

German Regulation – Drift Modelling

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Abstract

The application of plant protection products is associated with the unavoidable occurrence of direct drift. The volume of transported and deposited drops is influenced by prevailing technical, technological, and meteorological conditions.

German regulations for handling drift provide two tables including values for drift. They are published by specialists of the BBA. On this basis farmers can handle drift in an easy way.

In Germany, first trials to develop a mathematical/physical model “PeDriMo” (Pesticide Drift Model) were made on the basis of step by step calculations for the movement and evaporation of droplet clouds. The multiple regression analysis (by using the SAS procedure¹) of measured data as part of “PeDriMo” is more feasible than the mathematical/physical calculation and is preferred.

The results of a big number of experiments in fields and in orchards with the wide variation of conditions are the basis for the multiple regression analysis. All parameters which could have an influence on the drift sediment as inputs of the model and the sediment itself as output of the model were measured.

The model includes the coefficients of the multiple regression analysis and the limits in variation of the relevant influencing parameters. It is the statistic mean for the given meteorological a technological situation. For field sprayers the model has almost been completed. For the more complicated drift from orchard provisional results are shown.

The main advantage of the model in comparison to field experiments is that the effect of several influencing parameters can be calculated in their complexity.

Introduction

The application of plant protection products is associated with the unavoidable occurrence of direct drift. Direct drift is the undesirable conveyance of plant protection agents beyond the target area. This unwanted transport is caused by air movement. The volume of transported and deposited drops is influenced by prevailing secondary technical, technological, and meteorological conditions.

German regulations for handling drift provide two tables. One contains drift values for field crops, fruit crops, grape vine and hops in dependence on the distance from the field (table 1). This table is based on a large number of field trials and includes the 90th percentile of the measured data.

The second table (example in table 2) gives the reduction of drift by using special technologies in steps of 50 %, 75 % and 90 % of the values in the first table. On the basis of this table, farmers can make use of technical advantages and developments in a very easy way.

¹ SAS[®] is a registered trade mark from SAS Institute Inc., Cary, NC, USA

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Table 1: Basic drift values – 90th percentile

[m]	Field					Hops
		early	late	early	late	
1	2.77					
3		29.20	15.73	2.70	8.02	19.33
5	0.57	19.89	8.41	1.18	3.62	11.57
10	0.29	11.81	3.60	0.39	1.23	5.77
15	0.20	5.55	1.81	0.20	0.65	3.84
20	0.15	2.77	1.09	0.13	0.42	1.79
30	0.10	1.04	0.54	0.07	0.22	0.56
40	0.07	0.52	0.32	0.04	0.14	0.25
50	0.06	0.30	0.22	0.03	0.10	0.13
75	0.04	0.11	0.11	0.015	0.05	0.04
100	0.03	0.06	0.06	0.009	0.03	0.02
125	0.025	0.03	0.04	0.007	0.024	0.01
150	0.021	0.021	0.03	0.005	0.018	0.006
175	0.018	0.015	0.024	0.004	0.014	0.004
200	0.016	0.011	0.019	0.003	0.011	0.003
225	0.014	0.008	0.016	0.003	0.010	0.002
250	0.012	0.006	0.013	0.002	0.008	0.001

Table 2: Register „Drift reducing equipment“ (Field crop sprayers - except)¹⁾

Drift Reducing Class	Number of BBA Approval	Type of Field Crop Sprayers and Drift Reducing Nozzles	Field of Use ²⁾	Manufacturer/ Applicant ³⁾
50 %	G 1535	Field crop sprayers with injector nozzles Lechler ID 03 POM	A	LEC
50 %	G 1546	Field crop sprayers with injector nozzles Lechler ID 03 C	A	LEC
50 %	G 1568	Field crop sprayers with injector nozzles Spraying Systems AI 110 03 VS ⁴⁾	A	SSC
75 %	G 1536	Field crop sprayers with injector nozzles Lechler ID 04 POM	A	LEC
75 %	G 1545	Field crop sprayers with injector nozzles Lechler ID 04 C	A	LEC
75 %	G 1569	Field crop sprayers with injector nozzles Spraying Systems AI 110 04 VS ⁴⁾	A	SSC

