Calculating probabilities of local-area and airborne disease spread in NAADSM *4*

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Abstract

This report describes the calculations used in *NAADSM* 4 for producing the daily probability of local-area and airborne transmission between an infectious source and susceptible recipient unit. These calculations have been implemented in a *Microsoft Excel* spreadsheet, useful for visualizing these probabilities as they will be applied in *NAADSM* 4-based models.

Document revision history

- 2012/10/01 – Initial public version released

Introduction

As described in the *NAADSM User's Guide* for version 4 (Reeves *et al.*, 2012), four values are required in order to parameterize local-area and airborne spread in *NAADSM* 4:

- The size (or the number of susceptible animals) of an arbitrarily selected susceptible unit
- The number of infectious (shedding) animals of an arbitrarily selected infectious unit
- The distance, in kilometers, between the two units
- The probability that, on any particular day, the infectious unit will infect the susceptible unit via local-area (or airborne) spread

From these parameters, the probability of local-area disease transmission from an infected unit in the model to any other unit in the population is extrapolated, based on the formulas discussed in the following sections.

We have developed a spreadsheet that implements the same calculations used in *NAADSM* to assist users to assist users in visualizing how the choice of these parameters affects the probabilities of disease transmission generated by *NAADSM* during a simulation.

Recall that the same formula (with independently established parameters) is used in *NAADSM* 4 to represent non-directional local-area and directional airborne transmission (Reeves *et al.*, 2012). For the sake of clarity, the remainder of this document refers only to local-area spread, but the same mathematics and concepts can be applied to airborne disease transmission.

The mathematics of local-area spread in *NAADSM* 4

In *NAADSM* 4, the daily probability of spread between a source and a recipient premises (designated *P* in the equations below) is calculated as shown in Equation 1:

$$P = e^{(-k((n_A \times p_A) \times n_B)/d_{AB})} \qquad \text{(Equation 1)}$$

Where:

n_A is the size of infectious farm *A*

p_A is the prevalence of infectious animals in source unit *A*

n_B is the herd size of susceptible unit *B*

d_{AB} is the distance between units *A* and *B*

k is a constant related to the infectiousness of the disease being modeled

Of these, the first four come directly from the simulation, for each pair of potential source and recipient units involved in local-area spread. The fifth value, k, is calculated from the parameters supplied by the user, as shown in Equation 2.

$$k = -1 \times \frac{\left[\ln(1 - P_{user}) \times d_{is}\right]}{\left(n_i \times n_s\right)} \qquad \text{(Equation 2)}$$

Where:

n_s is the size (or the number of susceptible animals) of an arbitrarily selected susceptible unit

n_i is the number of infectious (shedding) animals of an arbitrarily selected infectious unit

