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Cropping Management Using Color and Color Infrared Aerial Photographs

Manual airphoto interpretation proved useful in delineating seasonal plowing operations and in evaluating crop residue management in a watershed for a cropland erosion study.

Introduction

With the passage of the Federal Water Pollution Control Act Amendments of 1972 (PL-9200), each state is directed to control point and nonpoint sources of pollution. This legislation deals with the improvement of the quality of the nation's lakes and streams and includes controlling soil erosion from cropland.

Abstract: *The Universal Soil Loss Equation* (USLE) *is a widely accepted tool for erosion prediction and conservation planning. Solving this equation yields the long-term average annual soil loss that can be expected from rill and inter-rill erosion. In this study, manual interpretation of color and color infrared 70 mm photography at the scale of 1:60,000 is used to determine the cropping management factor in the* USLE. *Accurate information was collected about plowing practices and crop residue cover (unharvested vegetation) for the winter season on agricultural land in Pheasant Branch Creek watershed in Dane County, Wisconsin.*

Leaving crop residues (i.e., unharvested vegetation) has long been recognized as a significant factor in reducing cropland soil losses from wind and water. By 1880, Wollny (as stated in Baver *et al.*, 1972) realized the importance of canopy cover in preventing rainfall from reaching bare soil and initiating erosion. Past experience and research has demonstrated that adequate vegetative soil cover (1) reduces raindrop impact by dissipating rainfall energy, (2) prevents surface sealing, thus allowing greater infiltration, and (3) impedes surface flow velocity, therefore lowering the carrying capacity of the runoff (Gard *et al.*, 1956; Mannering and Meyer, 1963; Meyer *et al.*, 1970; Van Doren and Stauffer, 1943). The net effect of leaving crop residue on fields, as a management practice during the winter season, is a reduction in soil losses when compared to residue removal practices (Sloneker and Moldenhauer, 1977; Wischmeier, 1973).

The most common procedure used by the Soil Conservation Service (SCS) to collect information on residue management is to conduct field studies. However, this is costly and time-consuming when performed annually over extensive areas. An efficient, cost-effective technique is needed by planning agencies throughout the nation to record up-to-date information.

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Background

To compute long-term average annual soil losses, Wischmeier and Smith (1965) developed the Universal Soil Loss Equation (USLE) given in the form:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

In this equation, A is the estimated soil loss expected from a field due to rill and inter-rill (sheet) erosion (typically expressed as $kg/m^2/year$). The factors R, K, L, and S are the watershed parameters of rainfall, soil erodibility, slope length, and slope gradient, respectively. Vegetation cover is represented by C, the cropping management factor. This factor is the ratio of soil loss from a field with specific cropping management or plant cover to that from a fallow condition. The P factor considers erosion control practices such as contouring, strip cropping, terracing, or grass waterways employed by farmers to slow runoff velocity and reduce the movement of sediment off of cultivated fields.

C and P values vary as a function of the land management systems used. In particular, crop residue practices and seasonal plowing operations employed by a farm operator are the C factor determinators.

This equation is widely used by the SCS for soil erosion predictions and conservation planning. The product of six major erosion factors in the USLE represents the average annual soil loss that can be expected from a field, under a particular set of conditions.

Study Area

Pheasant Branch Creek watershed encompasses 6136 hectares and is situated in the terminal and recessional moraine area of Dane County, Wisconsin (Figure 1). The city of Middleton, with a population of 11,200 and surrounded by an agricultural area which supports a considerable number of dairy, beef, and swine operations, provides the study area with extensive urban and rural runoff. Almost 70 percent of the land in the Pheasant Branch Creek watershed is classified as agricultural by the Dane County Regional Plan Commission. Fifty percent of the cropland in this watershed is devoted to corn, 12 percent to oats, and 38 percent to hay. Estimated soil loss from the cropland in Pheasant Branch is 1.5 $kg/m^2/year$ (6.5 tons per acre per year), although some fields exceed 3 $kg/m^2/year$ (12 t/a/yr) (Brink *et al.*, 1977).

Tolerable soil loss limits in this portion of Dane County are 0.7 to 0.9 $kg/m^2/yr$ (3 to 4 t/a/yr). Not only is there a potential for water quality problems in Pheasant Branch, but soil removal also is greater than soil replacement. When this occurs, there is a decrease in the overall natural agricultural productivity (Hudson, 1971).

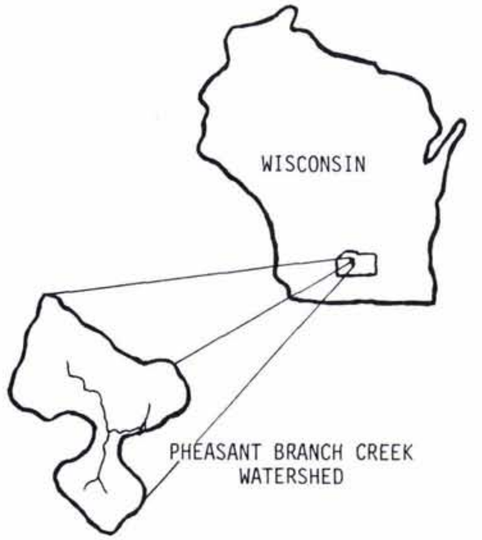

Fig. 1. Location of Pheasant Branch Creek watershed in Dane County, Wisconsin.

In our study area, conventional tillage is the predominant agricultural practice used by farmers. This means that moldboard plowing is performed in the fall or spring with crop residues either left or removed over the winter season (Griffith *et al.*, 1977). Figures 2, 3, and 4 are ground photos depicting the possible seasonal plowing and residue management combinations for conventional tillage.

