period

Defines the natural immune period for units of this production type.



Click on the graph to download the highest possible resolution.

Name\*  
Zero Constant

X axis units\*  
Time Step Unit

Notes

Equation type\*  
Fixed Value

Mean

Std dev

Min

Mode  
0.0



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

**ADMS** Sample Scenario

Scenario Description

Population

Disease

Disease Progression

**Assign Progression**

Disease Spread

Review Disease Spread

Controls  on

**Assign Disease Progressions**

Swine

Swine Reaction

Cattle

Cattle Reaction

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Cattle Reaction

Swine Reaction

Apply

*Be sure to [Apply] to save the changes.*

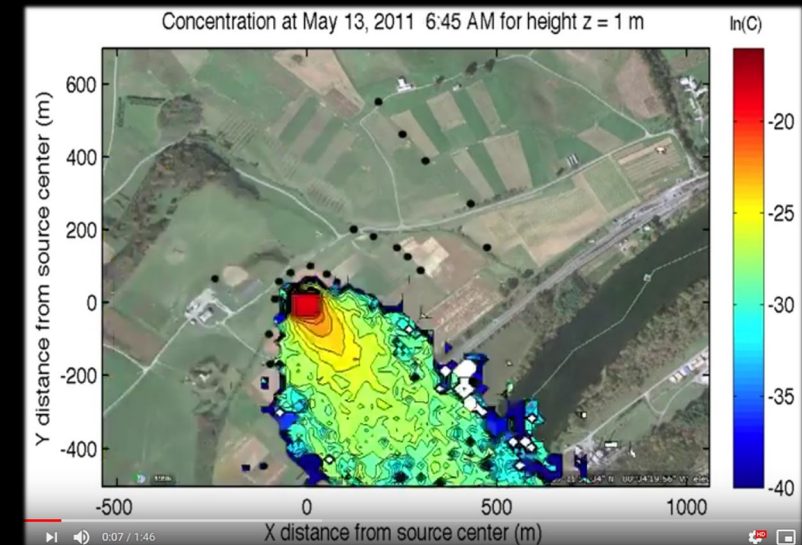
# Disease Spread

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ADSM simulates three types of contact that may spread disease:

Direct Contact  
Indirect Contact  
Airborne Contact





# 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 that can be drawn into lung alveoli. This type 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...