d is the distance between the two units

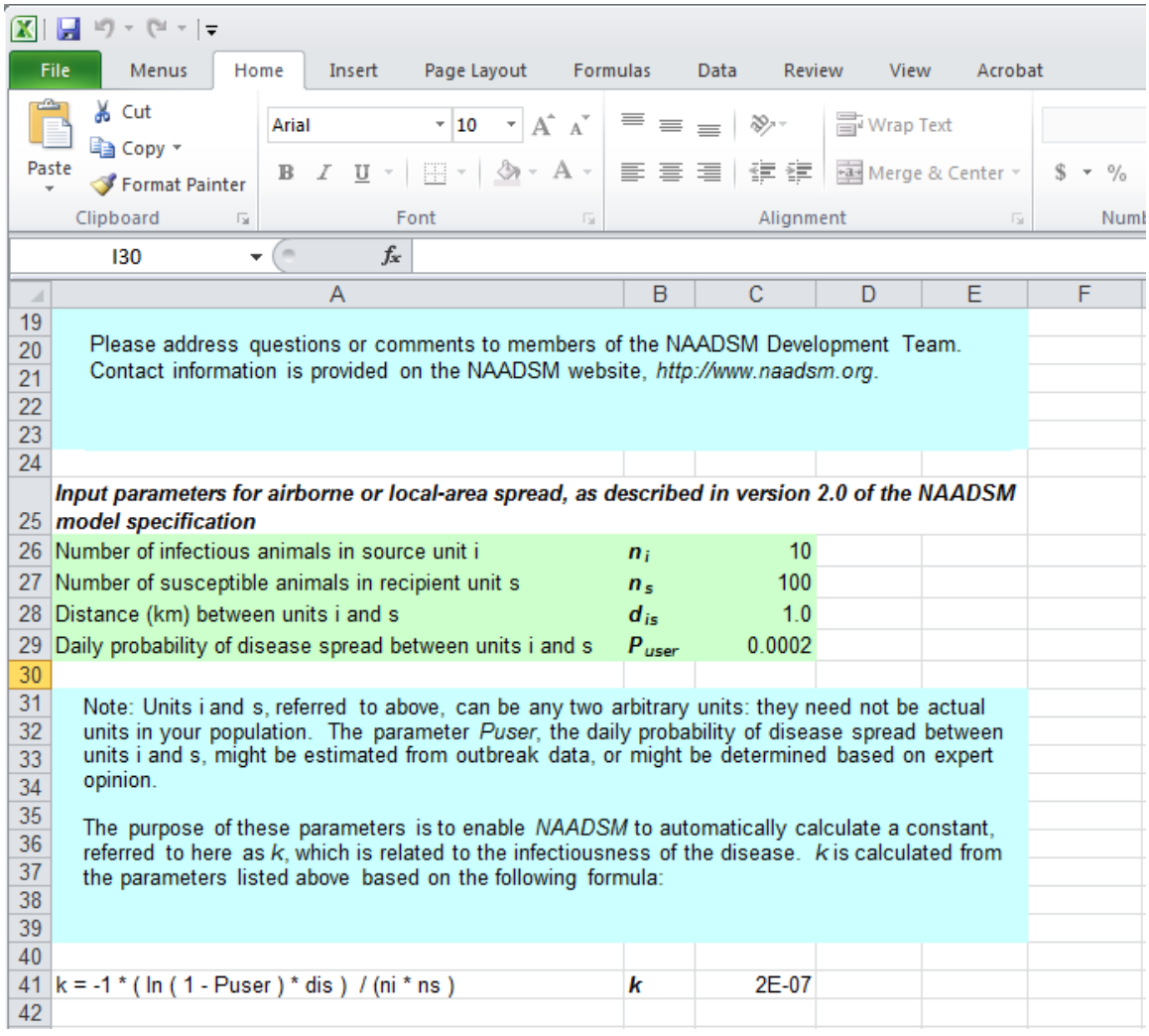
P_{user} is the user-supplied probability that, on any particular day, the infectious unit will infect the susceptible unit via local-area spread

Using the spreadsheet

The calculations described in the previous section have been implemented in a *Microsoft Excel* spreadsheet, available for download from <*http://www.naadsm.org/techpapers*>. The spreadsheet has two worksheets, named ***InputParameters*** and ***SpreadBetweenUnits***.

Figure 1 shows the ***InputParameters*** worksheet. In the green highlighted block are four cells in which the user can change the values of n_i, n_s, d_{is}, and P_{User}. (Note that the rest of this sheet has been locked to prevent accidental editing: editing is allowed only in these four cells.) These four parameters can be set and changed using the same values that would be entered in *NAADSM*. Below the input box is a line that shows the value of *k* calculated from these input parameters.

As these input parameters are changed, the calculations and charts on the second worksheet, named ***SpreadBetweenUnits***, will be updated (Figure 2). On this sheet, just as in the previous one, values in cells highlighted in green can be changed. The size and prevalence of the infectious unit can be set. Sizes can also be set for a variety of recipient units. The calculations shown in the table will be plotted in the graphs.



	A	B	C	D	E	F
19						
20	Please address questions or comments to members of the NAADSM Development Team.					
21	Contact information is provided on the NAADSM website, *http://www.naadsm.org*.					
22						
23						
24						
25	***Input parameters for airborne or local-area spread, as described in version 2.0 of the NAADSM model specification***					
26	Number of infectious animals in source unit i	n_i	10			
27	Number of susceptible animals in recipient unit s	n_s	100			
28	Distance (km) between units i and s	d_{is}	1.0			
29	Daily probability of disease spread between units i and s	P_{user}	0.0002			
30						
31	Note: Units i and s, referred to above, can be any two arbitrary units: they need not be actual					
32	units in your population. The parameter *Puser*, the daily probability of disease spread between					
33	units i and s, might be estimated from outbreak data, or might be determined based on expert					
34	opinion.					
35						
36	The purpose of these parameters is to enable *NAADSM* to automatically calculate a constant,					
37	referred to here as *k*, which is related to the infectiousness of the disease. *k* is calculated from					
38	the parameters listed above based on the following formula:					
39						
40						
41	k = -1 * (ln (1 - Puser) * dis) / (ni * ns)	***k***	2E-07			
42						

Figure 1. Input parameters in the local-area transmission spreadsheet, shown on the ***InputParameters*** sheet.