¹⁾Latest publication: 14 January 2000

²⁾A: Arable crops; 20 m minimum range;
5 km/h driving speed
3 bar spray pressure

³⁾LEC: Lechler

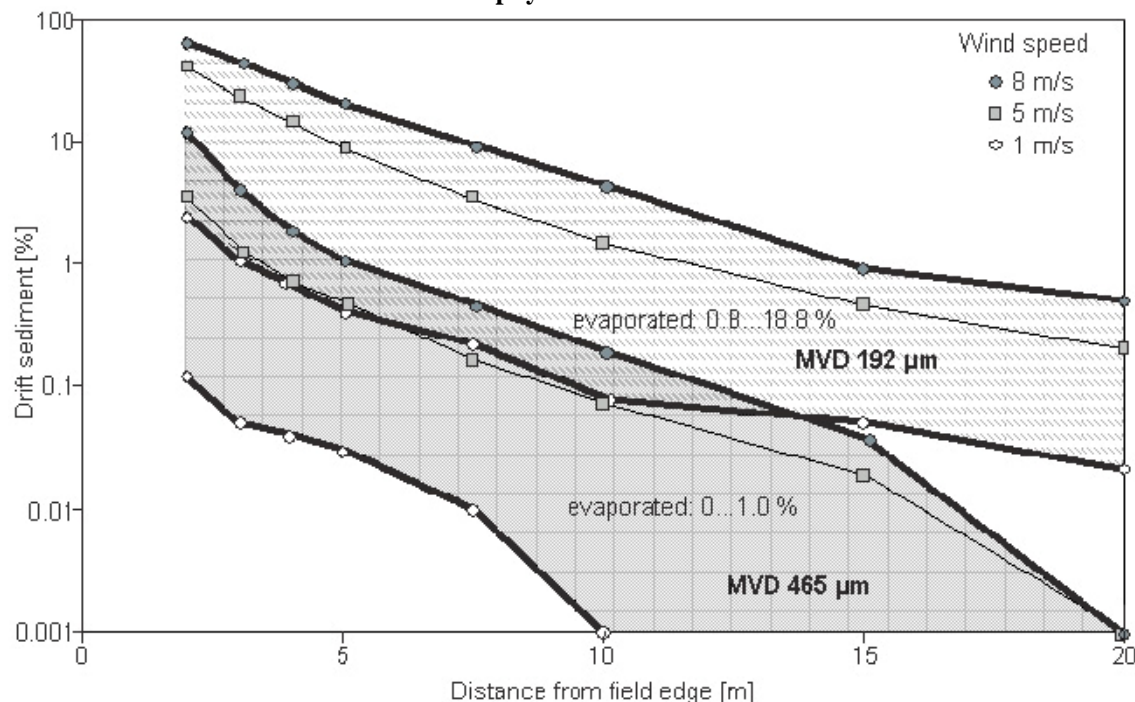
SSC: Spraying Systems Company

⁴⁾Limited to 40 – 60 cm nozzle height

Both tables are official documents published by specialists of the BBA. In addition to the direct analysis of field trials, models of drift are used as a basis for these two tables. That way, the handling of these complicated models is done by specialists and farmers are relieved. Mistakes are avoided and different methods to collect and update the data for the tables can be used.

In Germany, first trials to develop a mathematical/physical model “PeDriMo” (Pesticide Drift Model) were made on the basis of step by step calculations for the movement and evaporation of droplet clouds for aircrafts and field sprayers in 1990 (VDI-Richtlinie 3782, 1992; TRAYFORD and WELCH, 1977; WILLIAMSON and THREADGILL, 1974; WALKLATE, 1987; Kaul et al., 1995 and 1996). The calculation was made for two droplet clouds: the first one below the nozzles and the second one behind the vehicle. Meteorological drift models of point source which move on a line were the basis. That way, it was possible to express the effects of influencing parameters on drift values logically (figure 1). But the absolute mass of drift sediment was calculated incorrectly.

Figure 1. Comparison of drift potential of two nozzles, wind speed 1...5 m/s (max. 8 m/s) under extreme drift conditions – mathematical /physical model



Difficulties in the formulation of initial conditions for field sprayers and in the calculation of the sediment in connection with the layer boundary caused the necessity to correct the results (figure 2; 3).

