Developments in bystander and resident exposure assessments

Clare Butler Ellis
Silsoe Spray Applications Unit
NIAB TAG

Developments in bystander and resident exposure assessments

- Background – the UK BREAM project
- Objectives of BROWSE work package 3
- Progress so far
- What we expect to achieve by the end of BROWSE

BREAM – rationale and background

- Public concern
- Recommendations of the Royal Commission on Environmental Pollution
- Weaknesses of current boom sprayer exposure assessment
  - Based on application parameters typical of the 1980s
  - Distance from the sprayer too great
  - Single pass of 12 m boom
  - Single ‘average’ value – no link to application/environmental parameters
  - Vapour drift not seen to be properly accounted for

BREAM objectives

- Develop a model of potential exposure from a **single application event** – ‘Bystander and Resident Exposure Assessment Model’
  - **Boom sprayers** only
  - Exposure to both **spray drift** and **vapour**
  - Consider one-off exposures as well as long-term or repeated exposures on bystanders
  - Consider surface deposition only on horizontal flat surfaces – model of transfer to human outside project scope
  - Base around defined **UK scenarios**
  - Take account of **variability**
- Obtain experimental data for model development
- Conduct field trials for model validation

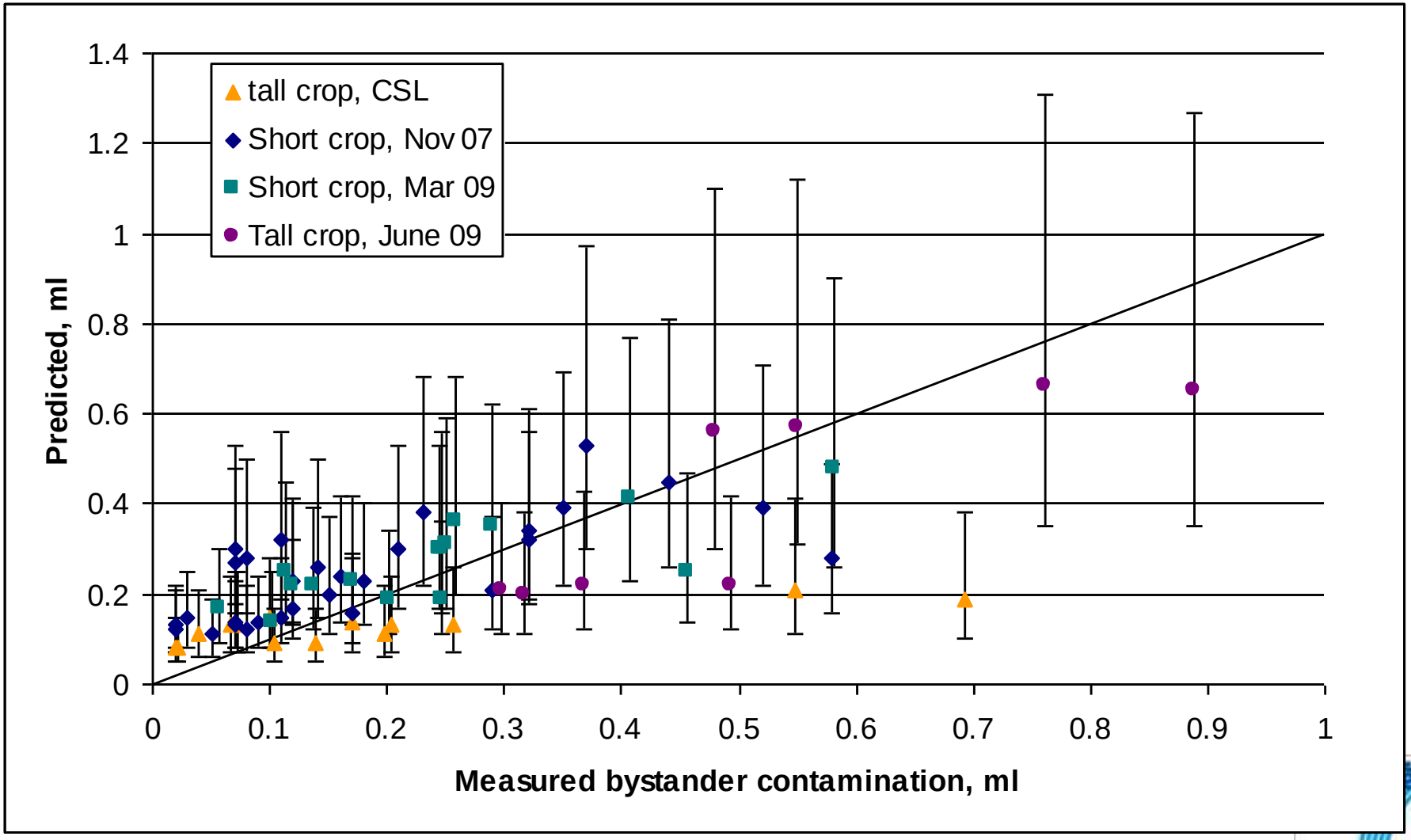
Summary of BREAM findings on vapour exposure:

- Huge uncertainty over emission of vapours from treated fields
  - No current model accurately predicts emissions under all circumstances
  - Further work needed
- Improvements in the current ‘model’ are possible by including realistic UK met information
- Proposed new model based on applied dose
- Need to recognise potential for high one-off exposures, particularly with high-dose chemicals

Summary of BREAM model of exposure to spray drift

- Model robust and well validated for conditions close to standard scenario
  - Flat fan ‘reference’ nozzle
  - Short crop and cut grass downwind
- More work needed
  - Adding more nozzles to the database
  - Improvements in simulating a taller crop and downwind vegetation
- Mean (or 75th percentiles) for standard scenarios significantly greater than current approach
- 95th percentile for high drift scenario more than an order of magnitude higher

BREAM - Comparison between measured and predicted bystander contamination

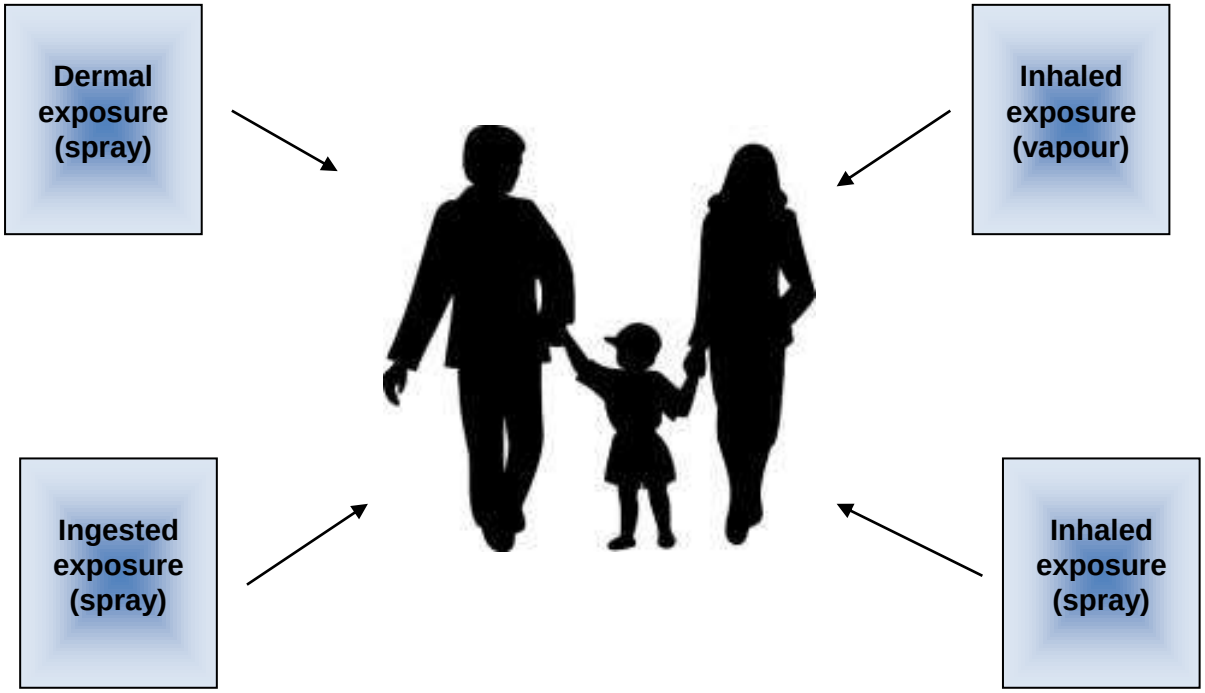


Error bars show 25th and 75th percentiles

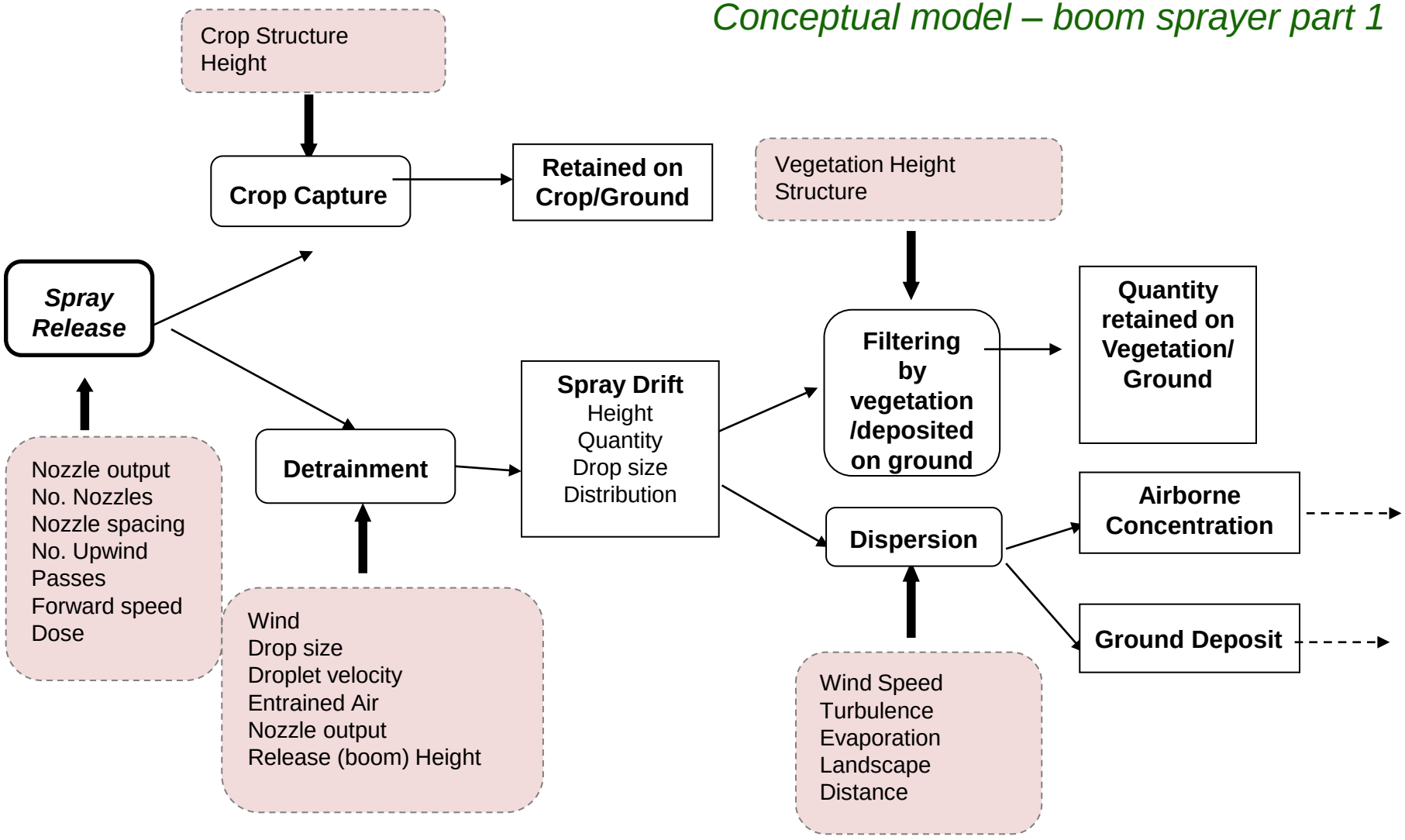
BROWSE priority scenarios:

- Spray
  - Boom sprayers
    - Field crops, amenity,
  - hand-held (downwards)
  - Broadcast air assisted
    - Orchards, fruit, hops, vines
- Vapour
  - Outdoor applications