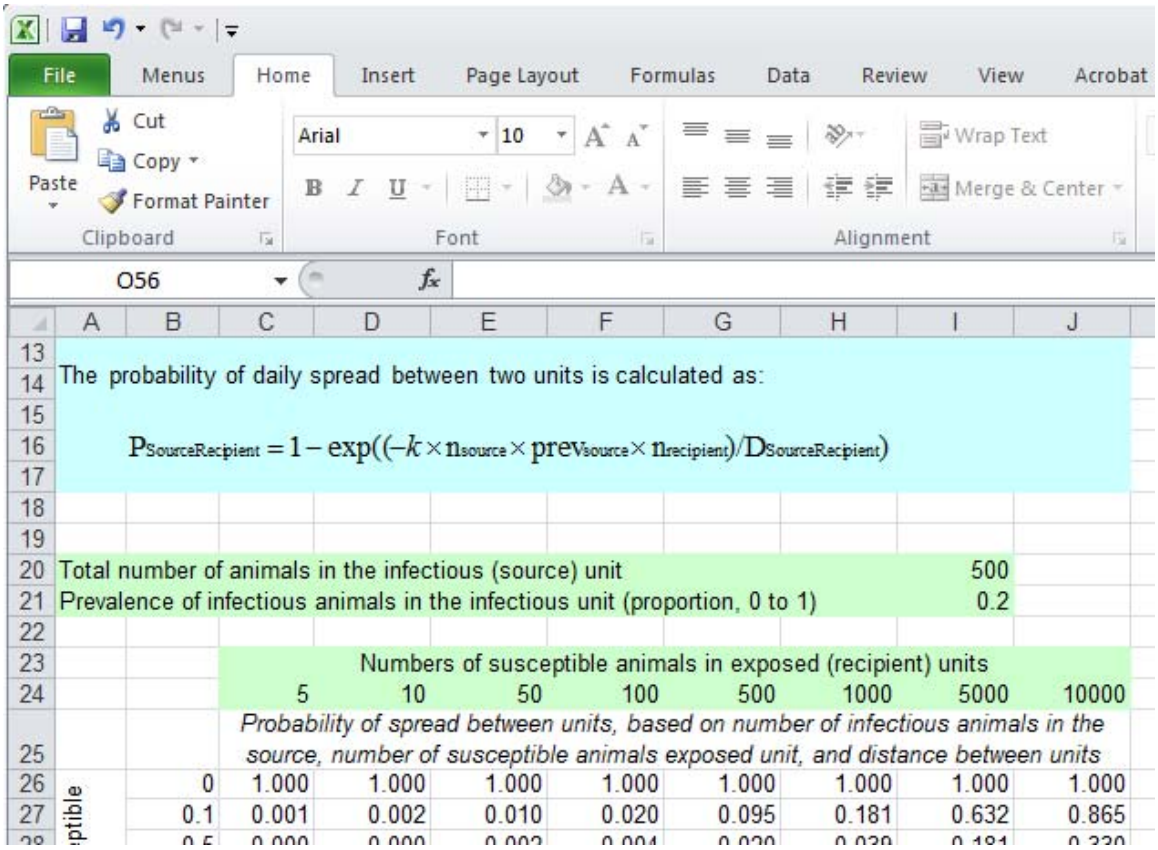


Figure 2. The ***SpreadBetweenUnits*** worksheet.

The plot on the left in the spreadsheet (shown in Figure 3) shows the probabilities of local-area transmission between an infectious source unit and a variety of susceptible recipient units, from 0 to 100 km apart. The plot on the right (not shown) represents the same data, plotted on a log scale.

Box 1. The probability of spread between two units located in the same place

Note that the probability of airborne spread between two units that occupy exactly the same location (*i.e.*, the distance between them is 0) is 1: under this condition, local-area transmission is guaranteed to take place. This represents the maximum probability of local-area transmission.

