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Combining Spray Drift and Plant Architecture Modelling

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Abstract

Vegetation type and structure can play an important role in determining the amount of spray drift moving away from a treated area. While there have been numerous attempts at modelling the movement of spray droplets from both ground and aerial application, the inclusion of canopy or downwind vegetation parameters within these models have often been either non-existent or somewhat simplistic.

Plant architecture informatics is an emerging discipline for the study of dynamic 3D plant architecture in relation to the environment. It enables investigation of relationships between plant architecture and environmental entities such as spray droplets and insects. The plant architecture model utilises a set of growth rules expressed in the Lindenmayer systems (L-systems) formalism and programmed using L-studio software.

By combining the plant architecture models with spray drift modelling it is possible to greatly extend the predictive ability of various vegetative structures to minimise spray drift.

Introduction

Pesticides remain an essential tool for agricultural industries in the production of high quality produce even when genetically modified crops are in use. Pesticides are used as a key component of integrated crop management (ICM) systems in most Australian cropping systems. There are however, increasing concerns over the effect of pesticides in the environment particularly when they move beyond a field boundary.

Vegetation type and structure can play an important role in determining the amount of spray drift moving away from a treated area. The movement of spray droplets is influenced by vegetative structures within the sprayed area as well as vegetation downwind of the sprayed area.

Combining spray application modeling with plant architectural modelling will enable strong and fundamental links to be made between pesticide application processes and the role of plant architecture. By improving our understanding of the complex relationship between the deposition of pesticide droplets on vegetative surfaces (e.g. crop canopy, weeds, downwind buffer vegetation) it will be possible to develop application procedures that will minimise risk to public health and the environment.

Spray Drift Modelling

Considerable research has been focused on understanding the movement of sprays down wind from the release point and various computational models have been developed to simulate the spray application process. The various spray models have been described as Lagrangian (eg AgDRIFT® (Teske et al 2002), AGDISP® (Bilanin et al 1989, Teske et al 2003)), Random Walk (Ley 1992, Hashem and Parkin 1991, Walklate 1987), Ballistic (Mokeba 1997, Cox 2000), and Gaussian plume (Bach and Sayer 1975, Lawson 1989 Woods et al 2001, Craig 2004, AGDISP now includes a Gaussian extension to extend the prediction distance (Teske and Thistle 2004)).

Most of these models have concentrated on quantitatively determining the deposition or fallout of pesticide droplets reaching a particular point downwind. The inclusion of canopy or downwind vegetation parameters within these models has often been either non-existent or somewhat simplistic. For example the AGDISP 8.08 canopy model uses a probability of penetration that is based on foliage density and envelope dimensions, or determined from optical measurements as a function of sun incidence angle (Teske et al 2003). Cox (2000) developed a simple barley model.

Plant Architectural Modelling

Plant architecture informatics is an emerging discipline for the study of dynamic 3D-plant architecture in relation to the environment. It enables investigation of relationships between physiology and morphogenesis and between plant architecture and environmental entities such as spray droplets and insects and can represent the entire developmental trajectories of plants and canopies (Prusinkiewicz 1999). The approach uses the L-systems formalism (Lindenmayer 1968, Prusinkiewicz and Lindenmayer 1990) for modelling plant architecture linked to stochastic dynamical systems for modelling plant physiology and environmental interactions.

L-systems are the foundation of a plant modelling language called cpfg (Prusinkiewicz et al 2000) well suited for modelling for all these purposes. To overcome some of the limitations of cpfg a new language L+C (based on C++) has recently been introduced (Karwowski and Prusinkiewicz 2003). L+C programs are translated into C++, compiled into a DLL, and linked with a simulation program called lpfg at runtime.

L-systems

The L-system formalism (Lindenmayer 1968) models plants or parts of plants as an assembly of components, each represented by a symbol with associated parameters called a module. A string of modules captures the architecture of a plant, by positioning the components relative to their neighbours, with a hierarchy of branching topology. Growth and development of the plant structure are captured by a set of growth rules or productions that are applied in parallel to the modules in the current structure in order to produce the structure at the next time step. In cpfg, productions are expressed in the form

predecessor : condition --> *successor*

where the *predecessor* is a string of modules with parameters expressed as variable names that will be assigned the actual values that will appear in the string, the *condition* is a logical expression that must evaluate as true for the production to be applied, and the -->, read as "produces", delineates the start of the *successor*, a string of modules whose parameters contain expressions to be evaluated before the successor is placed in the new string. In addition, statement blocks (enclosed in braces) may appear immediately before or after the condition, in which case the pre-condition statements are executed once the predecessor has been matched to a module in the current string, and the post-condition statements are executed if the condition then evaluates as true, and before the successor is produced. Statement types include assignment statements with standard mathematical expressions, if-then-else conditional statements, and while loops.

Global parameters and arrays may also be defined, and global statement blocks can be specified to include processing statements at the start and end of a simulation, and the start and end of each step in the plant's development. For complete details of the language syntax see the cpfg and lpfg manual available with the L-studio package from http://www.cpsc.ucalgary.ca/Research/bmv.

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Combining Plant Architectural and Spray Drift Modelling

Plant architectural models enable the location of various plant components in 3-D space. Some examples of plant architectural models that have been developed using L-systems are shown in Figures 1 to 3.

Figure 1. 3-D Cotton Model

Figure 2. 3-D Sweet Corn Model

Figure 3. Coniferous tree model (Mech and Prusinkiewiez 1996)

When 3-D position of the plant elements is combined with particle trajectory models (Figure 4), it is possible to effectively model the removal of spray droplets by the various vegetative elements. The introduction of this level of detail also enables the amount of spray deposited on various plant structures to be determined. The proportion of spray retained by various plant components can have a significant influence on the efficacy of a product. The ability of vegetative elements to remove of spray droplets from the air can reduce the magnitude of off target spray drift deposition.

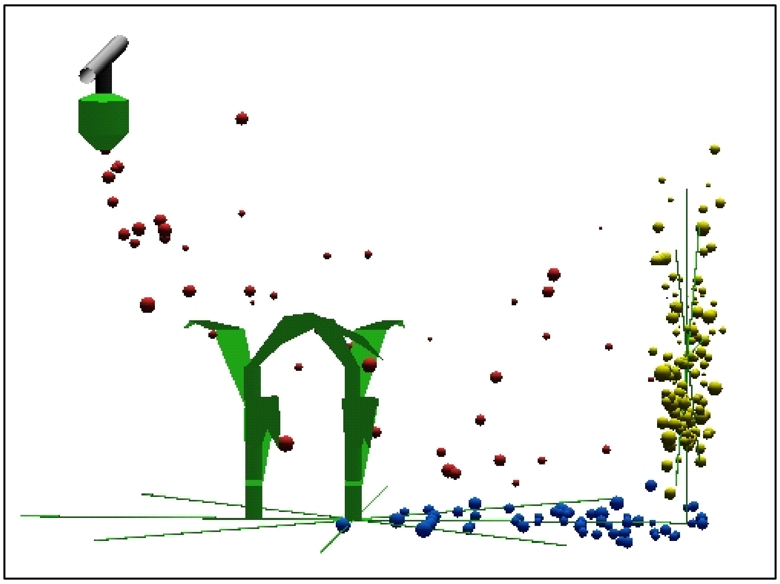

Figure 4. Combining particle trajectory and plant architectural models for simple plant structures.

Conclusion

Vegetation type and structure can play an important role in determining the amount of spray drift moving away from a treated area. By combining plant architecture models with spray drift models current research is focusing on extending the predictive ability of various vegetative structures to minimise spray drift.

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