Total exposure for bystanders and residents



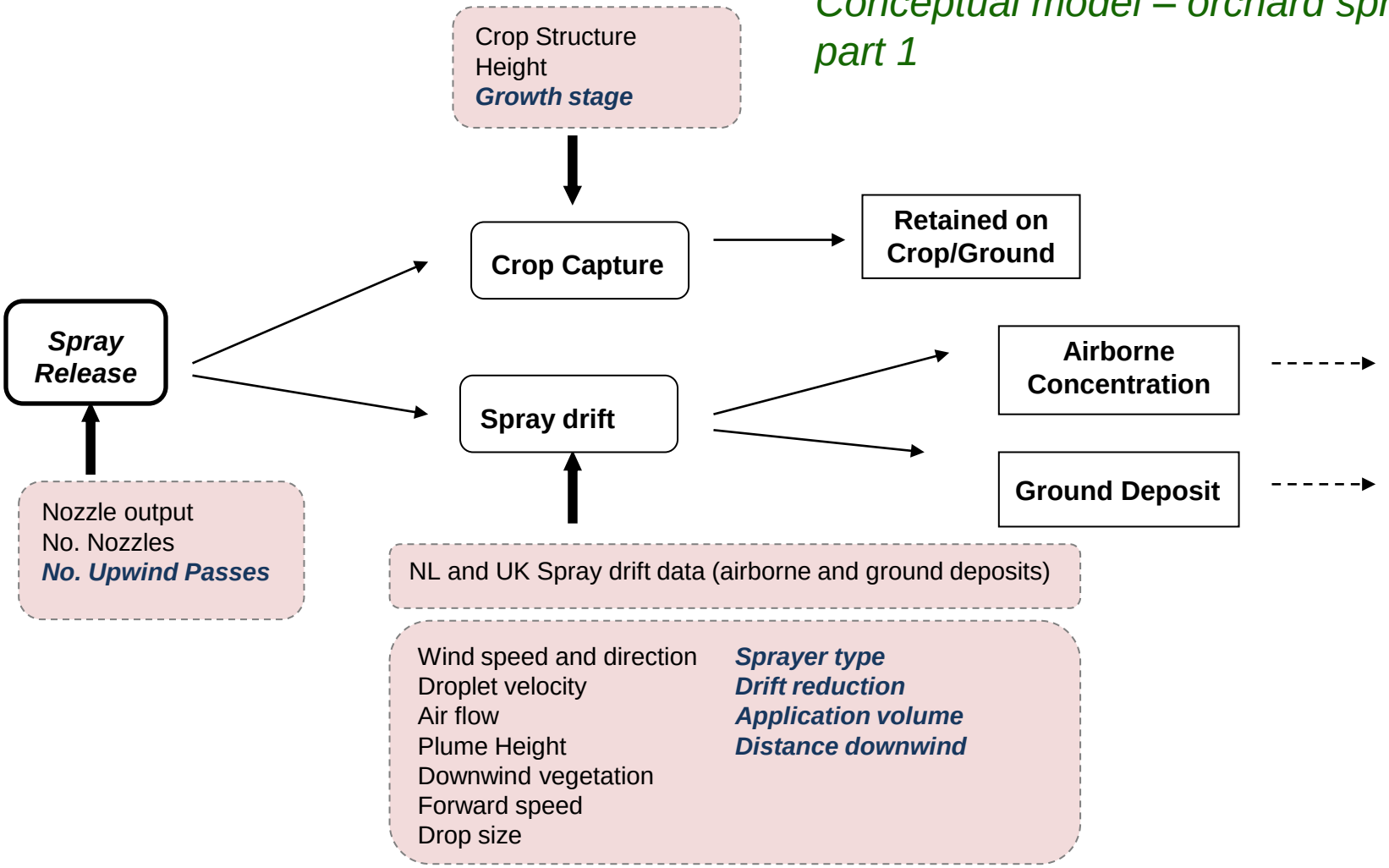
Conceptual model – boom sprayer part 1



Drift from boom sprayers

- Silsoe spray drift model
