Appendix 7

Probabilistic model descriptions for orchard sprayers

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1. Introduction

The resident and bystander exposure models for orchard spray were derived in a different way to those for boom spraying. In this case statistical models could be fitted directly to the empirical data. The airborne spray and ground deposition models were slightly different, because of the different types of data available.

Finally, airborne spray and ground deposition outputs were adjusted for the drift reduction class of the nozzles using scenario-specific data.

2. Model for airborne spray

Airborne spray data were available at 7.5m for multiple scenarios (sprayer type/growth stage/age group of individual). For the selected scenario, values were randomly drawn from the corresponding dataset. Given this fixed distance volume, a statistical model was then used to derive spray levels at other distances. Dermal spray volume $y(x)$, as a % of the applied volume, is assumed to be an exponentially decreasing function of distance x. For the output $y(x)$ at distance x we assume

$$y(x) = \exp(b_1(x - 7.5) + \varepsilon),$$

where $\varepsilon_i \sim N(0, \tau^{-1})$ are independent error terms. In the simulation model, distances less than 5 m were set to 5 to minimise extrapolation errors. A Bayesian model was used to estimate the parameters. The model was fitted separately for cross flow data and axial data. Prior distributions were non-informative:

$$b_1 \sim N(0{,}10000); \quad \sigma \sim U(0, 100);$$

where $\sigma = \tau^{-0.5}$. 4 MCMC chains of 100000 iterations were run and gave essentially the same results (summaries shown in Table 1). The impact of the parameter uncertainty is not implemented within the Browse software. Further work would be necessary to assess its impact on the results.

Table 1: Parameter values for the orchard airborne spray models, fitted independently based on dermal data and inhalation factor data. In parentheses are the 95% credible intervals

	Dermal		IF	
Scenario	m1	sigma	m1	sigma
Axial Fan, full leaf, Child	-0.1486 (-0.157, -0.140)	0.2448 (0.154, 0.409)	-0.1486 (-0.157, -0.140)	0.2448 (0.154, 0.409)
Cross Flow, full leaf, Child				
Axial Fan, dormant, Child	-0.1382 (-0.145, -0.132)	0.1916 (0.121, 0.319)	-0.1382 (-0.145, -0.132)	0.1916 (0.121, 0.319)
Cross Flow, dormant, Child				

Axial Fan, Transition, Child	-0.1431 (-0.150, -0.136)	0.2027 (0.127, 0.338)	-0.1431 (-0.150, -0.136)	0.2027 (0.127, 0.338)
Cross Flow, Transition, Child				
Axial Fan, full leaf, Adult	-0.1412 (-0.150, -0.133)	0.2403 (0.151, 0.401)	-0.1341 (-0.143, -0.126)	0.2410 (0.151, 0.402)
Cross Flow, full leaf, Adult				
Axial Fan, dormant, Adult	-0.1308 (-0.138, -0.123)	0.2170 (0.136, 0.362)	-0.1252 (-0.134, -0.116)	0.2605 (0.164, 0.434)
Cross Flow, dormant, Adult				
Axial Fan, Transition, Adult	-0.1357 (-0.143, -0.128)	0.2144 (0.135, 0.358)	-0.1294 (-0.138, -0.121)	0.2389 (0.150, 0.399)
Cross Flow, Transition, Adult				

Notes:

- AxialFan and CrossFlow fans produce same distance model for a given population and growth stage.
- For children, dermal and inhalation factor outputs are identical

3. Model for deposition

For ground deposition the data used comprised a large number of deposition curves, more so than in the airborne spray case. It was therefore decided to model these curves directly (by making the focus on the model the distribution of the parameters, and allowing those to represent variability in the system). By contrast, the airborne spray model includes variability in the independent error terms $\varepsilon_i \sim N(0, \tau^{-1})$.

Deposition $y(x)$ as % of applied volume is assumed to be an exponentially decreasing function of distance x. For the ith observed deposition curve we assume

$$y_i(x) = \exp(b_{0i} + b_{1i}x + \varepsilon_i)$$

Where $\varepsilon_i \sim N(0, \tau^{-1})$ are independent error terms and the remaining parameters are random effects distributed as

$$b_{0i} \sim N(m_0, \tau_0^{-1}); \qquad b_{1i} \sim N(m_1, \tau_1^{-1})$$

which account for variations between realisations of the decay. A Bayesian model was used to estimate the parameters. The model was fitted separately for cross flow data and axial data. Prior distributions were non-informative:

$$m_0 \sim N(0{,}10000); \quad m_1 \sim N(0{,}10000); \quad \sigma \sim U(0, 100); \quad \sigma_0 \sim U(0, 100); \quad \sigma_1 \sim U(0, 100)$$

where $\sigma = \tau^{-0.5}, \sigma_0 = \tau_0^{-0.5}$, and $\sigma_1 = \tau_1^{-0.5}$. 5 MCMC chains of 100000 iterations were run and gave essentially the same results (summaries shown in tables 2 & 3 below). When using these equations to simulate deposition curves probabilistically in the BROWSE model, the noise term ε_i is generated independently from the normal distribution $\varepsilon_i \sim N(0, \tau^{-1})$ at each distance. This results in a non-smooth curve in any given run of the model, to more accurately reflect real deposition curves. This variation is in additional to the variation in the smooth deposition curves.