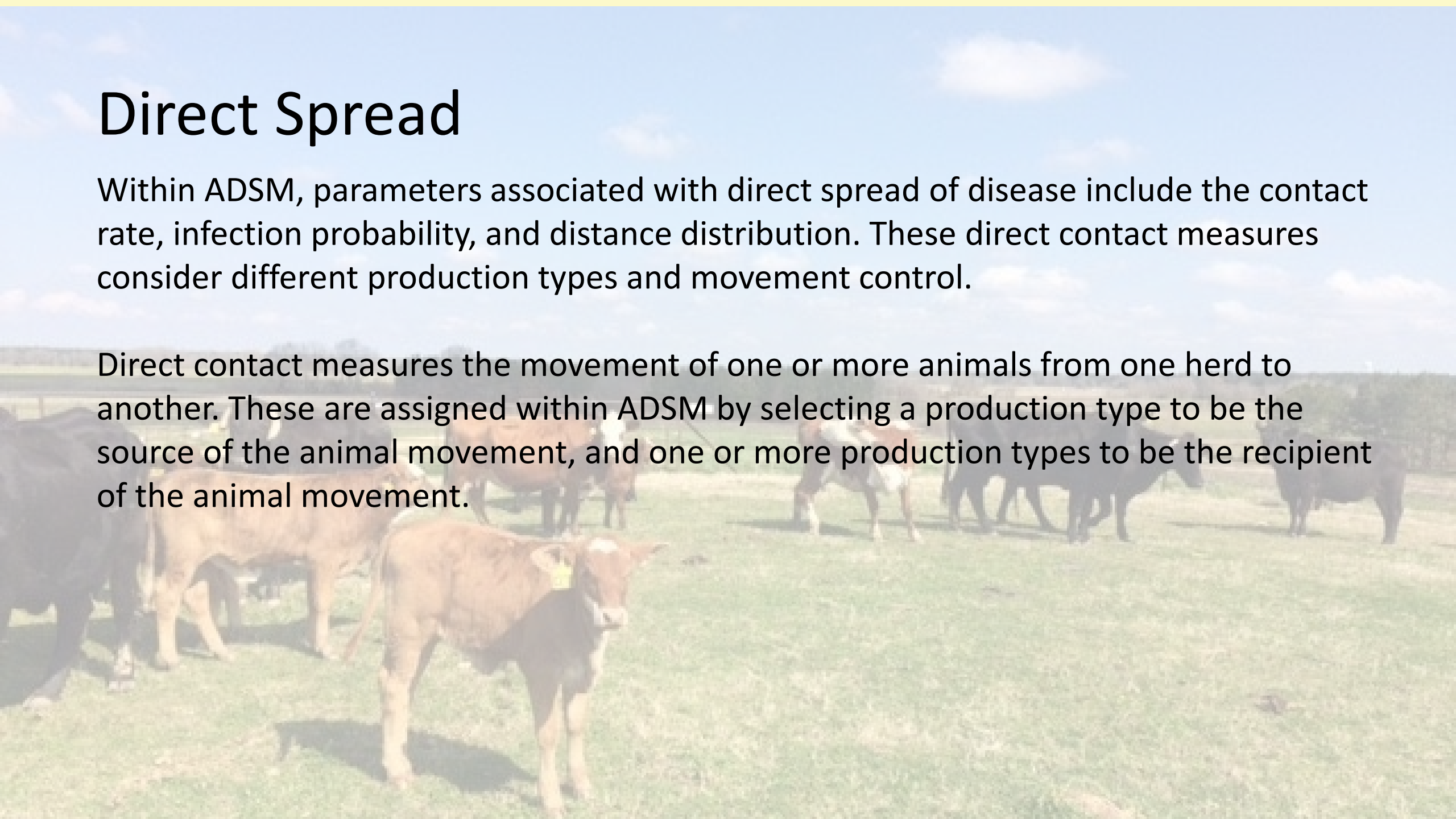
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- ⚙️ Latent cases can be a source of infection in direct disease spread.
- ⚙️ Simulation results are achieved at the herd level, not at individual level.
- ⚙️ Production types differ in their susceptibility to disease and can greatly influence the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

# Direct Spread

Within ADSM, parameters associated with direct spread of disease include 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.





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.

**Name\***  
Cattle > Cattle

**Latent units can infect others**  
Indicates if *latent* units of the source type can spread disease.

**Subclinical units can infect others**  
Indicates if *Subclinical* units of the source type can spread disease.

**Use fixed contact rate**  
Use a fixed contact rate or model contact rate as a mean distribution.

**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.

**Distance distribution\***  
Direct contact distance  
Defines the shipment distances for *direct or indirect contact models*.

**Movement control\***  
Unrestricted movement  
Relational function used to define movement control effects for the indicated *production types combinations*.

# Contact rate

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

- ☀ If within-unit prevalence is used, the function selected generates the infection probability.
- ☀ Alternately, another option is 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.

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

## 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. ADASM supports 22 general types of probability density functions (pdf).

Some distributions are more suitable to certain applications than others, but ADASM provides a selection to ensure maximum flexibility to model users.

*The red bar indicates that an edit has been made. Use [Apply] to save changes.*

**Name\***  
New

Latent units can infect others  
Indicates if **latent** units of the source type can spread disease.

Subclinical units can infect others  
Indicates if **Subclinical** units of the source type can spread disease.

Use fixed contact rate  
Use a fixed contact rate or model contact rate as a mean distribution.