  - ‘emulator’ used instead of model directly
- Some revisions and improvements
- Addition of other spray qualities

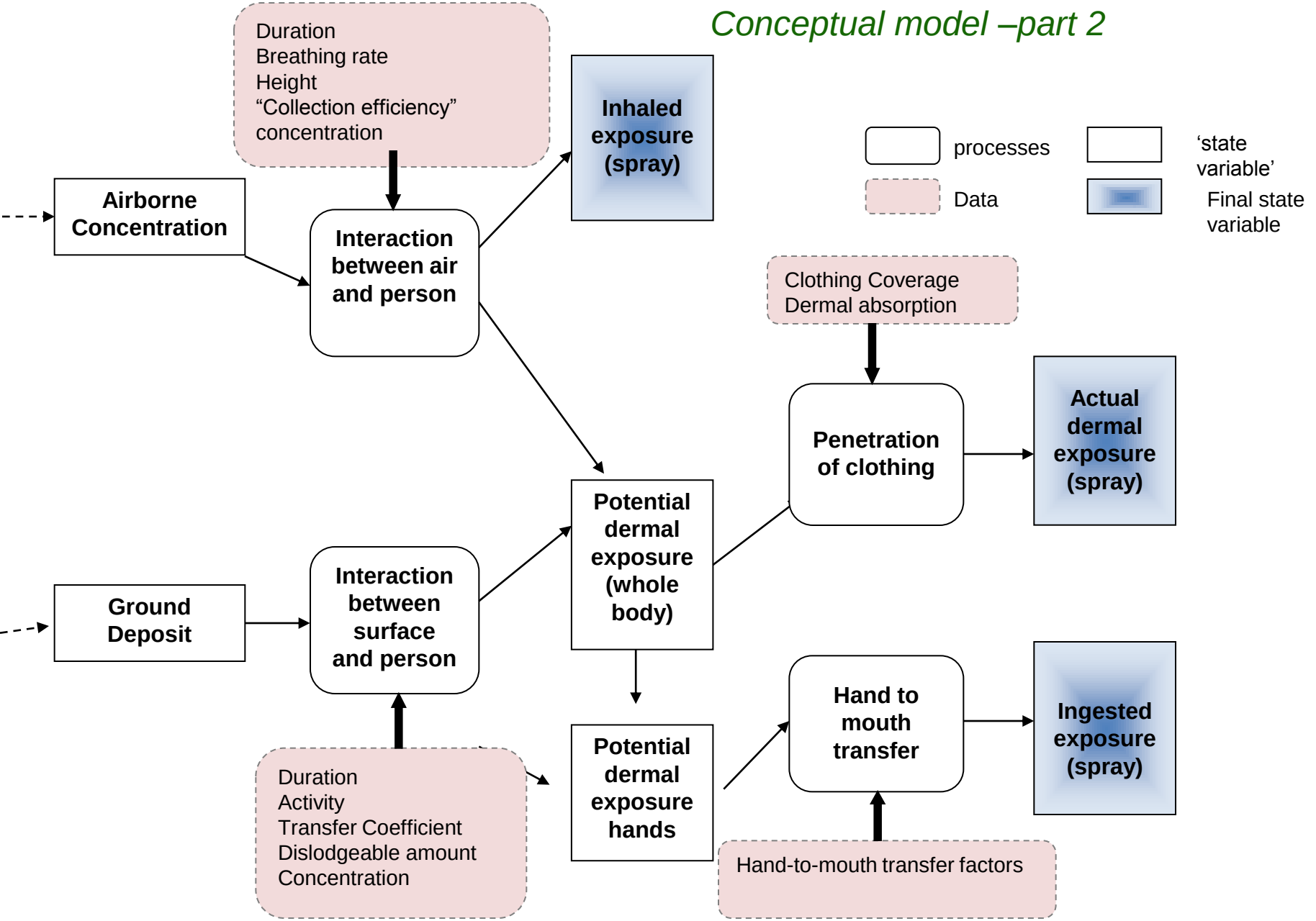
Conceptual model – orchard sprayer part 1