Table 2: Parameter estimates (and 95% credible intervals, showing uncertainty) using cross flow data:

Growth stage	m_0	m_1	σ_0	σ_1	σ
BBCH 0-60	3.6593 (3.58, 3.73)	-0.13528 (-0.145, -0.127)	0.28838 (0.224, 0.356)	0.02523 (0.011, 0.039)	0.53765 (0.522, 0.554)
BBCH 61-73	3.13665 (2.96, 3.31)	-0.13658 (-0.146, -0.127)	0.48152 (0.367, 0.636)	0.02507 (0.019, 0.034)	0.1778 (0.168, 0.188)
BBCH 74-92	3.1513 (3.05, 3.26)	-0.2079 (-0.235, -0.181)	0.6115 (0.538, 0.696)	0.1601 (0.141, 0.182)	0.2748 (0.267, 0.283)

Table 3: Parameter estimates (and 95% credible intervals, showing uncertainty) using axial data:

Growth stage	m_0	m_1	σ_0	σ_1	σ
BBCH 0-60	3.62798 (3.57, 3.69)	-0.13394 (-0.141, -0.128)	0.28803 (0.236, 0.342)	0.02081 (0.012, 0.030)	0.53726 (0.523, 0.552)
BBCH 61-73	3.27979 (3.15, 3.41)	-0.13513 (-0.142, -0.129)	0.45727 (0.369, 0.571)	0.02118 (0.017, 0.027)	0.17376 (0.166, 0.182)
BBCH 74-92	3.1761 (3.09, 3.26)	-0.1885 (-0.209, -0.168)	0.5443 (0.485, 0.611)	0.1423 (0.127, 0.159)	0.2729 (0.266, 0.280)

Figure 1 shows some example curves simulated from the fitted model. These illustrate how the model generates variation between random realisations of a scenario in a way that is consistent with random variation seen in the observed deposition curves.

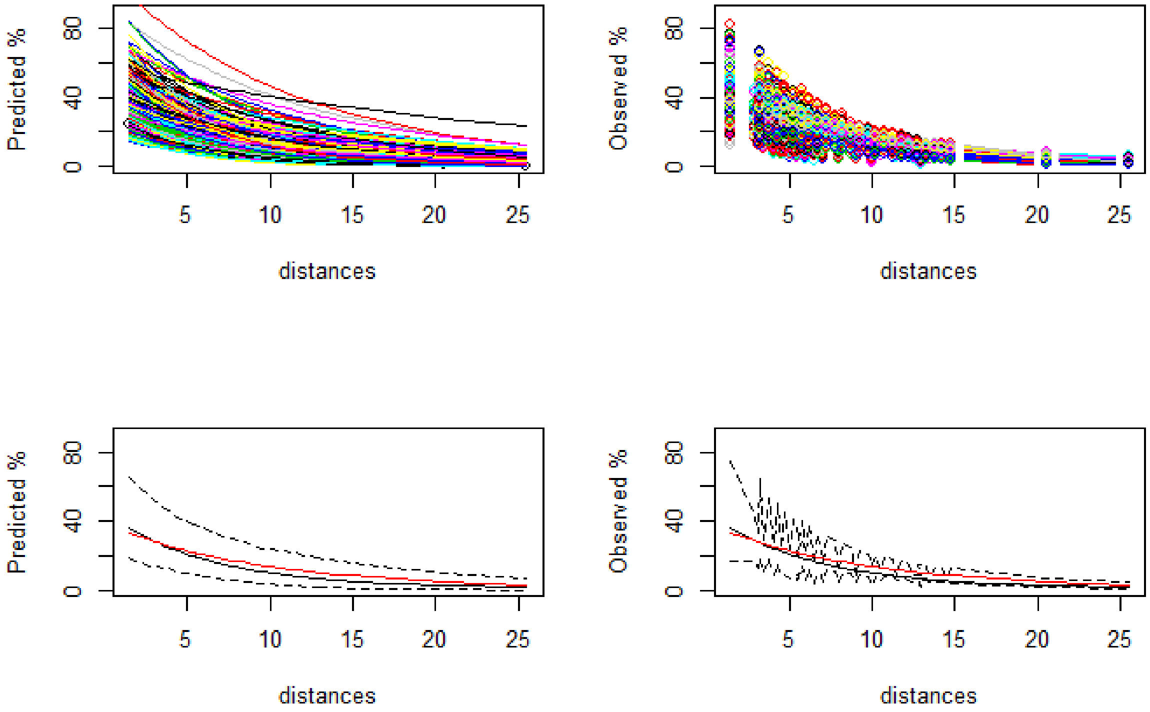

Figure 1: Simulated and observed curves (top panels). Mean and P2.5, P97.5 pointwise quantiles (bottom panels). Red line is fitted exponential curve from Excel. The jagged lines in the bottom-right panel reflect the unstable computations when using the data, due to large numbers of non-detects and unbalanced design.

4. Accounting for drift reduction

Separate data files were used to modify airborne and ground deposit data to account for drift reduction. For airborne spray, separate values were available for the following categories:

- Inhalation or dermal factors
- Adult and Child
- DRT classification DRT50 (50%), DRT75 (75%), DRT90 (90%), DRT95 (95%)
- Growth stages (Dormant, Transition, Full leaf)
- Sprayer type (Axial fan, crossflow)
- Distances 7.5, 10.5, 13.5, 16.5, 19.5, 22.5, 25.5, 28.5, 31.5, 34.5, 37.5 metres

For ground deposition, separate values were available for the following categories:

- DRT classification DRT50 (50%), DRT75 (75%), DRT90 (90%), DRT95 (95%)
- Growth stages (Dormant, Transition, Full leaf)
- Distances 3, 4, 5, 6, 7, 10, 13 metres

For distances other than those represented in the data, drift reduction percentage was calculated using linear interpolation. Below 7.5 metres or above 37.5 metres the drift reduction value of the appropriate distance (7.5 m or 37.5 m) was assumed.