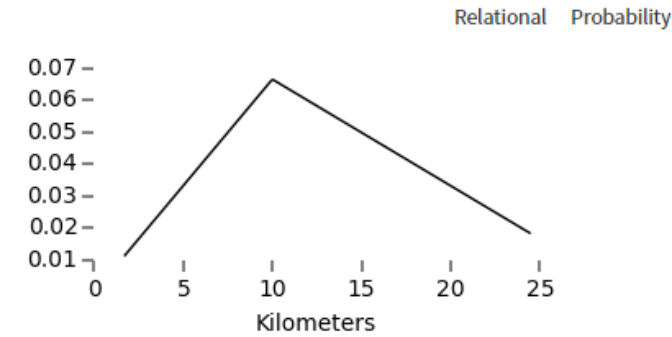
**Contact rate\***  
.4  
Mean baseline contact rate (in outgoing contacts/unit/day).

**Infection probability**  
.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 is NOT determined by within unit prevalence.

**Distance distribution\***  
Direct contact distance  
Defines the shipment distances for **direct** or **indirect contact** models.

**Movement control\***  
direct movement control  
Relational function used to define movement control effects for the indicated **production types** combinations.

**Production Type Combinations**  
Production Types Combinations represent how disease spreads between the different production types. The list will become available when the disease spread parameters above have been filled out and saved.



Click on the graph to download the highest possible resolution.

**Name\***  
Direct contact distance

**X axis units\***  
Kilometers

**Notes**

**Equation type\***  
Triangular

**Min**  
0.0

**Mode**  
10.0

**Max**  
30.0

Referenced by:  
[Missy](#)  
[missy2](#)  
[Cattle > Cattle](#)  
[Swine > Swine](#)

# Assign source of transmission to destination

## Cattle > Cattle Example

- ⚙️ 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 automatically save the changes.

**Production Type Combinations**

Sources without destinations are not used and only serve as placeholders.