Figure 2. Simulation of drift

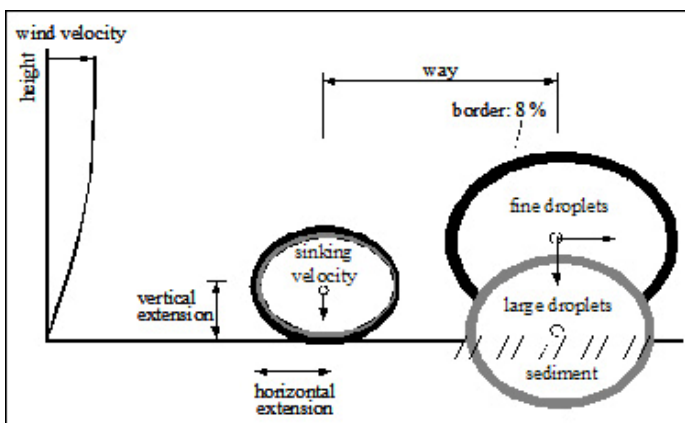
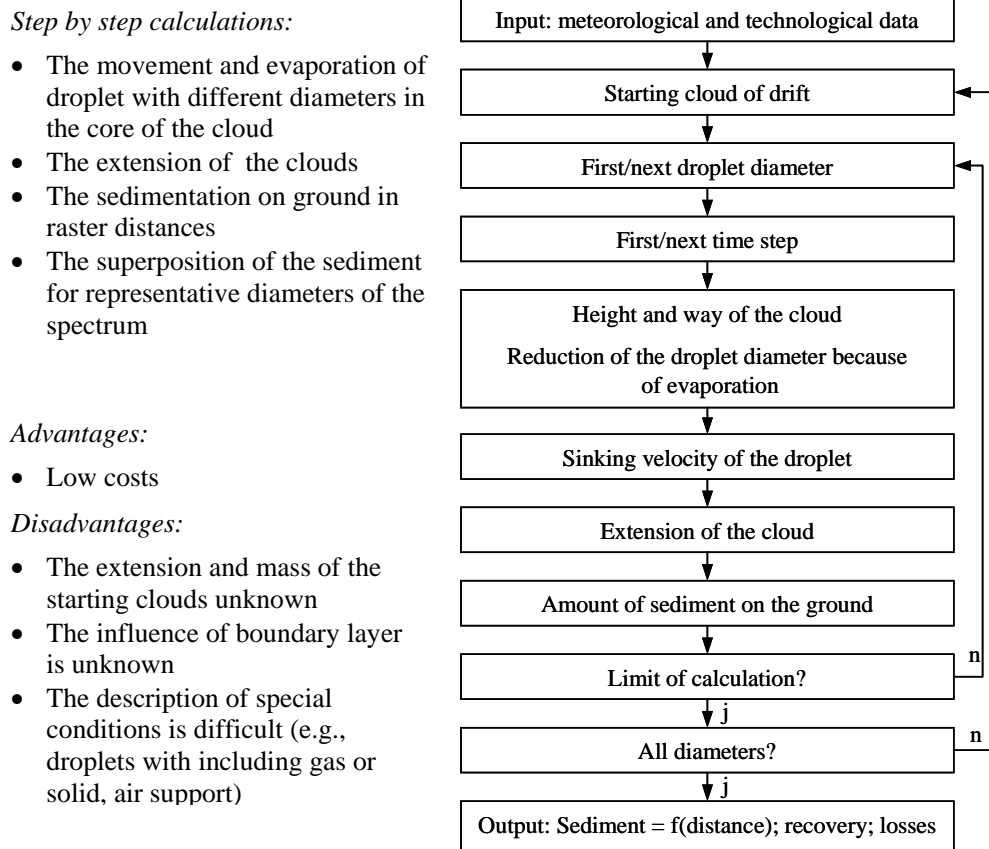


Figure 3. The calculation scheme for the drift model “PeDriMo” on the basis of equations for the evaporation and the movement of droplets in clouds



Therefore, the mathematical/physical model could not be transferred into practical use. This resulted from comparing the model results with the measured field data in particular. For this comparison, the multiple regression analysis of measured data was used to develop the model “PeDriMo” further (Kaul et al., 2001). The multiple regression analysis and the model which resulted from it is more feasible than the mathematical/physical calculation and is, therefore, preferred. The following text is about this model.

Methods or Major Points

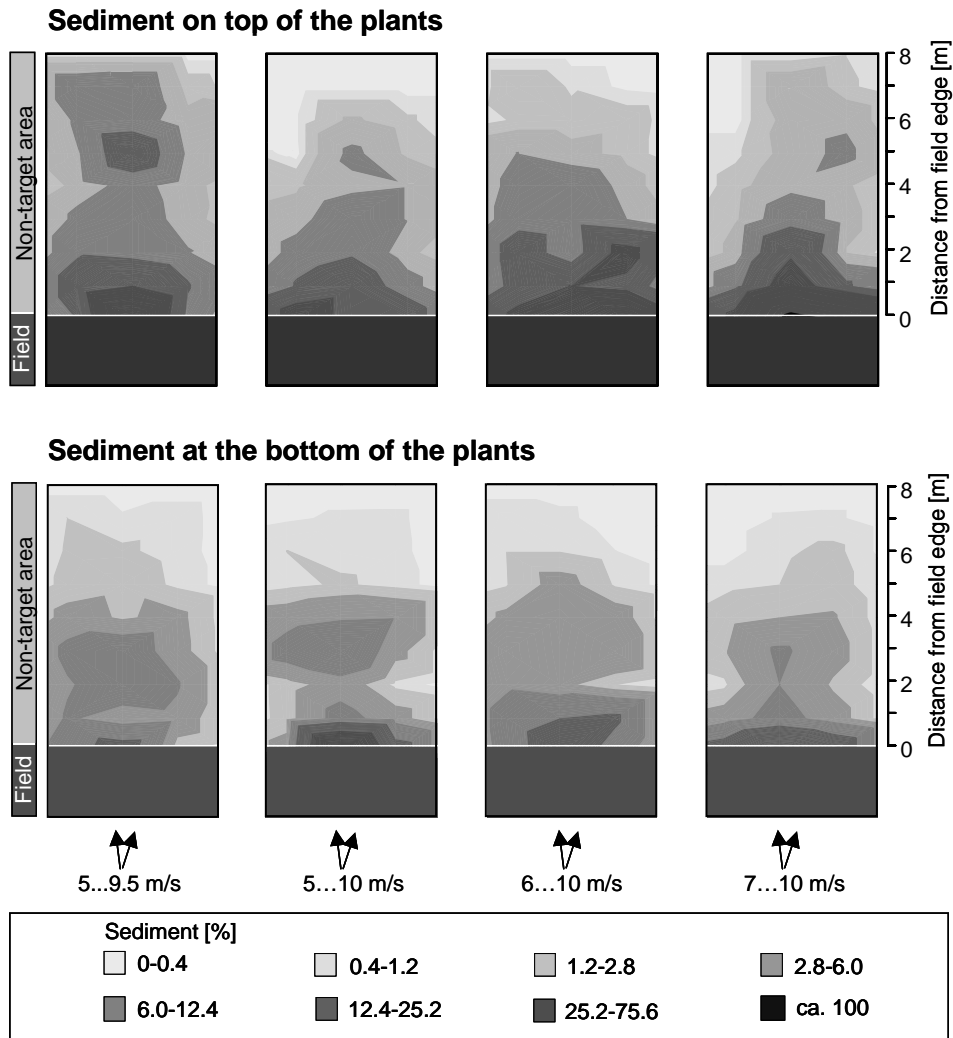
Drift sediments are usually described as a one-dimensional process. This is reasonable and will be done here as well. However, it should be said that the drift process is actually three-dimensional as shown in figure 4.

