Semi-Automatic Survey of Crop Damage Using Color Infrared Photography

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ABSTRACT: In the Province of Quebec, crop insurance is available to protect producers against harmful effects. An aerophotogrammetric approach, using color infrared transparencies at a scale of 1:10,000, permits identification of damaged crops into three classes, mapping them with an analytical plotter, and compiling the results with a microcomputer. The data analysis provided by ground sampling would permit quick evaluation of crop damage and settling of allowances to producers.

INTRODUCTION

THE YIELD ESTIMATION of crops can be carried out using different approaches depending on resource and operational constraints. The usual procedure to determine mean yield consists of measuring the total amount of the specified product and dividing by the total area. However, this approach does not permit one to determine the variation of yield in relation to the variables causing damage for which the insured producer can obtain an allowance. In other words, the problem is not to evaluate the damage by subtracting the "normal" from the "actual" yield (McAdams, 1976), but to verify if the actual yield of crops represents a ratio over or under the one specified by the law.

In the Province of Quebec, the crop insurance act (Bill No 20, 1974) protects the producer against harmful effects of the forces of nature, including excessive rainfall. The producer may have insurance coverage on the basis of an individual plan or with regard to specific commercial crops. Each category of insured crop is guaranteed up to 80 percent of the average yield.

If the damage is spread evenly over the whole field, the average yield is a good estimate to evaluate the amount of loss. But, if the damage is heterogeneous, i.e., if some sections of the field are covered with good crops while other sections give lower than normal yield, determining the average actual crop damage becomes a problem. An appropriately weighted average is the logical answer to this problem.

To obtain an accurate average yield in such cases, it would be necessary to weight the different yields by their respective areas, and even discard areas for which the yield is too low to be economically harvested. This is almost impossible with ground procedures; therefore, an aerophotogrammetric approach is suggested. This would permit evaluation of areas of different classes of yield for which one can then estimate the yield values by ground sampling.

Details are presented below on a case study based on this principle. This study concerns the evaluation of pea and corn crops damaged by excessive rain during the growth period in July.

TEST AREA

The agricultural area chosen for this study is located on Bouchard Island, in the St. Lawrence river, near Montreal City. The elevation of the ground does not exceed 20-feet above sea level, and sometimes during the spring season the St. Lawrence river inundates the lowlands of this Island. The soil is silty-loam, very fertile, but requires very good drainage.

During the month of July 1982, rain was abundant (25-cm over normal). This created soil conditions too wet for normal production of peas and corn in many places. As a result, damaged crop areas of irregular shapes (Figures 1 and 2) spread over most parts of the fields under study.

METHOD OF STUDY

As it was impossible to accurately estimate the damage on the ground, an aerophotogrammetric approach was chosen. Color infrared film was loaded into a Wild RC-10 camera (23 by 23 cm) with a focal length of 150 mm and a yellow filter to image the test area at a scale of 1:10,000 during the first week

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FIG. 1. Normal and damaged corn crop.

FIG. 2. Normal and damaged pea crop.

TABLE 1. CLASSES OF CROP DAMAGE

Class	Crop quality	% of cover
1	Good	70 to 100
2	Medium	30 to 70
3	Bad	less than 30

of August, when the vegetation is normally at a maximum level of growth.

The photo interpretation done by an expert permitted separation of pea and corn crops based on image factors of color, texture, height, pattern, and so on (Philpotts and Wallen, 1969; Ladouceur, 1978). Moreover, for each crop, three separate classes of damage, based on their percentage of cover and crop quality (with regard to height of stem and minimum area), were considered (see Table 1).

The percentage of cover served to classify both the peas and the corn damage, whereas the height of stem was used only for corn. The texture was defined by an analog procedure, not a numerical approach (such as the one used by Maurer (1974)). Although the color is affected by many external factors, including illumination angle and film development, it was used to identify crops and damage. Concerning the minimum area, it was impossible to register the limits of very small areas of damaged crop. When the polygon was too thin, representing only a few rows, or where the damage was limited to a spot smaller than 0.25 ha (that is a polygon smaller than 0.5 by 0.5 cm on an image at a scale of 1:10,000), these small areas were added to a larger polygon identified by another class (Figure 3).

