A new system for evaluating the distribution of aerially spread material

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Abstract

A new system for evaluating the capabilities of aerial-spreading equipment and determining optimum settings for particular equipment is described. The system allows the mean application rate and overall evenness of distribution to be modelled for various flight-line spacings from sample passes flown using particular spreader settings and flying parameters. It utilises an improved design of catcher that is larger, lighter and more portable than those used previously, allowing catches to be recorded volumetrically on-site. It includes a computer program which gives an immediate analysis of application rate and uniformity of spread based on the coefficient of variation. The net effect is that equipment testing is quicker, easier, cheaper and more reliable than it was previously.

Introduction

In modern forestry, various particulate materials including fertiliser, seed and granular herbicides may be spread most efficiently from the air. Evenness of distribution is very important to the achievement of maximum effectiveness at minimum cost. The distribution of aerially applied fertiliser has traditionally been assessed by means of sampling catchers spread over the treated area. The results have been interpreted on the basis of the resultant uniformity quotient (UQ), which is the ratio of the amount of material in the heaviest 50% of samples to that in the lightest 50%. A perfectly even distribution would give a UQ of one, but a figure of three or less has often been regarded as acceptable (Kimber 1976).

With the advent of satellite flight guidance systems, it is now possible to control aircraft flight-line spacing more accurately and, because no prior marking out is required, to vary it at will. Provided that the distribution profile across a swathe produced by a particular aircraft / spreader combination under given flying conditions can be determined, the modelling of repeat passes at different regular spacings should now give a reasonable indication of the effect of varying these parameters on overall application rate and evenness of distribution. With the introduction of dust-free granular fertilisers, there is less drift than previously, so the distribution profile can be more reliably assessed from individual sample flights.

The preferred index of evenness is now the coefficient of variation (CV), a statistic derived by expressing the standard deviation derived from a sample as a percentage of the mean. The lower the figure, the more even is the distribution. In agricultural operations, a figure of 30% or less may be regarded as acceptable for herbicide spraying (Woods and Lisle 1988, p. A-87), whereas a figure below 12% is required for rice sowing (R. McNeill, pers. comm.). Forestry Tasmania aims for a figure below 20% for the aerial fertilising of plantations.

The assessment of a distribution profile across a swathe, even under ideal conditions, was previously a fairly laborious and not very reliable exercise. Sampling catchers were generally made from sheet metal and had to be relatively small to make them manageable in the field. For operational sampling, catchers with receiving areas as small as 0.1 m^2 have been used by Forestry Tasmania. This meant that the quantity collected was often only one or two grams, so careful weighing on a sensitive balance was needed to produce meaningful results. Furthermore, such small sampling units would have been subject to a level of chance variation in catch which is

Photo 1. A catcher set up for use.

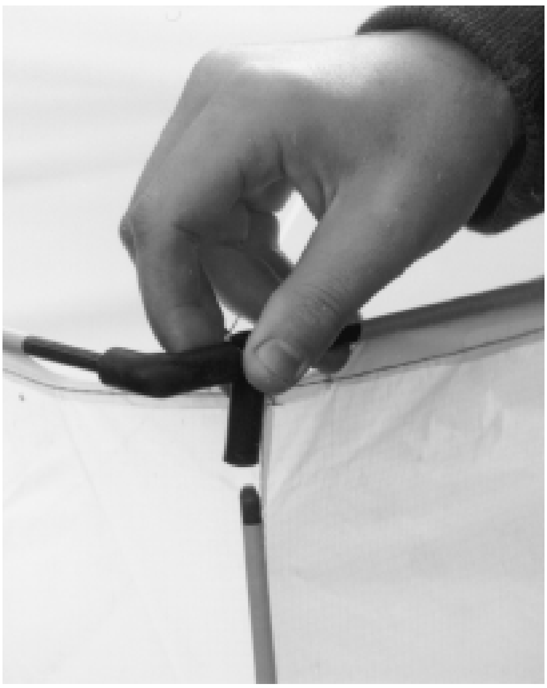


Photo 2. Mounting a catcher on its legs.