In figure 4, the drift sediment is not only a function of the distance to the field edge. In reality, the drift sedimentation is a physical process, which is strongly effected by random impacts. Plants on the field as well as behind the field have an influence on the drift result too.

The multiple regression analysis is based on field trials. Therefore, the conditions of these trials have to be formulated. In our case, the drift sediment is measured on cut grassland. The application process is that of a “black box”. The drift sediment is the output. The input is a number of influencing parameters. The connection between the output and input was found with the help of the multiple regression analysis by using the SAS procedure¹. This means, several solutions are possible

¹ SAS® is a registered trade mark from SAS Institute Inc., Cary, NC, USA

Figure 4. Measured Spray-drift in field margin – view from above



(ARVIDSON, 1997). The optimisation of the result was done with the ‘Modified Akaike Criteria’ (SUMPFF and MOLL, 2003). The multiple regression analysis was done for sections of the distance and not for the whole. This is necessary because of the non-linearity of the drift curve in dependence on the distance from the field edge. The influencing parameters should be varied in a wide range. This determines the calculability of their influence.

Field Drift Model

Almost all of the feasible influencing parameters were varied when the trials were carried out. Thus, they were considered for the development of the model. 129 experiment with 8944 data were the basis for the multiple regression analysis. Table 3 shows all the parameters which, according to the analysis, are relevant. The extreme variation of these parameters can be seen in figure 5. This means that special trials have to be carried out for such an analysis.

Non-relevant parameters are: the time of application, the amount of applied chemicals, the degree of cloudiness, the width of application (the width of the field), the air temperature and the active principle of the nozzle (injector or conventional). No conclusion could be made for the plant height on and behind the field, the vehicle type (for instance, with or without air support) and the distance between the nozzles (50 cm are usual, the variation is not necessary). These parameters were not varied.

Figure 5. The cumulative frequency of the influencing parameters in the data (in percent)