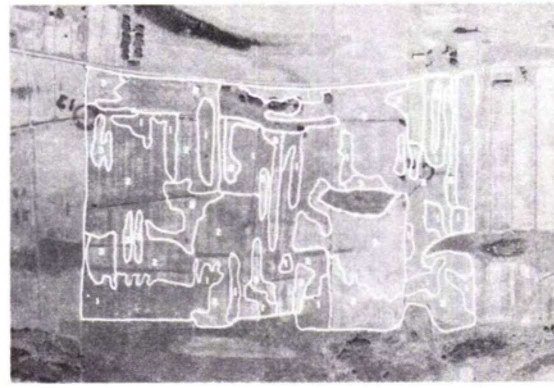

FIG. 3. Part of aerial photograph on which three levels of crop damage have been outlined.

TABLE 2. RESIDUAL ERRORS (RMS) FOR EACH STEREO MODEL

Model	Root mean square (m)		
	X	Y	Z
2-3	1.30	0.40	0.23
3-4	1.45	1.26	0.20
4-5	0.35	1.68	0.29
5-6	2.50	3.38	0.73
6-7	3.46	4.20	0.82
7-8	5.36	3.79	1.55
8-9	3.98	4.12	0.96

In order to map all of these polygons, certain different steps were followed.

IMAGE RECTIFICATION

On a base map at a scale of 1:10,000, already prepared by a photogrammetric procedure, five well identifiable control points were chosen for each stereo model in order to carry out the absolute orientation. This was done by the analytical procedure by using a Zeiss Stereotop modified into an analytical plotter (Ladouceur *et al.*, 1982). Table 2 shows the precision of absolute orientation obtained in each model.

The results shown in Table 2 indicate that the residual errors are smaller than the planimetric limits of line-tracing. Indeed, the largest error of five metres equals 0.5 mm at a scale of 1:10,000, which represents the precision of polygon boundary lines.

When the absolute orientation of a model was performed, the limits of polygons (followed through

TABLE 3. AREAS OF CROP DAMAGE CLASSES

			Damage classes		
		1	2	3	Total
Corn	Area (ha)	33.4	44.3	22.7	100.4
	%	33.3	44.1	22.6	
Pea	Area (ha)	39.7	53.6	32.6	125.9
	%	31.5	42.6	25.9	

FIG. 4. Instrumentation used for semi-automatic mapping.

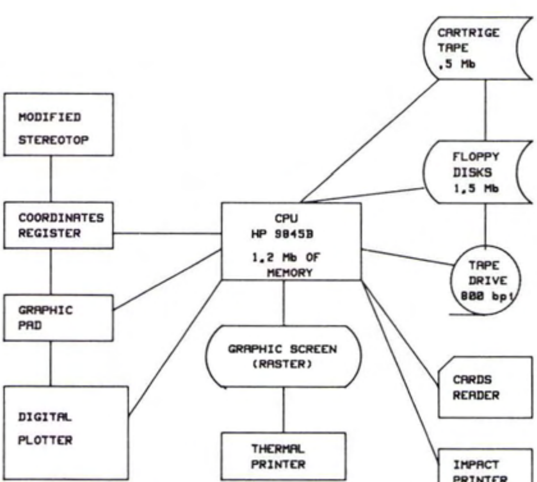

FIG. 5. Schematic of instrumentation arrangement used in the studies.

TABLE 4. WEIGHTING FACTORS AND STANDARD DEVIATION FOR EACH CLASSES OF DAMAGE CROPS (SIMULATION)

		Damage classes	
Crop	1	2	3
Corn	1	0.55 ± 0.15	0
Pea	1	0.45 ± 0.12	0

the floating point of the stereoplotter) were registered. Each polygon was identified and numbered with the help of a graphics pad. The coordinates of polygons were registered on "floppy disks" after they were rectified by algorithms in the HP 9845 microcomputer.

MAPPING

The mapping was carried out by the digital plotter HP 9870 at a scale of 1:10,000, while the cumulated areas of polygons for each class of crop damage were compiled and written to an HP 9871 printer (Table 3). The instrumentation arrangements are presented in Figures 4 and 5.

GROUND SAMPLING AND WEIGHTING

The last step is that of ground sampling in each crop damage class to determine yield. When the crop harvesters are in the fields, they are used to evaluate the yield of pea and corn for classes one and two only, because the third one furnished a rather low yield. The sampling consists of picking at random on the map a number of fields (around 20) of each class, one or two, for pea and corn crops. For each number, we establish that a strip covered by the crop harvester and made in the middle of the polygon represents a sample. The amount of produce gathered for each sample is registered and compiled in order to evaluate the average and the standard deviation for each class. If the average yields of class one show a value over 80 percent of normal yield, it is assumed that this amount is normal and the weighting factor equals unity. For the second class, the weighting factor represents the ratio, proportion of the yield of the first class. An extremely poor yield would be given a weight factor of zero. Table 4 presenting simulated results of a ground sampling would illustrate the idea. Eventually a combination of data from Tables 3 and 4 would be used to compute the weighted averages.