Photo 3. Adjusting the cross-ties.

irrelevant operationally. In the case of plantation fertilising, the important consideration is whether each tree receives an acceptable overall dose, rather then how the dose varies between small sections of the tree's feeding area.

This project started as an investigation into methods of evaluating the capacity of contractors' equipment to deliver acceptable results and eventually resulted in a whole new sampling system, including sampling equipment and procedures, and computer software for in-the-field analysis.

Catcher design

Up to the point where they match the area occupied by one tree, the larger the catchers the more meaningful their results will be. Previous catchers were either unduly small, or heavy and bulky. A collapsible catcher of maximum area which could be readily transported, combined with minimum bulk and weight, was therefore designed.

The breakthrough was the adoption of light-weight kite technology. The catcher comprises a one-metre square framework of fibreglass rods joined by flexible connectors at the corners, from which hangs an inverted pyramid of lightweight spinnaker cloth funnelling through an opening in an attached screw cap (Photo 1). Sleeves at each corner of the frame fit over the ends of four fibreglass legs inserted into the ground (Photo 2). Easily adjustable cross-ties of strong thread keep the opening square (Photo 3). After initial field trials, a vertical extension 200 mm high was added to the upper edge of the catchers to prevent granules from fast-flying aircraft bouncing out on impact.

The catchers can be quickly collapsed and rolled up into a neat bundle (Photo 4). A set of 17 catchers weighs a total of 12.7 kg and packs neatly into two bags which can easily be carried by one person (Photo 5), and will readily fit into the boot of a small car. If preferred for temporary storage, the legs may be left attached and folded in so that the catchers can be folded flat and stacked on top of each other. A similar set of metal catchers would have required a truck for transport and been much more laborious to set up.

Setting up and sampling

A 17-catcher row running at a right angle to the flight path has been adopted by Forestry Tasmania as the standard for determining the swathe profile. The catchers are normally spaced at two-metre centres so that the outside catchers are 32 m apart and the nominal width of sample is 34 m. For most spreaders, this ensures that the whole swathe is sampled, even if it is displaced somewhat from the nominal centreline above the ninth catcher. For equipment giving an unusually wide spread (e.g. larger fixed-wing aircraft or helicopters with bucket spreaders), the catchers may be spaced at three-metre centres to increase their coverage.

To set up, a tape is run out in the desired direction and legs are inserted into the ground

Photo 4. Rolling a collapsed catcher for storage.

Photo 5. A complete set of catchers can be carried easily by one person.

at one-metre intervals. A parallel row of legs is set up one metre away and the catchers are set in place on the legs (Photo 6). Cheap plastic vials are screwed into the caps to collect the contents (Photo 7). After each sample flight, the vials are quickly removed, capped, labelled and replaced with new ones for the next flight.

Data collection and analysis

With catchers of this size, common fertiliser application rates of around 200–300 kg / ha will yield 20–30 g per catcher. In a narrow vial, the amount of material present can be determined reasonably accurately by volume. To facilitate this, a plunger was made which fits neatly into the vials and is graduated in kg / ha using weight / volume conversion factors for the types of fertiliser in use. The plunger is inserted into the vial and levels out the surface of the contents, whereupon the

