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The Pesticide Drift to Non-Target Areas

Modelling and Computing

Using the pesticide drift specifications for single applications in field farming by the Federal Biological Research Centre for Agriculture and Forestry (BBA), the distribution of a pesticide from a flat spray nozzle is modelled by a truncated Gauchy distribution. This is correspondent to uniformly spraying the pesticide within a circular segment, where the angle of the principal wind direction is 90° and the angle j in the opposite direction is somewhat smaller. A formula for determining the amount of pesticides drifting away from the target field to a non-target area downwind is presented.

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Keywords

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The pesticide drift was mainly investigated and discussed in connection with surface waters. In conjunction with the increasing area of organic farming, the conflict of use between conventionally and ecologically farmed areas gains in importance. Under conditions, which are described in Ganzelmeier et al. (2000), the BBA only investigated the amount of pesticide drift at various distances from the target field edge, but did not present values for the total amount drifted to a complete non-target area. Yet such values are of interest, too, when considering both aquatic systems and ecologically farmed areas.

Modelling the pesticide spreading

To calculate the total amount of pesticide drift, we need to model the distribution of the pesticide amount spreading from a spray nozzle. The model should approximate the basic drift values of BBA as accurately as possible. Then we can use it for calculating the total drifting amount to a non-target area via integration.

A truncated Cauchy distribution fulfils these requirements best, as shall be shown in *table 1*. This distribution can be derived from a uniform distribution on a circular segment as illustrated in *figure 1* below.

The uniform distribution on the circular segment facilitates the calculation of the distribution function. It results in (cf. [5])

$$F_{\mu,\sigma,\varphi}(x) = \begin{cases} 0 & \text{für } x < \mu - \sigma \cdot \tan\varphi \\ \dfrac{\varphi + \arctan\left(\frac{x-\mu}{\sigma}\right)}{\varphi + \frac{\pi}{2}} & \text{für } x \geq \mu - \sigma \cdot \tan\varphi \end{cases}$$

where μ gives the location of the modelled nozzle, the scale parameter σ denotes the distance of the modelled nozzle from the ground, and φ gives the spreading angle (in radian) from the plumb line to the left, i.e. against the principal wind direction. In figure 1 where φ is not explicitly drawn, we have φ = 70° = 1.22173 . Under the idealised assumption that the nozzles on the spray boom form a continuum, the fraction of pesticide entry in a distance x from the field edge, related to the intended pesticide entry on the target field, (300 l/ha) results in 1 - $F_{\mu 0,\sigma,\varphi}(x)$. This is shown in the extensive version of this paper in Agrartechnische Forschung. The parameter μ_0 denotes the value by which the right target field edge is exceeded by the model nozzles during spreading the pesticide. The negativity of μ_0 = -0.058 m means that the model nozzles did not reach the last 5.8 cm at the right field edge. Related to the real nozzles, this distance is a bit greater, because a real nozzle is on the left of the corresponding model nozzle (see figure 1). Essentially, the result 1 -

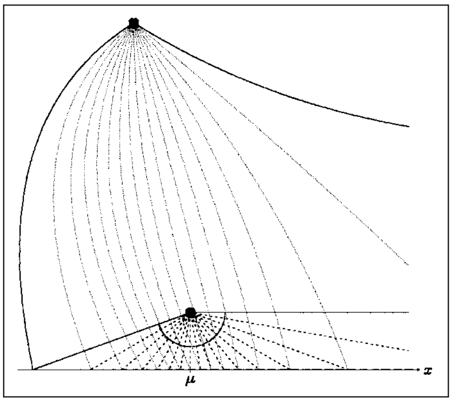

Fig. 1: Approximating the distribution of the pesticide amount from a real spray nozzle (above) by a model spray nozzle spreading uniformly on a circular segment with angle φ + π/2 (below)

Table 1: The accuracy of modelling percentage basic drift values of BBA via a truncated Cauchy distribution

Abstand *x* zur Zielfläche	1 - $F_{\mu 0, \sigma, \varphi}(x)$ mit μ_0 = - 0,058 m, σ = 0,082 m, und φ = 70° = 1,22173	Abdrifteckwerte der BBA
1 m	0,0276990 = 2,77 %	2,77 %
5 m	0,0058050 = 0,58 %	0,57 %
10 m	0,0029194 = 0,29 %	0,29 %
15 m	0,0019501 = 0,20 %	0,20 %
20 m	0,0014640 = 0,15 %	0,15 %
30 m	0,0009769 = 0,10 %	0,10 %
40 m	0,0007331 = 0,07 %	0,07 %
50 m	0,0005866 = 0,06 %	0,06 %
70 m	0,0003912 = 0,04 %	0,04 %
100 m	0,0002935 = 0,03 %	0,03 %

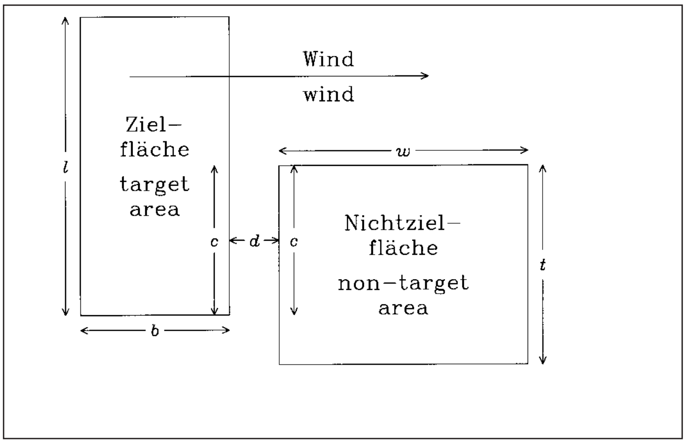

Fig. 2: Target and non-target area

$F_{\mu 0,\sigma,\varphi}$ (x) comes from integrating the density of the truncated Cauchy distribution from $-\infty$ to μ_0, because we have to form a sum (i.e. integrate) over the entire width of the target area. In the trials of BBA this area was considered as being infinitely wide on the left.

