PREDICTING OFF-SITE DEPOSITION OF SPRAY DRIFT FROM HORTICULTURAL SPRAYING THROUGH POROUS BARRIERS ON SOIL AND PLANT SURFACES

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New Zealand is a recognised leader in horticultural practices which include the use of boundary shelterbelts around orchards. These shelterbelts were primarily established to provide protection to the crop but are also an effective means of ameliorating agrichemical spray drift that may arise from the crop production area. Shelterbelt structure ranges from large trees (ranging from broad leaf to needle in structure) to hedgerows and artificial netting. The efficiency of the shelterbelt in capturing spray drift is known to depend on factors such as spray drift droplet size, wind velocity and the vegetation structure. However more specific information and models are required to define the capture efficiency to form part of a comprehensive spray drift management system.

The task set the MISG team was to develop and investigate a mathematical model of shelterbelt efficiency. Factors such as wind profiles through and above the shelterbelts, release height of the spray drift, capture efficiency of different droplet sizes and evaporation rates all need to be considered. The object is to either produce a better working model or to clearly define the deficiencies in the existing models. Any model that is developed would need to be usable at the farm level. That is, any inputs to the model need to be easily measured or estimated quantities such as free stream wind velocity, optical porosity of the shelterbelt and typical vegetation element size of the shelterbelt. In practice barriers effective at trapping spray drift must have some airflow through them, solid barriers will direct airflow with spray droplets upward and over the barrier.

The team began by dividing the task into three main areas. Firstly, we determined the mean flow through and over the shelterbelt and surrounding crop. Secondly, the spray drift droplet size distribution and the effects of evaporation and settling was calculated. Thirdly, we modelled the capture efficiency within the shelterbelt as a function of the characteristics of the shelterbelt and the wind field.

The wind through and over the shelterbelt and crop is strongly turbulent. Accurately determining the wind profile was beyond the scope of the project and unnecessarily complicated given the generic nature of the desired outcomes. A general guideline for the typical flow fields is desired, not an investigation of specific cases. A simplified turbulence model was used where the eddy viscosity increases linearly with height and then the model solved to get the mean flow. Remember that turbulent flow is intermittent and thus, although we only considered the mean flow, there will be significant departures from the mean that will occur from time to time in unpredictable gusts of wind. Such intermittency may not always be ignorable. The shelterbelt and crop was modelled with a quadratic drag law term that is applicable for the flow speeds considered in this scenario.

Remarkably, the geometry of the air flow through the shelterbelt was found to be largely independent of the wind speed. The reason for this is that the turbulence scales with the velocity and so the eddy diffusivity scales with the inertial effects. Similarly, the quadratic drag also scales with the inertia. Consequently the same pattern of air flow appears for all wind speeds. This was a very useful finding as it means that for the later work on the capture efficiency only changes in the magnitude of the mean flow need to be considered and not changes in the flow field due to different strength winds.

By considering the Stokes settling velocity of droplets (a balance between the gravitational effects and the buoyancy and drag) in the spray drift it was found that droplets larger than about 200μm are not present in the spray drift. For a typical spray scenario droplets of this size or larger have settled out onto the target crop and do not reach the shelterbelt nor the flow over the shelterbelt. Also we showed that the larger droplets are very effectively captured by the shelterbelt so they are not an important part of the spray drift calculations.

Evaporation of the droplets is relevant for the relatively small droplets less than about 50μm as they will significantly change their volume and hence radius in the time taken to reach the shelterbelt. For these droplets the distance of release from the shelterbelt, velocity of release and wind velocity are important factors. For larger droplets the time scales of evaporation are more relevant to the spray drift that goes over the shelterbelt and is deposited far downstream a significant time later. In the time these droplets spend near the target crop their radius does not change significantly to warrant modelling.

An existing model of the capture of droplets in the shelterbelt was analysed for the range of parameters of interest here and found to be a suitable predictor of shelterbelt efficiency. To model the capture efficiency within the shelterbelt certain assumptions about the flow had to be made. These include that the flow through the shelterbelt is horizontal, the wind is perpendicular to the shelterbelt, there is no vertical variation in the flow field or the incoming droplet concentration. The earlier flow calculations suggest that these are reasonable assumptions to make over the parameter range considered in this project.

By considering the inertia of droplets in the mean air flow we determine their capture efficiency onto individual vegetation elements. As fluid flows around each shelterbelt vegetation element the small droplets are swept along with the flow while larger particles with more inertia will deviate from the flow and possibly impact on the vegetation and be captured. Hence larger droplets have a higher capture efficiency. Small vegetation elements have a better capture efficiency since the flow around them is deflected less than that for large elements so the droplets have a higher probability of hitting the element and being captured.

The total capture efficiency of a shelterbelt is then determined as a function of the bleed velocity (the velocity through the shelterbelt), the optical porosity of the shelterbelt, and the vegetation characteristics. The optical porosity is a useful variable as it is relatively easy to measure in the field. It was then possible to calculate the bleed velocity as a function of the optical porosity and the mean wind velocity to obtain a formula for the capture efficiency of the shelterbelt. We found that there is a trade off in the efficiency of the shelterbelt with respect to the optical porosity. A dense shelterbelt (low optical porosity) has a low bleed velocity but a high capture efficiency hence very little of the flow, and hence the spray drift, enters the shelterbelt but what does is efficiently captured. Whereas a sparse shelterbelt (high optical porosity) has a high bleed velocity but a low capture efficiency. The maximum efficiency is found to be for shelterbelts with optical porosity between 10% and 30% and with fine vegetation elements (needles rather than broadleaf). Under these situations up to 50% of the spray drift is captured by the shelterbelt. Of the spray drift that is not captured the majority of it is very small droplets that are carried over the shelterbelt.

Streamlining of the vegetation elements in the wind was found to decrease the efficiency of the shelterbelt with a larger effect on the lighter vegetation elements that are easier to deflect in a wind.

One of the original assumptions was that the wind was perpendicular to the shelterbelt. For wind at an angle we find that the flow through the shelterbelt was still largely perpendicular to the shelterbelt with a suitably reduced velocity and hence all of the previous analysis still holds in this situation.

In conclusion the MISG team have verified that an existing model was suitable for use in determining the efficiency of a shelterbelt at collecting spray drift. The model is relatively simple to program and uses as inputs easily obtainable variables such as the free stream wind velocity, the optical porosity of the shelterbelt and the structure of the shelterbelt. With allowances for settling and evaporation the model was found to be valid over the range of inputs typically found for droplet distribution, wind velocity and vegetation element size. Numerical simulations of the flow field over and through the shelterbelt have justified some of the assumption used in the model and given insight into the flow characteristics that are important to consider. Although these models are never perfect representations of the real world, we believe they are suitably robust for inclusion in a larger spray drift management system. Although care must be taken to ensure that some of the original assumptions are not overly breached.

Further work on determining the optimal shelterbelt is also possible. This has implications to the design of artificial shelterbelts where the highest possible spray drift capture is desired.