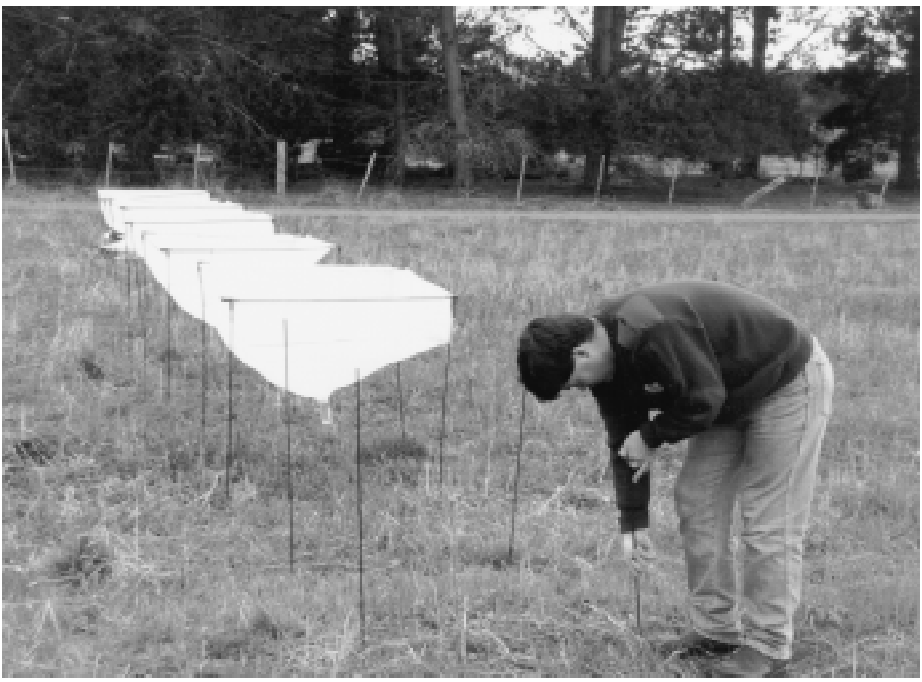


Photo 6. Setting up a row of catchers.

kg / ha reading can be taken at the top of the vial (Photo 8). This process is very quick and does not require sensitive weighing equipment to be taken into the field, as would be the case if an immediate result were wanted under the old system. If the vial contents are saved, it is possible to do a precise weighing subsequently, but this should not usually be necessary if the granular material is reasonably consistent.

A computer program ASPRAN (Aerial SPReading ANalysis), which is based on a Microsoft EXCEL spreadsheet, was devised to analyse the data. Flight details and catcher readings for the flight are entered and the program automatically produces a series of graphs showing repeated swathe profiles and total amount received over a 60 m band. This process is repeated for flight-line spacings at 2 m intervals from 8 m to 22 m. A table showing the effect of flight-line spacing on mean application rate and CV (calculated over two complete swathes including the two overlap zones) and a graph portraying these results are also shown. For convenience, the nine graphs, one table and the flight details are combined in a panel which can be viewed and, if desired, printed on a single A4 sheet (Figure 1).

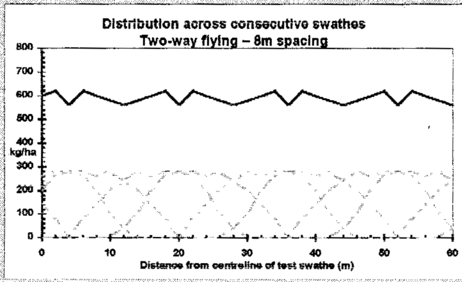
A two-way flying pattern with which adjoining passes are flown in opposite directions may produce different results from racecourse flying with which adjoining passes are flown in the same direction. The program therefore does separate analyses and produces separate outputs for the two patterns. For extra wide swathes where the catchers are spaced at three-metre intervals, another version of the program which plots results for line spacings of 12 m to 33 m over a 90 m band was produced. This analysis program, combined with the ease of reading individual catcher contents, allows results from an individual test flight to be quickly and easily assessed at the test site on a portable computer. If the initial results are unsatisfactory, adjustments can be made immediately to the equipment settings and / or flying techniques and the effects on distribution can be analysed from further test flights. Even without adjustments,

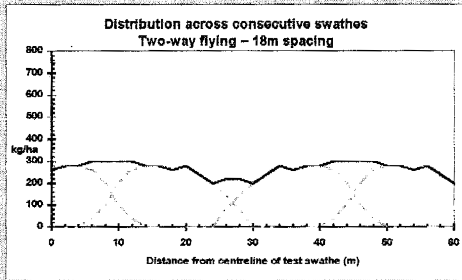
Photo 7. Attaching the collecting vial.

