Examples of the Wind Factor in Crop-Hail Damage

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ABSTRACT

1. Introduction

Those familiar with crop-hail damage are aware that the damage by hail is often made more severe by the wind occurring with the hailfall, but no simultaneous, quantitative data have ever been reported on wind, hail and crop damage. In an analysis of crop hail damages reported by Illinois farmers acting as hail observers, Changnon (1967) found that all heavy damages occurred with winds described as "damaging" by the farmer observers. Sizable hailfalls (those with many and relatively large hailstones) often occurred without producing significant crop damage, as long as strong surface winds did not occur. A later Illinois study (Changnon, 1971) of the relationship between hailfall characteristics and crop damage, based on hailpad data, showed that corn and soybean damages were well related to the impact energy or force of the stone impact. The impact energy will be stronger in high winds that drive hailstones horizontally at a faster speed than their terminal fall velocity. Schleusener and Jennings (1960) considered this in their test of a hail instrument developed to estimate hail energy per unit area. Some quantitative wind and hailfall results (Changnon, 1973; Morgan and Towery, 1975a) were obtained from data based on multi-sided passive hail sensors. These revealed that wind-blown hail occurred in 60% of the point hailfalls. The results also demonstrated that the total hail impact energy imparted by wind-blown hailstones can easily be five times as great as that in the absence of wind (Morgan and Towery, 1976).

A research project has been undertaken to investigate the feasibility of using aerial photography to assess crop damage, as proposed by Changnon and Barron (1971). Some of the photographs and associated surface crop damage assessments obtained as part of this research demonstrate the critical importance of wind in producing crop-hail damage. Crop damage patterns adjacent to large obstacles to the wind, such as trees, buildings or taller crops, clearly display the effects of wind shielding.

2. Observations of crop hail damage

Aerial photographs of crop damages in two hailstorms were taken approximately 2 weeks after storms at altitudes of 0.90 and 1.52 km above ground level (AGL) using color and false color infrared film. All photographs were taken with a Fairchild T-12 metrical cartographic camera having a 6-inch focal length lens.

Assessments of damages to drops were made by two crop-loss adjusters, one with 15 years experience and one with 5 years. These assessments of yield losses were determined by normal crop-loss adjustment procedures, which required examination of 100 plants at each location in a field. Loss assessment locations were determined with a tape measure and were referred to objects visible in the photographs.

The data are from two hailstorms which occurred in Illinois on 14 June and 12 July, 1975. The hailstorm on 14 June produced a large hailstreak (8 km wide by 40 km long). Hailstones were mostly 1.5–2.0 cm in diameter and very numerous. In certain locations they accumulated to depths of 30–50 cm on level ground. The storm occurred in moderately rolling country and large drifts of over 2 m were evident where the hail had washed into ravines and ditches. Crops were in the early stages of growth and not extremely susceptible to hail damage (Changnon, 1971). However, large areas of total (100%) crop damage occurred. Soybean plants were sheared off level with the ground and corn stalks were completely broken. Corn was about 1 m tall and soybeans 10–15 cm tall. Corn leaf canopies had begun to fill the 1 m spaces between rows, whereas the beans had not yet developed to that extent.

The second hailstorm studied occurred on 12 July and produced a hailstreak more typical in size (about 3 km wide and 11 km long) for Illinois (Changnon, 1970). Hailstone sizes were 1–2 cm in diameter and quite numerous. The stones accumulated to depths of 6–8 cm on level ground. Crops were fully grown, but not mature, and were more susceptible to hail damage than the crops in the June storm. Most of the damage was due to defoliation, although some stalk damage was evident. Very few broken plants were found. Corn was typically 2 m tall and beans were about 0.7 m high. Both corn and soybean crop canopies completely filled the spaces between the rows.

The heights of shielding trees were 13–17 m for the 14 June hailstorm, and 10–13 m for the 12 July hailstorm. No recorded wind measurements were available at either place. An observer who periodically examined a wind indicator at a small airport in the 14 June hailstorm said that the wind was over 25 m s^{-1} at times. Examination of crop damage (stalk bruises) indicated the surface winds came from a northwesterly direction for both storms. This is also supported by the aerial photographs and surface loss assessments.

3. Examples of crop protection by obstacles

Fig. 1 is a black and white version of an infrared photograph of hail damage from the 14 June storm taken from 0.9 km AGL. The hail-damaged soybean field had a pattern of damage which indicated protection from trees located at the northwest corner of the 20-acre field.

The protected area of soybeans is indicated by the light area immediately downwind (southeast) of the trees. The other white spotty areas in the photograph are small areas of light damage. There are also two small weedy drainage ditches (or low spots) which are indicated by a lighter, curved line in the southeast portion of the field and a northeast–southwest oriented line in the approximate center of the photograph. The soybean field is bound on the north by a road and by corn fields on the three remaining sides. The corn was bigger and stronger and did not sustain nearly as much damage as the soybean field.