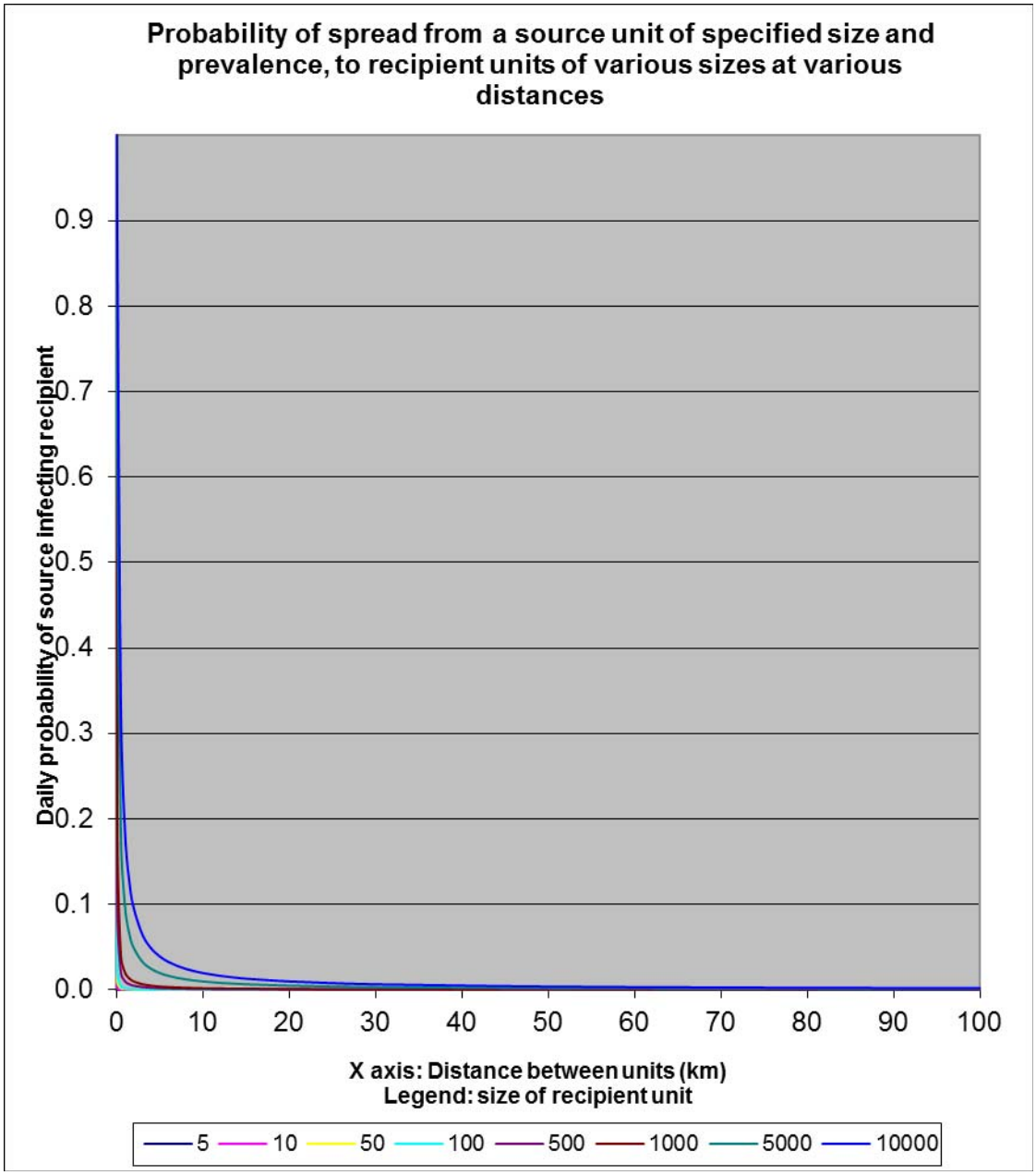


Figure 3. Plot of daily probabilities of local-area transmission between a source unit with 100 shedding animals (500 animals with 20% prevalence of infectious animals) and susceptible recipient units with 5 to 10000 animals. Input parameters that generated this plot are shown in Figures 1 and 2.

It is likely that most NAADSM users will have to rely on expert opinion in order to produce the required parameter P_{User}. This spreadsheet and the plots that it generates should be useful during the elicitation phase in the production of parameters for local-area and airborne spread.

Acknowledgements

We are grateful to Seth Dunipace, who originally suggested this approach for local-area and airborne spread in *NAADSM* 4. Some of the material used here has been adapted from the User's Guide for the North American Animal Disease Spread Model 4.0 (Reeves *et al.*, 2012), and is used under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike License, version 2.5. Please see <*http://creativecommons.org/licenses/by-nc-sa/2.5/*> for details.

References cited

Reeves, A., Hupalo, R., Patyk, K.A., and Hill, A.E., 2012. *User's Guide for the North American Animal Disease Spread Model 4.0*, 4th editio. Colorado State University, Fort Collins, Colorado, USA. Available from *http://www.naadsm.org/documentation*.