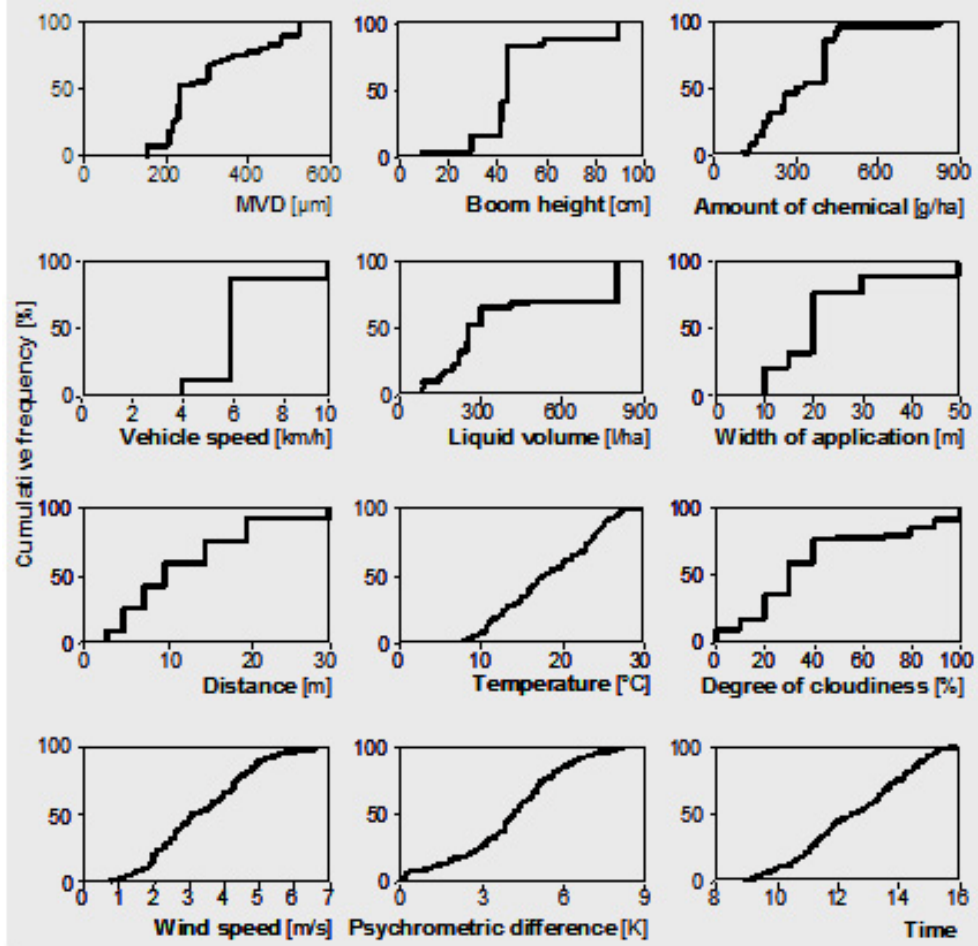


Table 3. Coefficients of multiple regression – field

Distance	1...3 m	3...7.5 m	7.5...30 m
Coefficient of determination [%]	52.0	58.92	43.7
Constant	-3.110094	-0.782856	0.074614
ln (distance)	-16.695321		
Psychrometric difference / ln (MVD)	4.104377	-3.377985	-1.652663
Psychrometric difference * Boom height		-0.003137	-0.000889
Psychrometric difference * Vehicle speed	-0.128785	-0.038290	
Boom height * Vehicle speed	0.005810	0.003919	0.000629
Boom height * Wind speed			0.000995
Vehicle speed / MVD	146.471786		
Wind speed		0.125000	
Psychrometric difference		0.935388	0.316595
Liquid volume		-0.000569	-0.000234
Vehicle speed * ln (distance)		-0.096767	-0.024365
Vehicle speed / MVD		43.064404	12.861496
ln (distance) * ln (MVD)	2.610190		
Width of application	0.051496		

Table 3 includes the results of the multiple regression analysis where combinations of the parameters are taken into account as well. This improves the coefficient of determination in a certain degree. This coefficient is about 50 %. In contrast, the coefficient of determination for the summation over the distance is about 70 %. This means that the process of sedimentation has a profound random effect. The equations from table 3 describe the sediment in three distance sections. These equations are one part of the model “PeDriMo”. It is a very useful field drift model because these equations result from the analysis of field experiments.

Orchard Drift Model

163 experiments with 13,040 data of the sediment were the basis for the multiple regression analysis. The coefficient of determination is 49...54 %. For the development of the orchard drift model, it is necessary to take more influencing parameters into account. That is because the orchard sprayer has many possibilities of adjustment.

In particular, the direction of the air stream and the part of the air stream loaded with droplets in relation to the height of the trees are further influencing parameters (figure 6). These parameters result from the adjustment regulations for orchard sprayers in Germany. Other important influencing parameters are the density of leaves and the number of rows with both sided application from the first six rows. The application with one and the covering of the other side of the orchard sprayer is a usual technology in Germany to reduce the drift.

Figure 6. Influencing parameters resulting from the adjustment of the sprayer

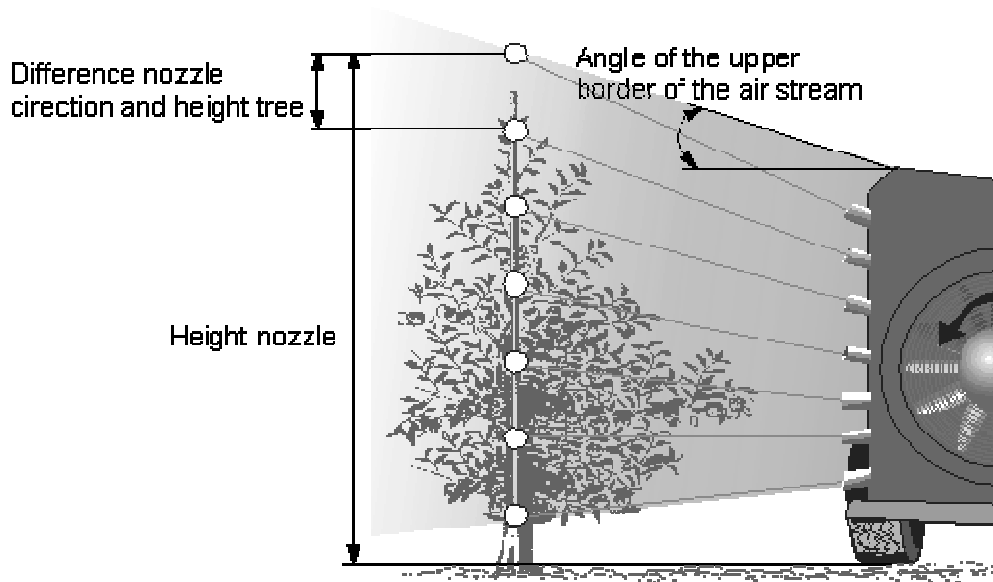


Table 4 shows all the parameters which, according to the analysis, are relevant. The variation of these parameters is not sufficient because the development of the model has not been completed yet. This means, the model is as good as the field model because the basis of its development is once again the result of field trials. However, the input of the influencing parameters is only possible for limited variations.