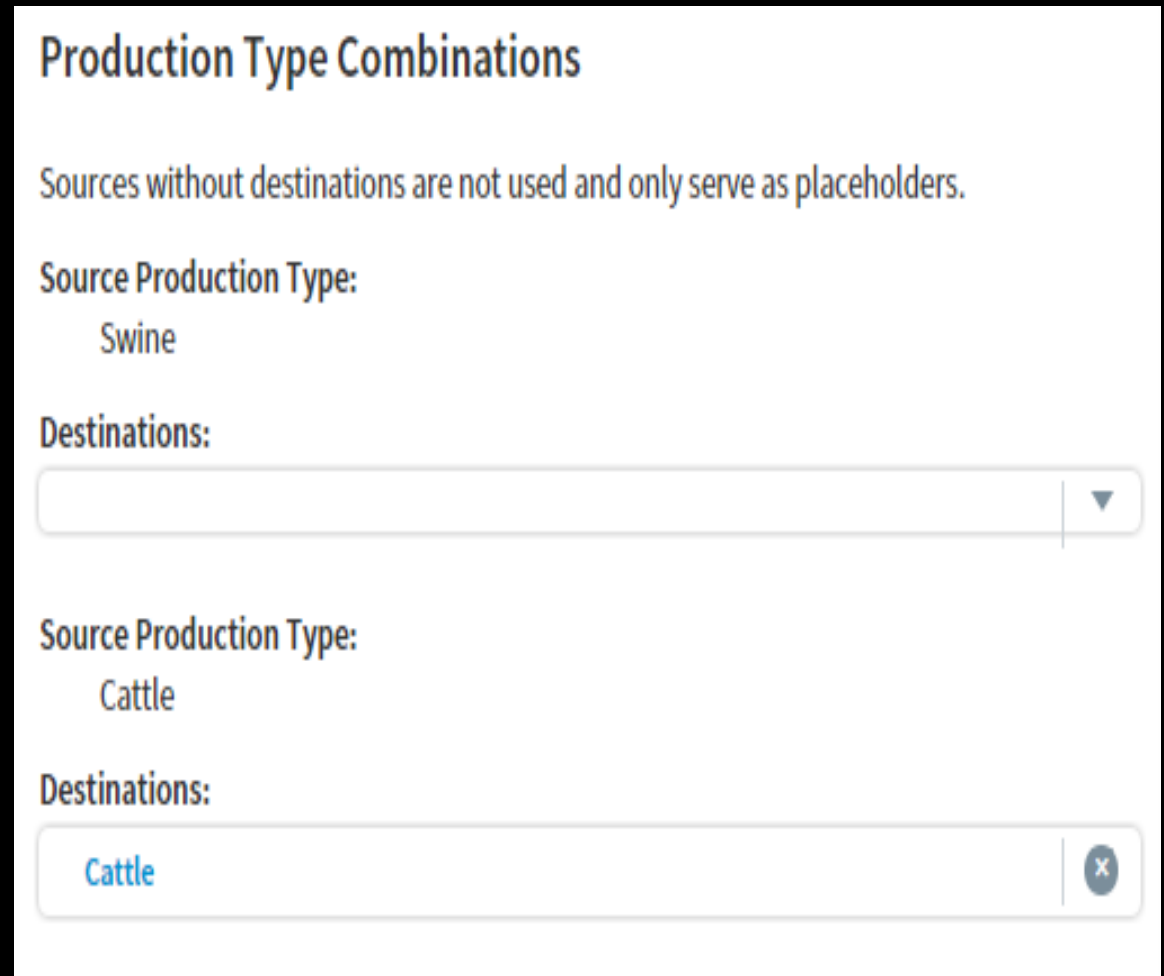
Source Production Type:  
Swine

Destinations:

Source Production Type:  
Cattle

Destinations:

Cattle



*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 like 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 the number of outgoing shipments using a pdf to represent **movement control**.



Image courtesy of [www.agweb.com](http://www.agweb.com)

Name\*

Cattle > Cattle

- Subclinical units can infect others  
Indicates if **Subclinical** units of the source type can spread disease.
- Use fixed contact rate  
Use a fixed contact rate or model contact rate as a mean distribution.

Contact rate\*

0.3

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

Infection probability\*

0.05

example:  $0.37 = 37\%$

The probability that a contact will result in disease transmission.

Distance distribution\*

Indirect contact distance

Defines the shipment distances for **direct** or **indirect contact** models.

Movement control\*

Unrestricted movement

**Relational function** used to define movement control effects for the indicated **product** types combinations.

Cancel

Apply

Production Type Combinations

Sources without destinations are not used and only serve as placeholders.

# Infection probability for indirect spread

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.

## Contact rate\*

0.2

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.



# Airborne disease spread

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.

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.





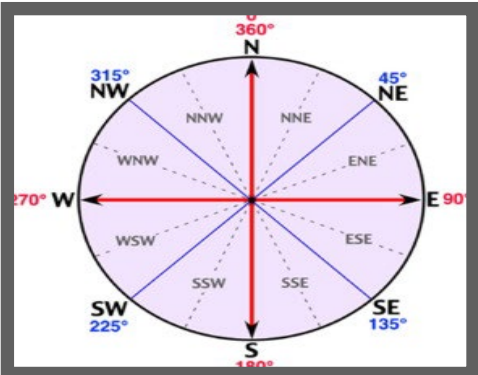
# Airborne Disease Spread – Linear Decay

**Create Disease Spreads**

▼ **Direct Spread**  
Cattle > Cattle  
Swine > Swine  
[+ New Direct Spread](#)

▼ **Indirect Spread**  
Cattle > Cattle  
Cattle > Swine  
Swine > Cattle  
Swine > Swine  
[+ New Indirect Spread](#)

▼ **Airborne Spread**  
Cattle source  
Swine source  
[+ New Airborne Spread](#)



**Name\***  
Cattle source

**Spread 1km probability\***  
0.1  
example: 0.37 = 37%  
The probability that disease will be spread to unit 1 km away from the source unit.