Exposure to orchard drift

- SSAU (UK) and Alterra (NL)
- No appropriate pre-existing mechanistic model
- ‘Large’ quantity of spray drift data
- Use data to determine airborne spray and ground deposits
  - Sprayer type, orchard growth stage, drift mitigation, volume applied, distance downwind
  - All other parameters contribute to variability

Conceptual model –part 2



Residents and Bystanders

EXPOSURE TO GROUND DEPOSITS POST-APPLICATION

Contact with contaminated turf

Currently use the same model as for contact with ***treated*** turf

- Lower 'applied dose' of active ingredient

Exposure (mg/day) = TTR x TC x D

TTR: Turf transferable residue (mg/m^2)

TC: Transfer coefficient (m^2/hour)

D: exposure duration (hours per day)

TTR = 'Applied' dose (mg/m^2) x F

F: fraction that is transferable

Turf Transferable Residues and Transfer coefficients:

- Data in the public domain very fragmented and inconsistent
- Earlier data based on very idealised scenarios
- More recent (US) work not in public domain (Outdoor Residential Exposure Task Force)
  - Most recent EPA protocol (Feb 2012) based on this data

- How should we extrapolate to spray drift?
- How should we extrapolate from adults to children?
  - Worst-case values used to make initial estimate of exposures

BROWSE model

- Will provide a choice of values based on current models
- Will allow manual override