RESULTS ANALYSES

CORN CROPS

As the class 3 had a too poor yield to be harvested, it was given a value of zero. Thus, the weighted average yield was the following:

$$33.3 \times 1 + 44.1 \times 0.55 + 22.6 \times 0.0 = 57.6 \text{ percent.}$$

TABLE 5. EVALUATION OF DAMAGED CROPS ACCORDING TO DIFFERENT DATA INTERPRETATIONS

	Interpretation based on		
	1	2	3
Crop	Weighted average yield	Class one discarded	Profitability consideration
Corn	$ 50,200.00	$33,500.00	$27,750.00
Pea	$ 62,950.00	$43,100.00	$40,150.00
Total	$113,150.00	$76,600.00	$67,900.00

If the average yield (57.6 percent) for the whole field was chosen, the insurance company would have to pay for the whole area, because this average is less than 80 percent of the normal yield. Thus, the producer would have received an amount of $50,200.00 ($500.00* × 100.4 ha).

As the class one areas got good yields and covered 33.3 percent of the total area, it was felt that the interpretation considering weighted averages was not fair (at least for the insurance company). Another interpretation of the damage, by excluding the areas yielding better than average crop, would be fair to all concerned parties. For this second interpretation, it was considered that class one represents a normal yield, whereas classes two and three gave low yields. In that case, by excluding area class one, the damaged area becomes (44.3 + 22.7) = 67.0 ha and dues are $33,500.00 ($500.00* × 67.0 ha).

Finally, after a cost study, the break-even point was fixed at 0.65 (65 percent of normal yield) when the areas are close to class one. Referring to the ground sampling results, the average and standard deviation was 0.55 ± 0.15. On plotting this population on a probability scale, it was found that 74 percent of class two shows a yield lower than 0.65. Also, the analysis of location of class two on a map permitted us to conclude that more than 30 percent of class two is close to class one. In view of these considerations, a third interpretation of the damage can be made. This would give the following amount:

(0.74 × 44.3 + 22.7) $500.00 = $27,750.00.

PEA CROPS

Following the same pattern, the weighted average yield of the three classes is 50.7 percent, which would represent a payment of $62,950.00 by the insurance company. The second approximation would give a value of $43,100.00. Finally, the average and standard deviation were equalled to 0.45 ± 0.12, while the break-even point was fixed at 0.60. The plotting of these data on a probability scale shows that 11 percent of class two got a yield value over 0.60. Therefore, the third approximation gave a total of $40,150.00.

*Simulated value, per ha.

The different evaluations of crop damage according to the different interpretations of data are presented in Table 5. In all of these, however, the data obtained from the aerophotogrammetric approach (Table 3) provide the support necessary for all such evaluations.

In summary, we present the steps of the procedure to estimate the financial allowance to a producer for crop damage.

- Obtain color infrared photos (scale 1:10,000 in the present study).
- Perform photo-interpretation. Identification of crops and damage classes (Table 1).
- Map the results on a base map (of scale 1:10,000 in the present study).
- Estimate damaged class areas (Table 3).
- Perform ground sampling (choice at random on map, around 20 strip samples in each class of crop).
- Gather the products in each sample with crop harvester and estimation of averaged yield.
- Compare averaged yield with the 80 percent value of normal yield established by agriculture department in order to fix the weighting factor and standard deviation for each class (Table 4).
- Estimate the economical yield in determining the break-even point of the study on expenses.
- Estimate on probability scale the proportion of damaged classes having a yield lower than the economical value.
- Compile areas having a yield lower than the economical value.
- Evaluate the financial allowance to producer according to the rate per hectare fixed in insurance.

CONCLUSION

This study shows that the aaerophotogrammetric approach, for which the cost was $3,200.00 (2.8 percent of the total amount of insurance), permits a fairer evaluation of crop damage necessary for payments by the insurance company. By considering this semi-automatic procedure, the evaluation is impartial, fair, and reviewable (because the photos stay as permanent records). The approach would be considered cost-effective if the cost does not exceed 10 percent of the total insurance coverage.

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