**Max distance\***  
6.0  
The maximum distance in KM of airborne spread.  
\*Max distance\* is used only if Linear Airborne Decay is selected (in the Disease tab). If using Exponential Airborne Decay \*Max Distance\* will not be an available option.

**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.

**Production Type Combinations**  
Sources without destinations are not used and only serve as placeholders.

Source Production Type:  
Swine

Destinations:

Source Production Type:  
Cattle

Destinations:  
Swine, Cattle



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, you determine the source and *destination* for disease spread (e.g., Swine > All).



To set the spread at a constant probability within the max distance, select all possible production types in the *destination*.

# Airborne Disease Spread – Exponential Decay

Create Disease Spreads

▼ Direct Spread

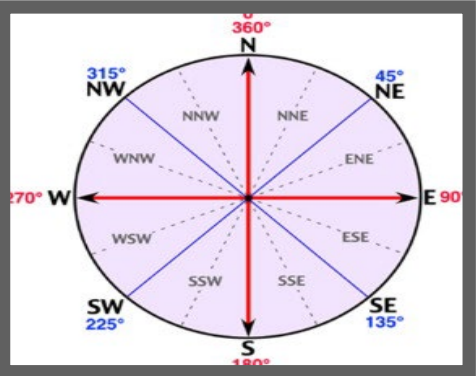
- Cattle > Cattle
- Swine > Swine
- + New Direct Spread

▼ Indirect Spread

- Cattle > Cattle
- Cattle > Swine
- Swine > Cattle
- Swine > Swine
- + New Indirect Spread

▼ Airborne Spread

- Cattle source
- Swine source
- + New Airborne Spread



Name\*  
Cattle source

Spread 1km probability\*  
0.1  
example: 0.37 = 37%  
The probability that disease will be spread to unit 1 km away from the source unit.  
"Max distance" is used only if Linear Airborne Decay is selected (in the Disease tab). If using Exponential Airborne Decay "Max Distance" will not be an available option.

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.

Cancel Apply

Production Type Combinations

Sources without destinations are not used and only serve as placeholders.

Source Production Type:  
Swine  
Destinations:

Source Production Type:  
Cattle  
Destinations:  
Swine, Cattle

⚙ 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 (e.g., Swine > All).

⚙ To set the spread at a constant probability within the max distance, select all possible production types in the *destination*.



# Airborne Disease Spread – Wind Direction

Exposure direction start\*

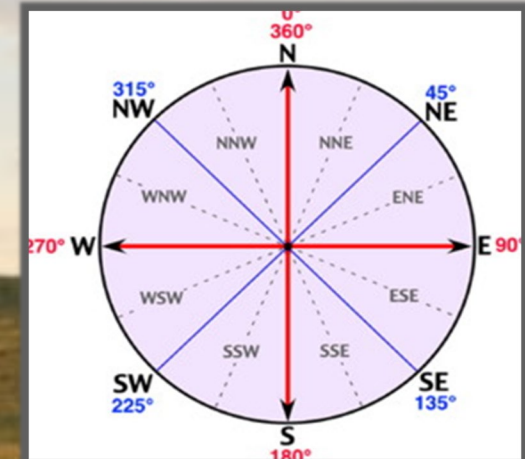
0

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 start* at 0 degrees (North) and to *exposure direction end* at 360 degrees. This example 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

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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 on the Review Disease Spread tab to see a summary of the connections between production types that were parameterized in the model. If you are not seeing colored blocks on this tab, you have failed to make a source to destination assignment.