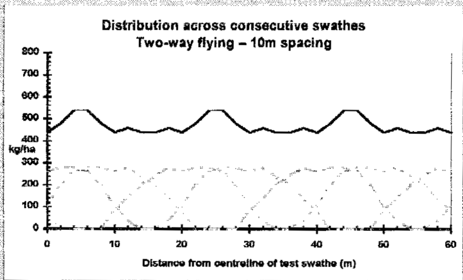
Photo 8. Reading the catch in kg/ha.

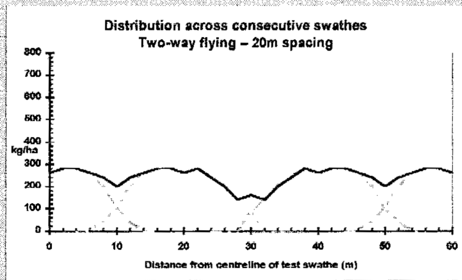
ASPRAN – Summary of analysis – Two-way flying

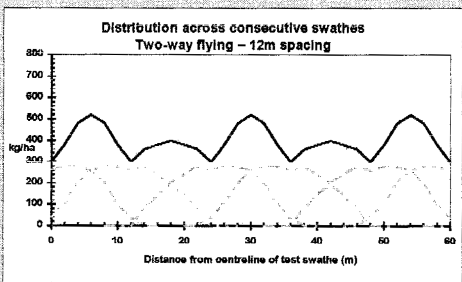
Date 1/4/97 **Contractor** Airspread Ltd. **Aircraft No.** VH – FLY **Flight No.** 1

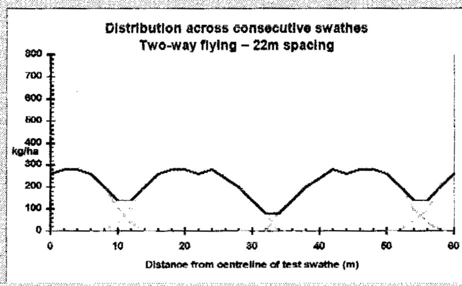


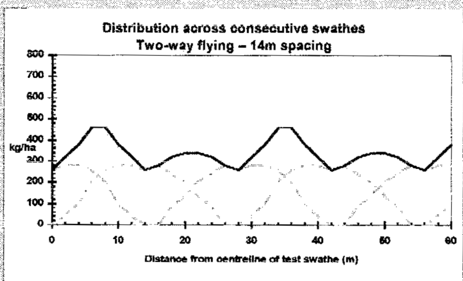






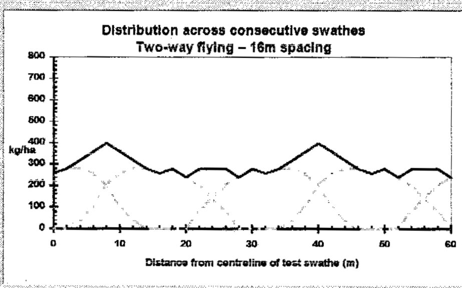


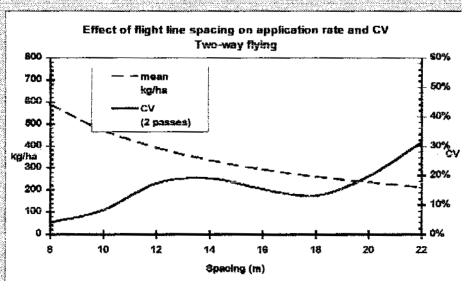




Effects of flight line spacing on application rate and CV
Two-way flying

Spacing	8m	10m	12m	14m	16m	18m	20m	22m
Rate (kg/ha)	590	472	393	337	295	262	236	215
CV	4%	8%	17%	19%	15%	13%	20%	31%





there will be some variation in the outcome between individual flights. It is therefore wise to base any analysis of the application rate and CV for different spacings on the average figures from a number of flights. A program to do this is included.