Table 1 shows that 1 - $F_{\mu 0,\sigma,\varphi}$ (x) is not only a good but even a nearly exact approximation for the basic drift values of BBA, when using the parameters ?0, ? and ? given at the head of this table.

The total amount drifted from the target field to a non-target field

Modelling the distribution of the pesticide spreading from a nozzle by a truncated Cauchy distribution facilitates the calculation of the total amount, which drifts from the target to any non-target area of interest. Proceeding from parallel and rectangular target and non-target areas, as illustrated in *figure 2*, we get the formula for the totally drifted amount via twice integrating the density function of the truncated Cauchy distribution, the first time over all nozzle locations of the treated width b + μ_0 of the target field, where the pesticide comes from, the second time over all locations x of the whole width w of the non-target field, where the pesticide may drift to. This double integral corresponds to a simple integral of the distribution function $F_{\mu 0,\sigma,\varphi}$ as this is already an integral of the corresponding density function. Of course, the result must be multiplied by the treatment intensity λ (e.g. λ = 300 l/ha = 300 • 10^{-7} m) and by the common length c of both areas.

By using the model parameters μ_0, σ and φ, given in *table 1* and the notations of *figure 2*, we get the following formula for the pesticide drift from the target to a non-target area:

$$\text{Abtrift} = \frac{\lambda \cdot c}{\varphi + \frac{\pi}{2}} \left[\frac{\sigma}{2} \ln\left(\frac{\sigma^2+(b+d)^2}{\sigma^2+(-\mu_0+d)^2} \cdot \frac{\sigma^2+(-\mu_0+d+w)^2}{\sigma^2+(b+d+w)^2}\right) + (b+d)\,\operatorname{arccot}\frac{b+d}{\sigma} - (b+d+w)\,\operatorname{arccot}\frac{b+d+w}{\sigma} - (-\mu_0+d)\,\operatorname{arccot}\frac{-\mu_0+d}{\sigma} + (-\mu_0+d+w)\,\operatorname{arccot}\frac{-\mu_0+d+w}{\sigma} \right]$$

An extensive derivation of this formula you can find in Agrartechnische Forschung. The formula is implemented in the Windows-based program QuickTrift and in the DOS-based program Abtrift.exe. These programs are available on the websites http://www.Quicktrift.de (in preparation) respectively

http://www.agridata.de/agrardos/agrardos/abtrift.html

Table 2 shows some total drift values for a few widths and distances of both areas.

Table 2: Pesticide drift from a 100 m long target area treated with λ = 300 l/ha to a parallel non-target area of the same length (t = l = c = 100 m; μ = -0.058 m, σ = 0.082 m, φ = 70° = 1.22173)

Breite *b* der Zielfläche	Breite *w* der Nichtzielf.	Abstand *d* zwischen beiden	Auf Nichtzielfläche gedriftete Menge an PSM absolut	bzgl. ausgebrachter M.	bzgl. abgedrifteter M.	bzgl. Mitbehandlg.
100 m	100 m	0 m	0,576 l	0,192 %	90,4 %	0,192 %
		3 m	0,250 l	0,0834 %	39,3 %	0,0834
		100 m	0,0253 l	0,00844 %	3, 98 %	0,00844 %
	500 m	0 m	0,621 l	0,207 %	97,5 %	0,0414 %
		3 m	0,294 l	0,0979 %	46,2 %	0,0196 %
		100 m	0,0474 l	0,0158 %	7,45 %	0,00316 %
500 m	100 m	0 m	0,621 l	0,0414 %	79,7 %	0,207 %
		3 m	0,294 l	0,0196 %	37,8 %	0,0980 %
		100 m	0,0475 l	0,00316 %	6,10 %	0,0158 %
	500 m	0 m	0,717 l	0,0478 %	92,2 %	0,0478 %
		3 m	0,398 l	0,0259 %	49,9 %	0,0259 %
		100 m	0,104 l	0,00696 %	13,4 %	0,00696 %

Specifically, the table contains absolute total amounts (in litres) drifted from the target to the non-target area and three types of relative values. These percentage values are related to

1. the total amount carried out on the target field (w.r.t. 1),
2. the total amount drifted from the target field (w.r.t. 2),
3. the total amount which would have been carried out on the non-target field if it had been treated by pesticides in the same manner as the target field (300 l/ha) (w.r.t. 3).

The third value shows at what fraction the non-target field is treated by pesticides, although a treatment was not planned.

Table 2 demonstrates that leaving a 3 m wide path between both fields already suffices in order to halve the pesticide entry. We can also see that the absolute amount drifting to a 500 m wide non-target field is not five times as the amount drifting to a field which is only 100 m wide; the mentioned amount is just somewhat larger. Therefore the creation of trans-border fields reduces the pesticide entry considerably. Such an effect was observed in the region Landl of the German administrative district Neumarkt where split ecologically farmed areas (a total of 309 ha) were pooled to trans-border fields with an average size of 9 ha. The result was that the pesticide entry could be reduced by 66%, from 131 litres to 44 litres [4]. Such effects can now be pre-estimated by using the program QuickTrift or Abtrift.exe, where the proposed calculations are implemented.

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