*How many possible spread options are there?*

Number of production types (2)  
 x  
 Number of production types (2)  
 x  
 Spread methods (3)  
 =

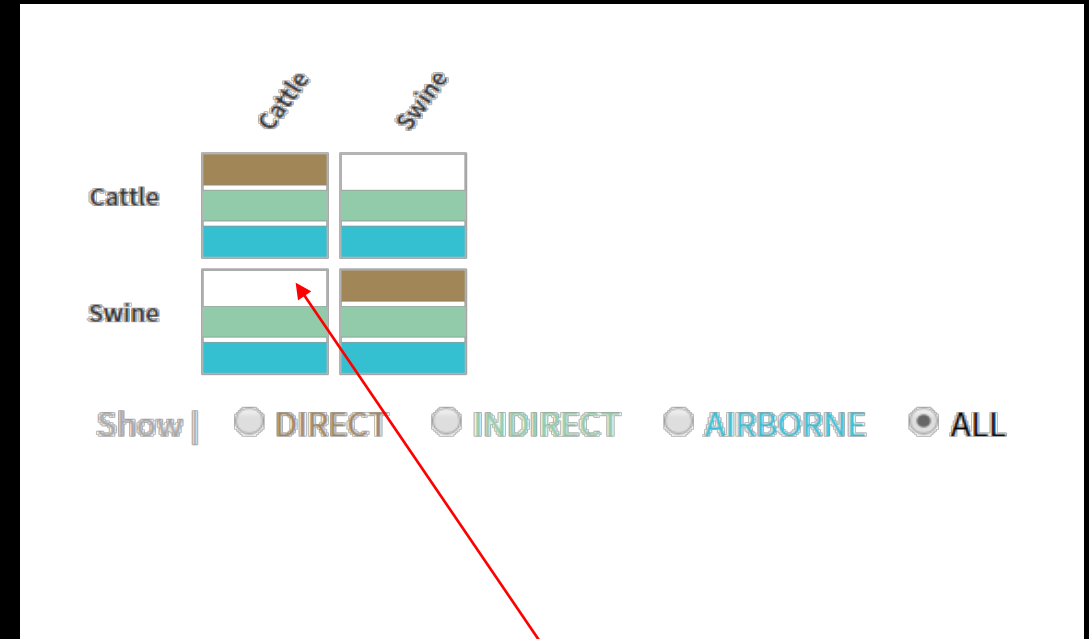
*12 possible spread options for a simple example!*

Brown represents [direct] contact

Green represents [indirect] contact

Blue represents [airborne] spread

White [All] 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 the block.



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

Number of production types (12)