Residents and Bystanders

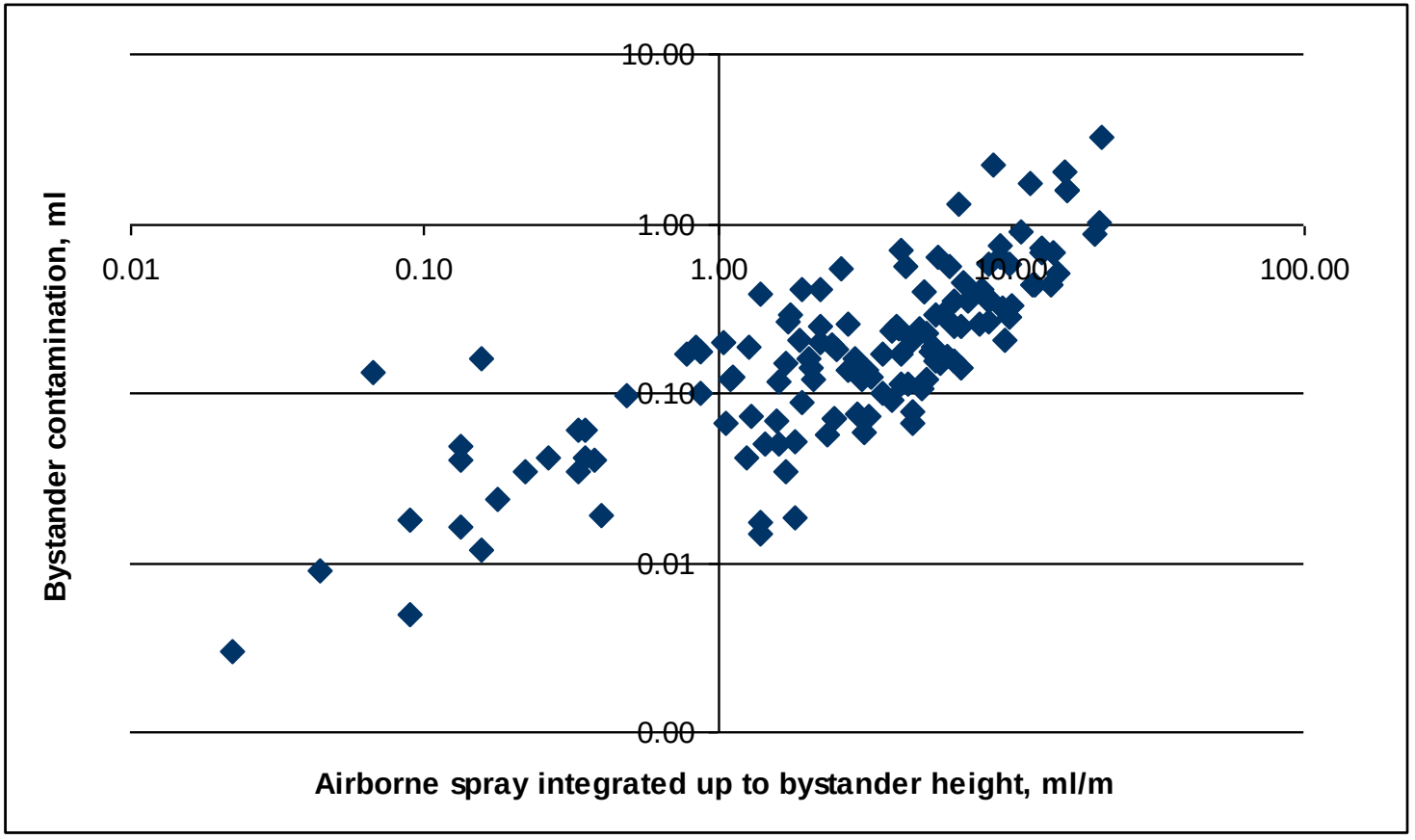
EXPOSURE TO AIRBORNE SPRAY DURING APPLICATION

Dermal exposure

- Model predicts airborne spray up to height of adult or child
- Need to turn this into a dermal exposure
- Based on empirical data from BREAM project and other sources
  - Stationary mannequin or volunteer
  - Need to obtain equivalent relationships for orchard sprayers