Evaluation of results

The aim is to find the widest, and therefore least costly, flight-line spacing which will give the required application rate at an acceptable CV. Often the CV will be low at narrow spacings which give the whole area a double dose, will increase at wider spacings which give some parts a double dose and some a single one, then decline again as the whole area receives a single dose before finally increasing as some parts receive nothing at all (see Figure 1). Where the curve of CV is rising steeply, the distribution will be particularly sensitive to drift or inaccurate flying. Racecourse flying will generally give a lower CV than two-way flying if the swathe profile is asymmetrical.

If the equipment is unable to deliver the material at a sufficient rate, it may be necessary to use a close spacing which gives a complete swathe overlap. This will double the flying costs and should be avoided if possible. If, on the other hand, the required overall application rate is achieved but at an unacceptable CV, it may be necessary to vary line spacing in order to produce a more even distribution while adjusting the flow to maintain the application rate. If a satisfactory compromise cannot be achieved, the contractor may be required to improve his spreading equipment before being considered for future work.

Once the preferred flight-line spacing, equipment settings and flying parameters have been determined, the flight guidance system can be programmed accordingly.

Discussion

The main advantages of this new system are:

- The equipment is very portable, and quick and easy to set up;
- With these larger catchers, the quantity of material can be easily and quickly assessed in the field without the need for sensitive weighing equipment;
- With a portable computer, the results can be analysed very quickly on-site (and printed out if a portable printer is also available), allowing immediate adjustments to be made until an acceptable result is achieved.

The net effect is that the evaluation of contractors' spreading equipment is quicker, easier, less costly and more reliable. Because the analysis is done immediately, there is also less likelihood of further testing sessions being required should the initial results prove unsatisfactory. The cost of flying time and fertiliser used in trials, as well as the labour costs, make this an important consideration. Furthermore, contractors usually like to keep their aircraft engaged in productive work whenever weather permits and may be reluctant to allow them to spend too much time on testing.

It should be noted that the CVs determined by this method which models exact replications of a single pass at precise spacings are likely to be lower than those derived by sampling an actual operation. Operationally, there would certainly be some variation in swathe profile between passes and also some variation from the nominal swathe spacings. However, this does not negate the method's value for comparing the capabilities of different equipment and determining how to optimise the performance of that equipment. It does mean though that it would be wise to run periodic checks of actual operations to see how operational performance compares with trial results.

Figure 1. An example of a printed summary of the analysis. The solid lines show the simulated catch across a 60 m band. In this case, if the intended application rate were 300 kg/ha, a flight-line spacing of 16 m would give near the required rate, at a low coefficient of variation of 15%.

In principle, the acceptable limit to the CV should be tied to the size of the sampling unit (catcher), which in turn should be related to what is a meaningful scale of variation for the purpose of the operation. Larger sampling units, by ironing out some of the variation, are likely to produce lower CVs than smaller ones. Larger sampling units are more appropriate for purposes such as fertilising trees, where it does not matter how the fertiliser is distributed within the tree's feeding zone as long as each tree receives a reasonable dose. By contrast, a smaller unit would be more appropriate for agricultural seeding or granular herbicide application, where even small, under-dosed patches can leave land unutilised or allow serious weed competition to persist. For fertilising plantations, the 1 m^2 sampling units used with this system are still a compromise between ideal size and manageability, but a preferable one to the smaller sampling units used previously.

Conclusions

By using lightweight, portable kite technology, this system has allowed a more appropriate, larger catcher to be used in sampling swathe profiles. The increase in catcher size should lead to more reliable results. The larger volume of material collected can be assessed with reasonable precision on a volumetric basis, eliminating the need to take sensitive weighing equipment into the field.

The compact size of the packed catchers facilitates transport and the ease with which they can be set up reduces the labour involved in running a trial. Thus, with this new system, it is possible for a reasonably thorough evaluation to be done by two people in one day. An additional advantage is the cost of the equipment which is less than that of the old-style catchers.

With the analysis program, it is easy to get immediate results from a portable computer and to make any necessary adjustments on-site. This should reduce the likelihood of follow-up trials being needed.

Acknowledgements

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