Fig. 2 is the pattern of crop loss within the field based on 15-point assessments by the crop adjusters. The isopleth pattern of percent loss of yield reflects the lessened damage in the lee of the trees. Crop losses immediately adjacent to the trees were 30–40%, losses within 60 m were 50–60%, and losses in unshielded areas were 95–100%, or three times those in the area of greatest protection.

It is impossible to precisely determine the dimensions of the area protected by the trees because of the natural

FIG. 1. Black and white rendition of aerial photograph taken from 0.9 km AGL of crops damaged by hail from the 14 June 1975 hailstorm.

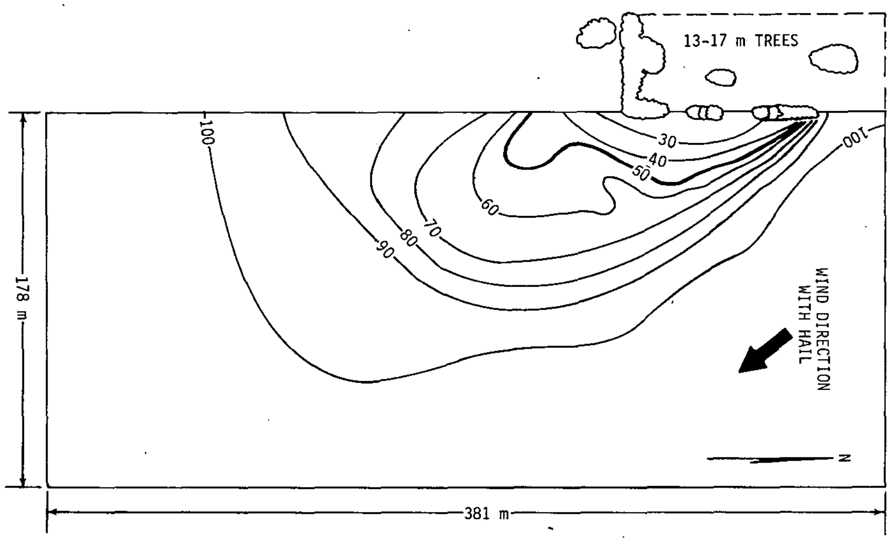

FIG. 2. Crop loss pattern (percent of yield) in a soybean field from the 14 June 1975 hailstorm.

variability in hail and crop damage, but it appears that some crop protection occurred as far as 120–150 m downwind of the trees, a distance-height ratio of 10:1.

Fig. 3 is a black and white version of an infrared photograph of hail damage from the 12 July storm taken from 0.9 km AGL. The soybean field was partially protected by the L-shaped line of trees on the northern edge of the field. This protection is indicated by the light area immediately downwind (southeast) of the trees. The 40-acre field is bound on the south by three cornfields and one bean field. The corn was not as badly damaged as were the soybeans. The small narrow field immediately north of the trees is a wheat field which has been harvested. The three distinct dark lines in the eastern half of the field occur because of the drainage pattern in the field.

Fig. 4 is the pattern of loss in this field based on 34 crop-loss assessments by the crop adjusters. Sharp gradients of loss values bound the area of crop protection in the immediate lee of the trees. Most of the shielded soybeans suffered less than 40% damage. Immediately adjacent to the trees, damage was as low as 6%. The loss in the unprotected areas ranges from 50 to 90%. The average of the loss estimates in the