X

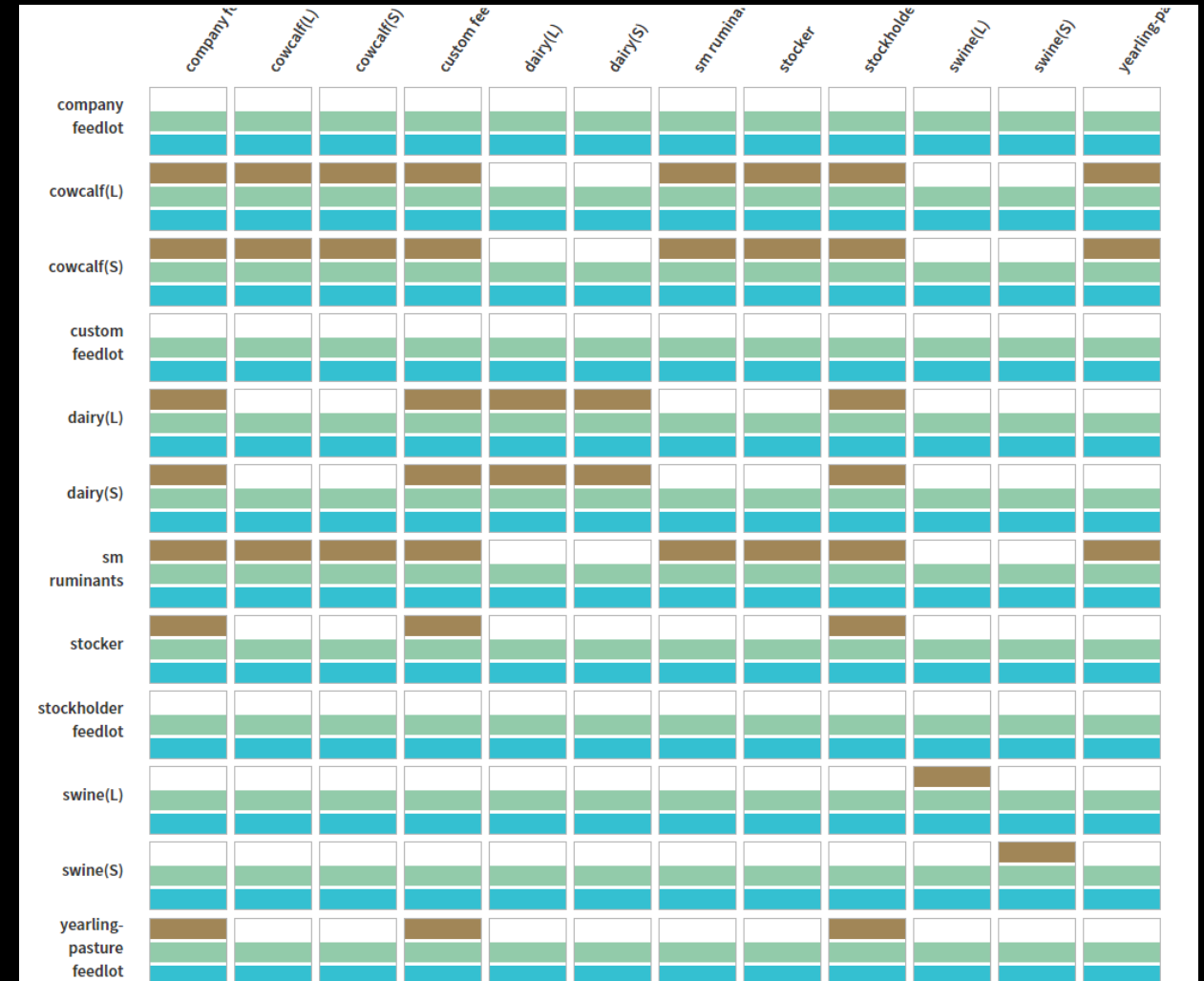
Number of production types (12)

X

Spread methods (3)