The parameter ‘degree of cloudiness’ was not relevant. The parameter ‘type’ should be replaced by the angle of the upper border of the air stream and the horizontal line for future calculations. The equations in table 4 are also part of the model “PeDriMo”.

Table 4. Coefficients of multiple regression and limits for calculation – orchard

Parameters		Limits	Sections of distance		
			5...10 m	10...20 m	
Gaps in the foliage	%	30...85	0.09814	0.02888	0.00488
Height nozzle	cm	245...280		-0.01341	-0.00275
Difference nozzle direction and tree	cm	20...50	0,04	0,0199	0,00372
Air volume	m ³ /h	20000...44000		0.00003422	0.00000431
Liquid volume	l/m	160...200		-0.0128	-0.00308
Type ¹⁾	-	1...5		0.48781	0.07792
MVD	µm	200...300	-0.0251	-0.01389	-0.00333
Wind speed	m/s	2...5	0.439	0.15452	0.03535
Air temperature	°C	11...25	-0.146	-0.0788	-0.01798
Psychrometric difference	K	3...6	-0.71149		-0.03038
Hours since sunrise	hours	6...13	0.62395	0.23488	0.03975
Number of rows with both side application from first 6	rows	3...5	1.1476	0.19199	0.02213
Vehicle speed	km/h	6			

¹⁾Type of fan (axial-radial:1; axial-radial with casing: 2; radial- radial: 3; across: 4; tubes: 5)

Results and Implications

Field Drift Model

The field drift model makes it possible to calculate the influence of relevant input parameters on the drift sediment in distances. Therefore, the mean value of the variation range is chosen for all input parameters. The calculation is done for the extreme variation of one of the parameters. The results are shown in figure 7.

From these results, one can conclude that the variation of the parameters ‘MVD’, ‘vehicle speed’ and ‘width of application’ have an effect on the sediment which is close to the field edge. The parameters

‘wind speed’ and ‘liquid volume’ change the drift in distances which are further away. The parameters ‘height of boom’ and ‘psychrometric difference’ have an influence on the sediment over the whole distance. That is because the influencing parameter is or is not in the regression equation for the distance segments.

The field drift model makes it possible to show the whole variation range in its statistic mean. All input parameters are chosen on the edge of their variation range which result in maximum drift. The curve ‘maximal drift sediment’ in figure 8 results from this calculation. The other curves are calculated with the help of the input of particular parameters which are on the edge of their variation range that result in minimum drift. The lowest curve shows the statistic mean of the minimum drift in general.

Figure 7. Results of variant parameters on drift sediment – field

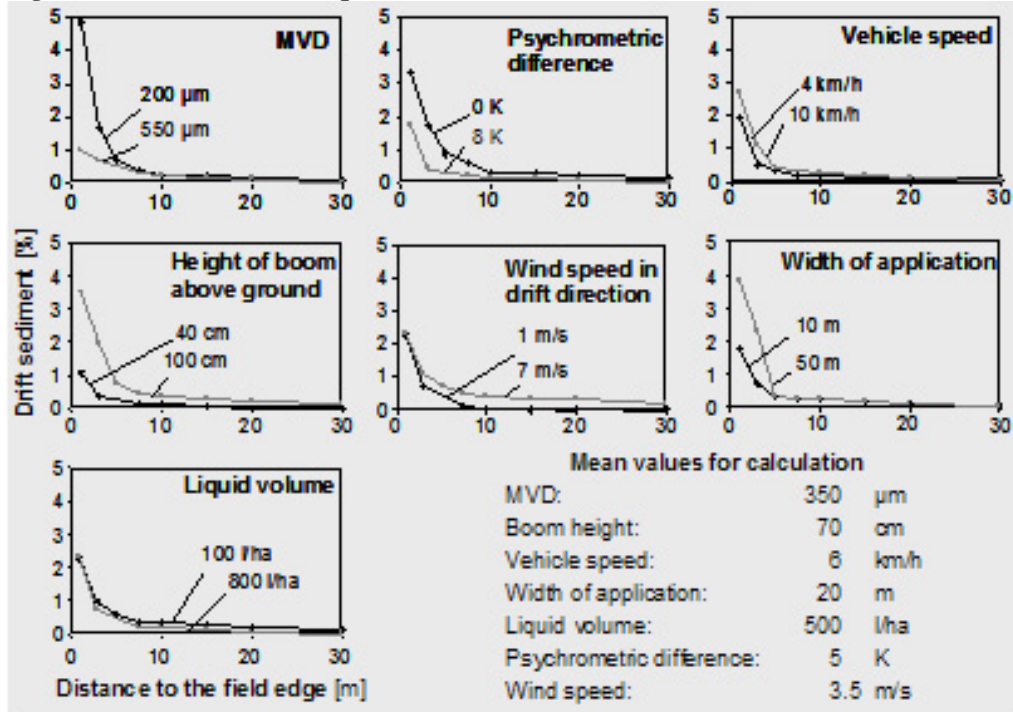


Figure 8. Reduction of the calculated drift sediment by advanced technology on field