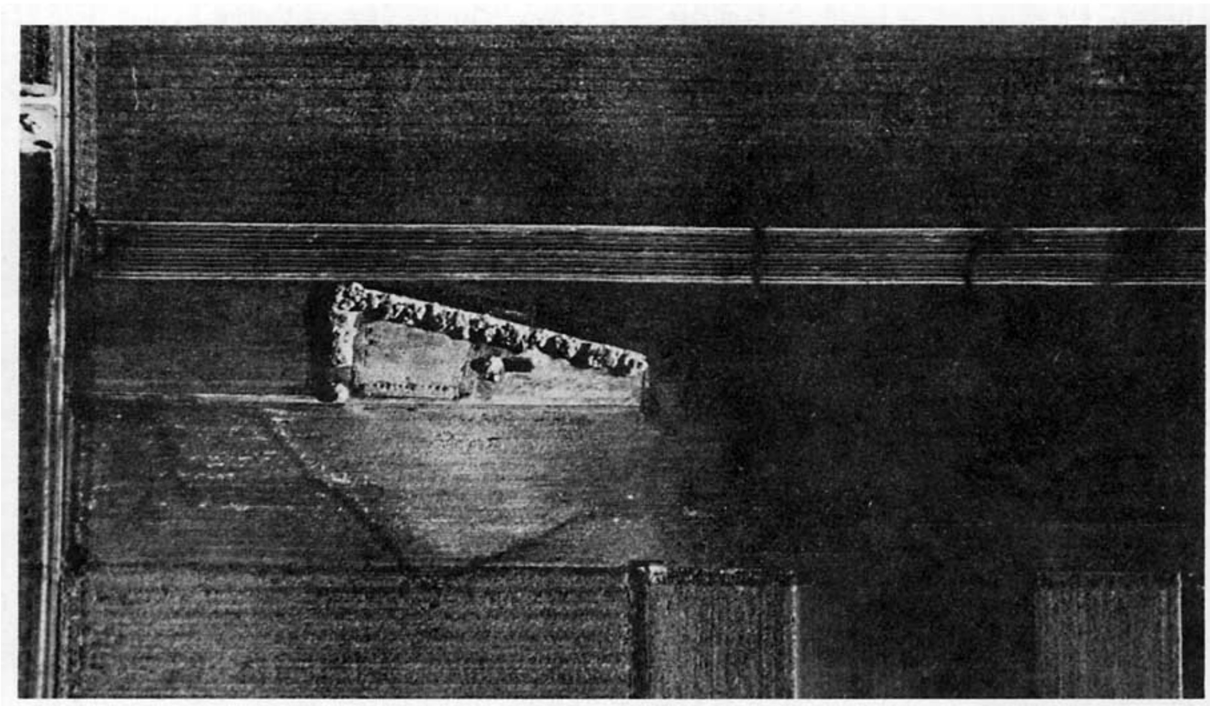

Fig. 3. As in Fig. 1 except for the 12 July 1975 hailstorm.

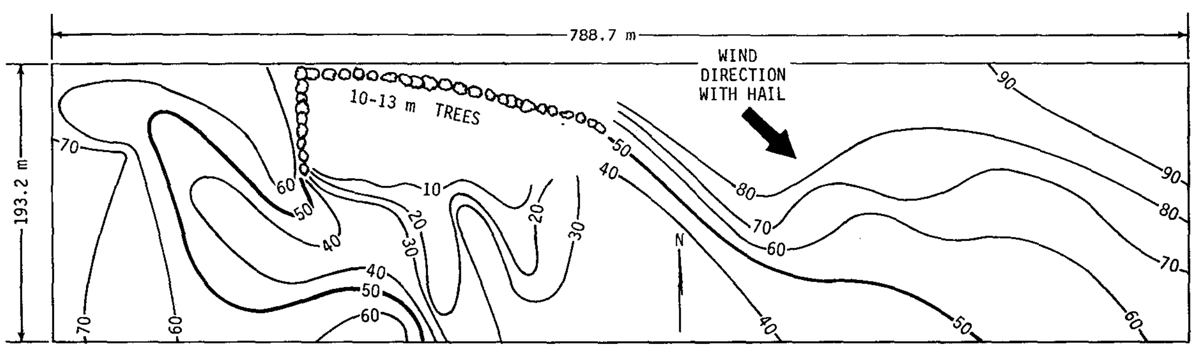

Fig. 4. As in Fig. 2 except for the 12 July 1975 hailstorm.

unprotected area was 71%, which is twelve times greater than the minimum loss of 6% in the shielded area and three times the average losses in the protected area. The downwind extent of the tree-protected area was at least 150 m, or 12 times the height of the trees.

Examination of several areas where fields of tall (2 m) corn were adjacent to fields of shorter soybeans has shown that corn fields typically shield the beans for 18–20 m downwind of the corn. The protection from wind-driven hail loss is obviously not as great as for trees, but the ratio of crop height to the length of the area is about 10:1 as in the case of trees.

4. Conclusions

In the examples shown, wind-driven hail loses were 3–12 times greater than where the crops were shielded from the wind by large obstacles. The area of reduced loss generally extended to 10 times the height of the obstruction.

The reduced damage in the lee of obstacles can be explained as a result of at least three factors, all related to the wind and its interaction with the obstacle. First, the obstacle will intercept some of the stones and create a partial shadow effect. From observations of the angle of arrival of hailstones ($\leqslant 60°$ from zenith) this shadow would extend downwind to one or two times the height of the obstacle. Second, the wind flow around and over the obstacle will be disturbed in three dimensions and this will cause a divergence of stone trajectories such that for some distance downwind fewer stones will reach the ground. At some greater distances more stones will be reaching the ground. Finally, the wind speed will be reduced in the lee of the obstacle and the total kinetic energy of stones falling there will be reduced. Of the last two effects, the latter is probably the major one because the kinetic energy of a hailfall (assuming all stones are of the same size) varies linearly with the number of stones but depends on the square of the wind velocity.

The wind-shielding effects shown are worth serious consideration for application in farm practice. For example, tree rows might prove quite valuable in reducing hail damage in particular situations.

Care must be exercised in using crop-hail damage as an evaluation tool for hail suppression experiments. Variations in loss over an area will be a function of the wind as well as of the hail intensity.

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