=

*432 possible spread possibilities*

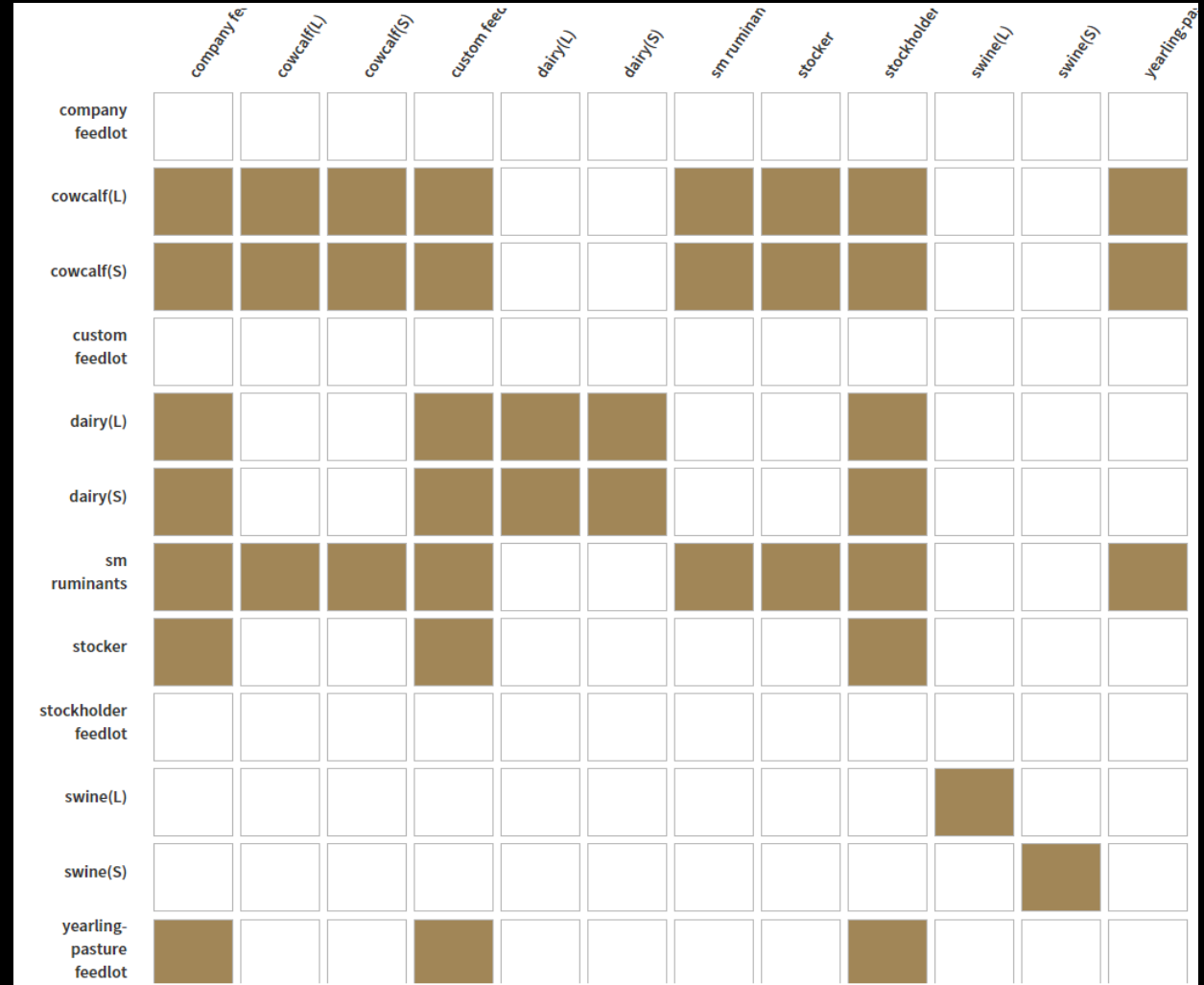


Show |  DIRECT  INDIRECT  AIRBORNE  ALL

In this view, only direct spread is showing.

The white space allows you to see if you have not selected a Production Type Combination in the Disease Spread tab.

The lack of a Production Type Combination may be intentional. In this example, Swine do not come into direct contact with Dairy.



Show |  DIRECT  INDIRECT  AIRBORNE  ALL

If any disease contact combinations are missing.....

Go back to the individual disease spread option and add it 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).



# What's Next

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A black bull with large, curved horns stands in a field of dry, yellowish-brown grass. The bull is facing the camera and appears to be walking or standing still. The background is a vast, open field with scattered patches of darker vegetation.

**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>

Training materials are posted at <http://navadmc.github.io/ADSM/>

Training includes:

Overview

Populations and Production Types

Getting Started

Defining Disease

Control Parameters

Output Settings and Run

Results

Detailed Evaluation of 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.*





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## Photo credits

Canva.com

Pinecroft Farms, Woodstock CT, Mariah Chapman

Ross Dynamics Lab (plume modeling)

[www.agweb.com](http://www.agweb.com)

Dr. Liesel Schneider

Dr. Danelle Bickett-Weddle

Ken Rager Photography

Judy Rodriguez – NAHMS Archives



**Animal Science**