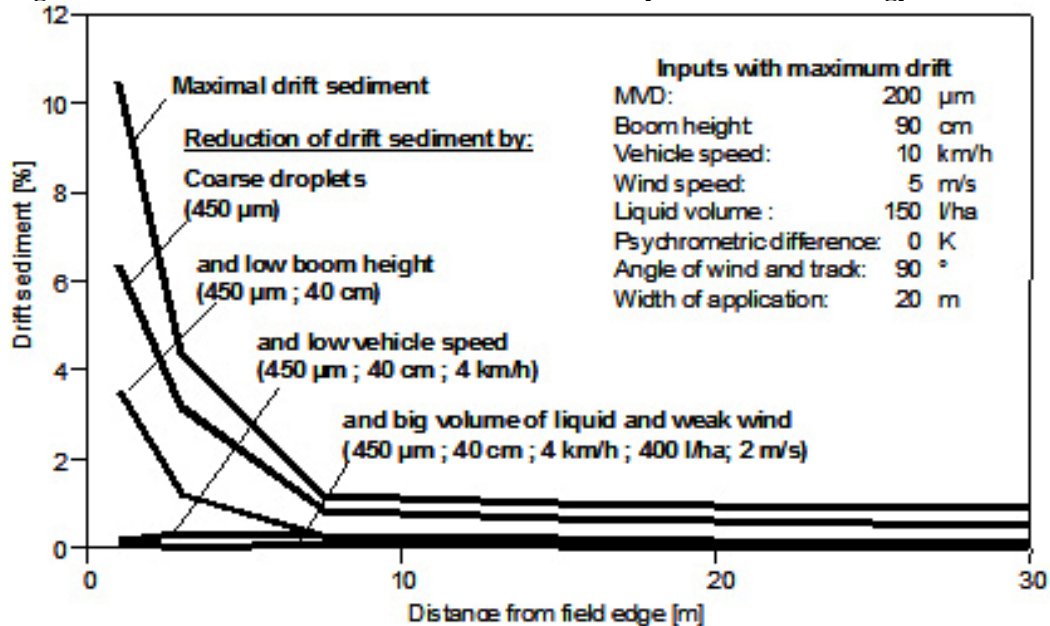


Figure 9. Results of variant parameters on drift sediment – orchard

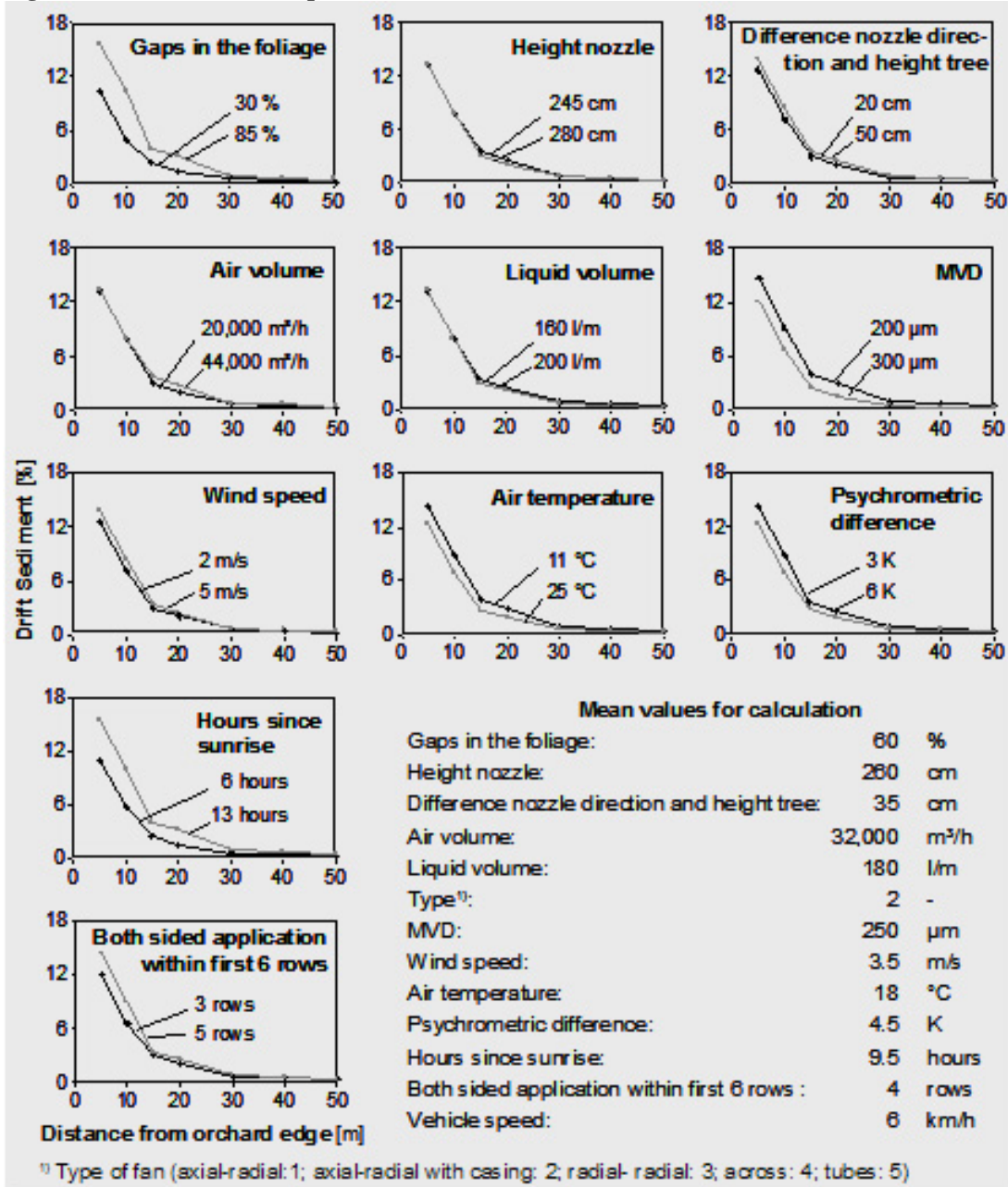
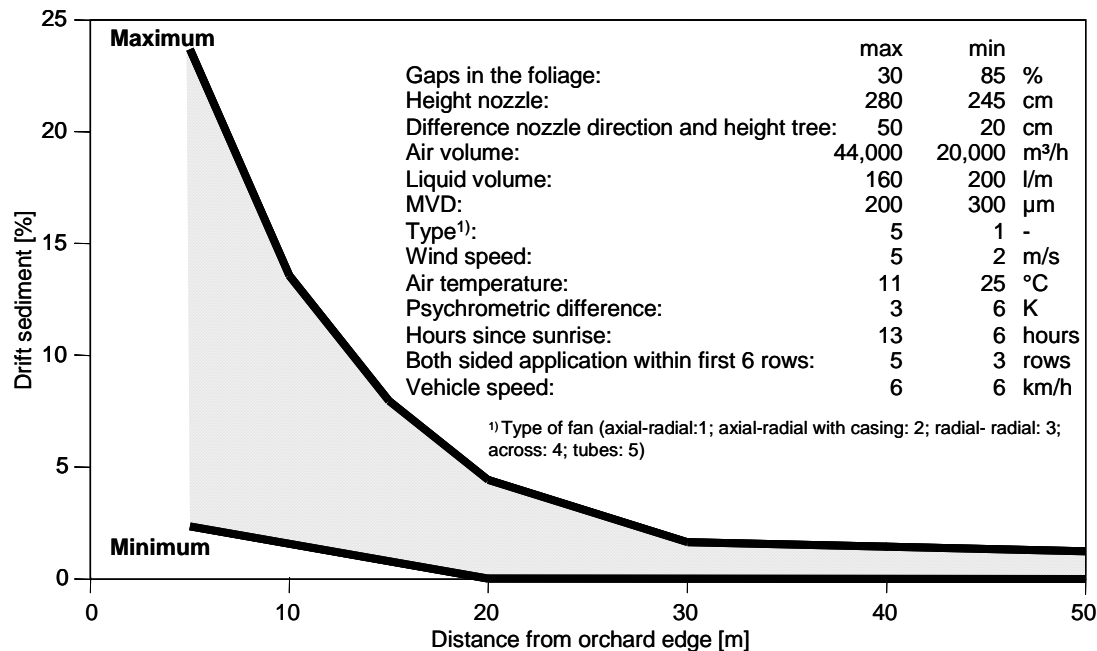


Figure 10. Reduction of calculated maximum drift sediment by procedural measures – orchard



Orchard Drift Model

The procedure for developing figure 9 and 10 is the same as the procedure described for figure 7 and 8.

For the drift in orchard, the results are only provisional. They show that the procedure for the orchard drift model can be used as well although it is much more complicated than the procedure for the field drift model. Further experiments also under extreme conditions are necessary to get final results.

Conclusions and Impacts

The deduction of a physical model for the field with help of a step-by-step calculation was not successful. This resulted from missing starting conditions of the drift clouds and from difficulties in describing the sedimentation in the layer boundary.

The multiple regression analysis makes the development of models which describe the drift sediment as a function of the distance possible. The basis for that is the implementation of experiments in fields and orchards. The quality of the model depends on a complete list of all possible influencing parameters. It is a statistical model that combines physical equations and random effects. By using the model, the sediment on neighboring areas can be calculated as the statistic mean.

The advantage of the “PeDriMo” (multiple regression analysis) is the direct connection with measured data from experiments in orchards and fields. In contrast, however, the experiments are very expensive and time-consuming. That is why immediate reactions to new technological developments are not possible yet. The main advantage of the model in comparison to field experiments is that the effect of several influencing parameters can be calculated in their complexity.

Among other things, the model “PeDriMo” will be used to give information for filling the official register ‘Drift Reducing Equipment’ in Germany (Table 2).

Invited Presentation Articles

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