SEVENTH FRAMEWORK PROGRAMME

Relationship between airborne spray and bystander contamination

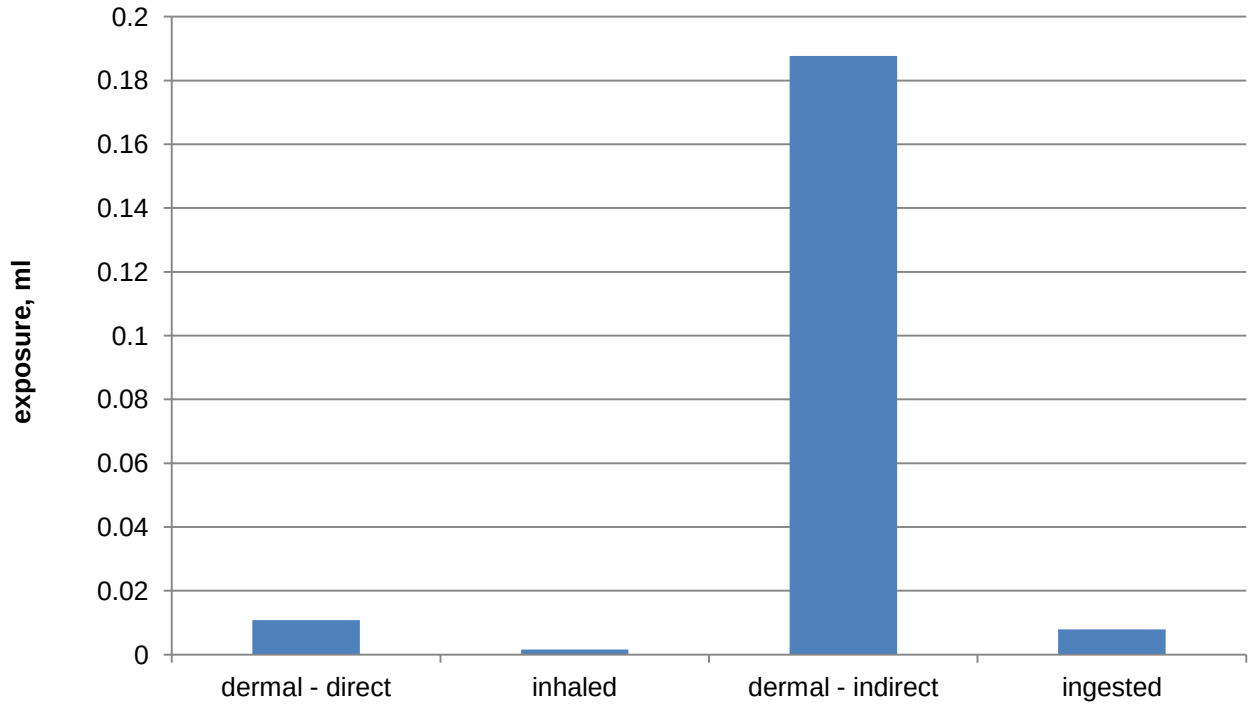


Exposure to airborne spray

- Use empirical data to translate from predicted airborne spray to potential dermal exposure
- Modify by
  - Clothing coverage/penetration
  - Dermal absorption
- Calculate inhaled fraction based on airborne spray in the breathing zone, wind speed and breathing rate

Example results from boom sprayer drift model – mean values only

Child 24-hour exposure to spray drift; 5 m from treated area, ml of spray liquid



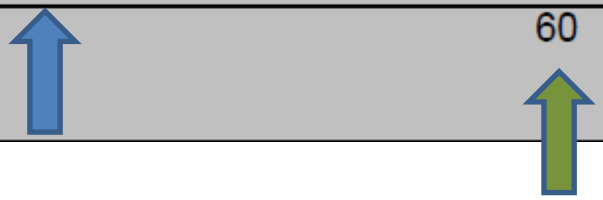
Example calculation for boom sprayers – adult dermal exposure

Systemic exposure = (PDE x SC x % absorbed + PIE x SC x 100%)/BW

Where:
PDE = potential dermal exposure (ml spray)
PIE = potential inhalation exposure (ml spray)
SC = concentration of active substance in spray
% absorbed = percentage dermal absorption (i.e. 17%)
BW = bodyweight (60 kg)

$$\frac{(\text{ml spray dermal} \times \text{mg/ml} \times \%\text{ absorbed}) + (\text{ml inhaled} \times \text{mg/ml})}{\text{kg bw}} = \frac{(0.1 \times 0.625 \times 17) + (0.01 \times 0.63)}{60} = 0.0002 \text{ mg/kg bw/day}$$

$$= 2 \text{ \% AOEL}$$



Adult dermal exposure – estimates from new model compared with existing CRD model

	2 m downwind	8 m downwind	Current CRD model
PDE (ml)	0.31	0.26	0.1
Inhaled (ml)	1.06×10^{-3}	1.02×10^{-3}	0.01
Total (mg/kg bw/day)	5.6×10^{-4}	4.7×10^{-4}	2.0×10^{-4}

These will be similar to the mean values – 75th and 90th percentiles will be considerably higher

Estimates relate to: 6 passes of a 24 m boom; 0.7 m boom height above bare ground; 12 km/h forward speed; conventional '03' flat fan nozzle at 3.0 bar; no protection from clothing

Child indirect dermal exposure

$$SE(d) = \frac{AR \times DF \times TTR \times TC \times H \times DA}{15\ BW}$$

$$= \frac{2.5 \times 1\% \times 5\% \times 5200 \times \mathbf{2} \times 17\%}{15\ BW} = 0.15\ \mu g/kg\ bw$$

Where:

SE(d) = systemic exposure via the dermal route

AR = field application rate, 0.125 kg/ha x 2 applications = 2.5 $\mu g/cm^2$

DF = drift fallout value, i.e. assumed average of 1% from field crop (boom) sprayer applications

TTR = turf transferable residues – the EPA default value of 5% was used in the estimate

TC = transfer coefficient – the standard EPA value of 5200 cm^2/h was used for the estimate

H = exposure duration for a typical day (hours) – this has been assumed to be 2 hours which matches the 75th percentile for toddlers playing on grass in the EPA Exposure Factors Handbook

DA = percent dermal absorption

BW = body weight - 15kg which is the average of UK 1995-7 Health Surveys for England values for males and females of 2 and 3 yrs.

Child indirect dermal exposure

	Current CRD model	Current EPA model	Suggestion for BROWSE	
			2.0 m	8.0 m
DF, %	1	-	4.23	1.15
TTR, %	5	1	50	50
TC, m^2/h	0.52	4.8 (adult = 18)	9	9
Total calculation, µg/kg bw	0.15	-	107	29

These will be similar to the mean values – 75th and 90th percentiles will be considerably higher

Residents and Bystanders

EXPOSURE TO VAPOUR

Exposure models for vapour emissions after applications to crops

- Universita Cattolica Del Sacro and Alterra lead this component
- Two elements to model vapour concentrations
  - Emission from the crop
  - Dispersion in the atmosphere
- Definition of the “scenario” is crucial
- Prediction of airborne concentration required

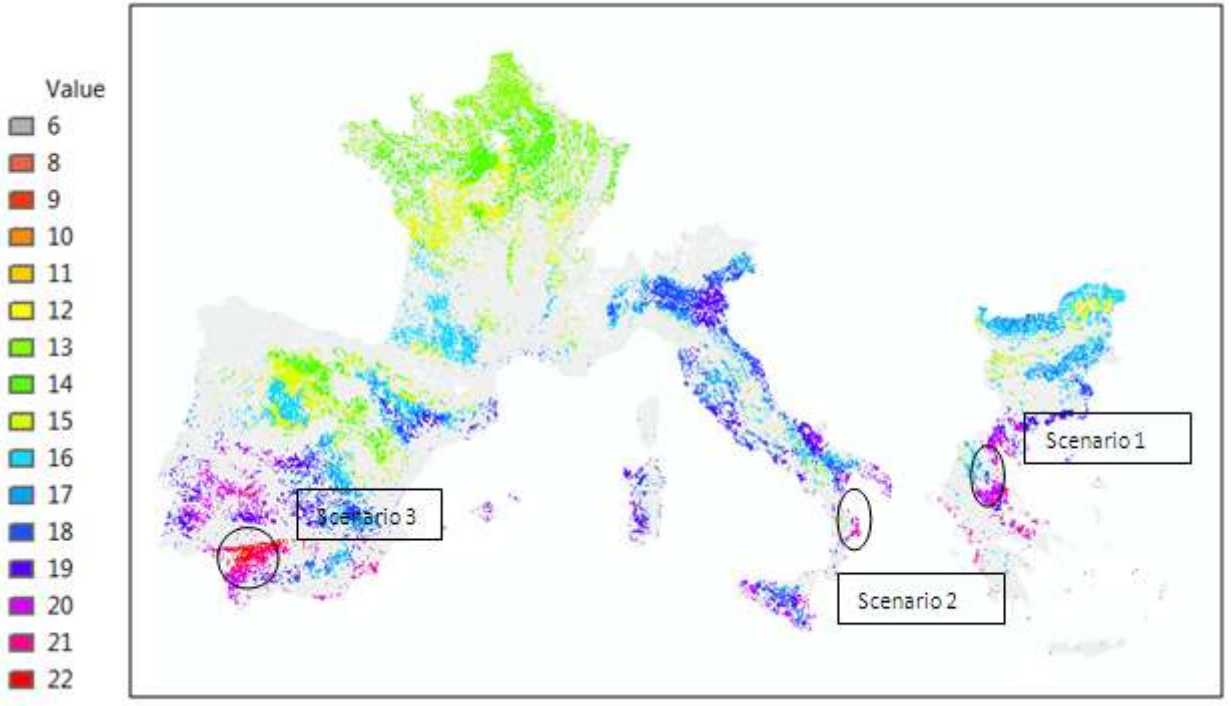
Vapour exposure model

- Volatilisation from the crop is calculated using the PEARL model which describes the fate of the plant production product in the soil-plant system
  - Volatilisation
  - Photo-transformation (first-order kinetics, dependent on global radiation)
  - Penetration into the plant tissue (first-order kinetics)
  - Wash-off from the plant leaves to the soil (dependent on water solubility, rainfall intensity)
- Dispersion in and around the treated field is calculated using the OPS model
  - Transport based on a modified Gaussian plume model (includes, e.g., atmospheric boundary layer mixing and plume depletion concept)
  - Uses real meteorological data

Progress to date

- Conducting a sensitivity analysis to identify the most important input variables
  - Vapour pressure important, but needs to be measured under appropriate conditions
- Identifying timescales for long-term exposure
  - “resident” exposure not considered previously
- Setting up the appropriate scenarios
  - Worst case, realistic worst case, typical??
- Identifying locations for obtaining meteorological data
  - 90th percentile of mean temperature April – October in each zone

Locations for met data – example from Southern zone



Expected deliverables

- A new, transparent model for bystander and resident exposure for:
  - Boom sprayer applications
  - Orchard/fruit sprayer applications
  - Amenity and hand-held applications
- That includes inhalation, dermal (direct and indirect), ingestion (hand-to-mouth) from spray and vapour drift
- That can take account of some environmental variables (especially meteorology), distances, application equipment and drift mitigation
- With some degree of validation and some consideration of exposure distributions
- With scope for continued improvement.


Thank you for your attention