Wischmeier (1973) reported the effect of residue (removed or left) on the magnitude of C values under various tillage and crop-

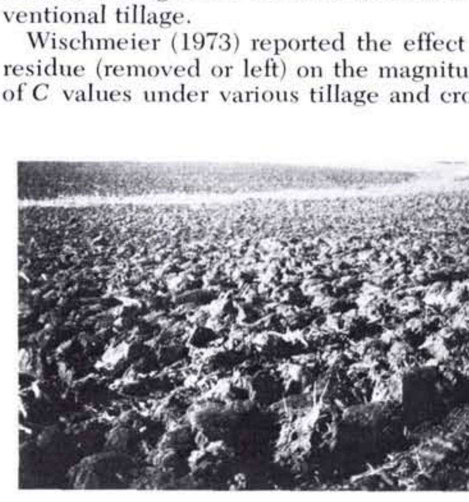

Fig. 2. Black-and-white ground photo taken in the fall of fall plowed field conditions.

FIG. 3. Black-and-white ground photo taken in the fall of fields that will be spring-plowed with residues-removed.

FIG. 4. Black-and-white ground photo taken in the fall of fields that will be spring-plowed with residues-left.

ping system combinations. Fields in Dane County, Wisconsin subjected to fall-plowed/residue-removed practices yield the highest *C* values (Table 1), whereas spring-plowed/residue-left operations provide the lowest *C* values for the predominant crop sequences (rotations) found in the area. When all other soil loss factors in the USLE are the same, lower *C* values indicate less erosive conditions.

Color and infrared photography can provide accurate land-use data for cropland identification (Eyre, 1971; Malgram and Garn, 1975). Also, results from other studies indicate the usefulness of remote sensing for identifying bare soil and differentiating between live and dead vegetation (Parry *et al.*, 1969; Stephens, 1976).

In our study, we used manual airphoto interpretation to determine crop residue management practices (*C* values) in a watershed. Area measurements of the percent of cropland devoted to various conventional tillage operations were made by visual estimates with a hectare-sized grid cell analysis. This method utilized the characteristic photo patterns produced by each cropland management combination.

MATERIALS AND METHODS

The procedure followed in this study consisted in obtaining appropriate low-altitude photography at a scale of 1:60,000, performing manual airphoto interpretation, and comparing the interpretation results with a field study of fall and spring plowing operations in the study area. Analysis was performed in Pheasant Branch Creek watershed on randomly distributed sample areas using a representative watershed sampling method (95 percent confidence interval) developed by the Wisconsin River Basin Planning Staff (Brink *et al.*, 1977). For our watershed, 18 sample areas of 65 hectares (160 acres) were randomly selected for simultaneous field and photo interpretive study. Taken collectively, the results obtained from the selected parcels represent the current

TABLE 1. CROP MANAGEMENT FACTOR VALUES FOR CONVENTIONAL TILLAGE PRACTICES AND FOUR CROPPING SEQUENCES IN DANE COUNTY, WISCONSIN*

Crop Sequences**	Crop Management Factor			
	Fall-Plowed		Spring-Plowed	
	Residue-Removed	Residue-Left	Residue-Removed	Residue-Left
CCC	0.50	0.45	0.45	.40
CCCOHH	0.25	0.20	0.20	.16
CCCOHHH	0.20	0.16	0.16	.14
CCOHH	0.14	0.12	0.12	.10

* Source: Soil Conservation Service (SCS).

** Refers to the predominant crop sequences found in Pheasant Branch Creek Watershed, where C = corn, O = oats, and H = hay. For example, CCOHH equals 2 years of corn, followed by 1 year of oats, followed by 2 years of hay.

TABLE 2. AERIAL PHOTOGRAPHY USED FOR INTERPRETATION OF SEASONAL PLOWING AND RESIDUE MANAGEMENT

Film Type	Date	Scale	Information Derived
Color	August 1977	1:60,000	Cropland
Color	March 1978	1:60,000	Fall Plowing
Color IR	March 1978	1:60,000	Fall & Spring Plowing

land-use management in Pheasant Branch Creek watershed.

PHOTOGRAPHY

Color and color infrared (CIR) 70 mm aerial photography was used in our study. Table 2 lists the film type, date, scale, and derived information selected for analysis. Some color prints also were made for use in the field survey.

PHOTOINTERPRETATION

Utilizing field survey information, combined with data acquired by manual analysis of selected aerial photos, the interpretive key in Table 3 was developed for pattern recognition of seasonal plowing practice and residue management in Pheasant Branch Creek watershed. For example, Figure 5 is a black-and-white copy of a color infrared photo taken in March, 1978, (preplanting season) of a portion of the study area. Corn is the predominant summer crop grown at this site.

In Figure 5, exposed soil shows up dark, whereas any corn residue remaining on the agricultural fields is represented by light tones. Any remaining crop residues in fall-plowed fields (dark photo tones) are turned under during the plowing operations so that bare soil conditions are produced.

Spring-plowed/residue-left conditions show up as smooth-textured light tones on the photo. For this management practice, an even spreading of residue remains during the winter season as a soil cover and the land is plowed in the late spring to prepare for planting.

In spring-plowed/residue-removed operations, plowing is performed later in the spring for planting on cropland that has all of the residue removed except for the base of the corn stalk (see Figure 3). Therefore, at the time the photo (Figure 5) was taken, both bare soil and crop rows can be distinguished and a characteristic striated photo pattern is produced (uppermost center portion of the photo).

Hectare-sized grid cells at the proper scale were printed on mylar. This mylar grid was placed over the photos and, utilizing a zoom stereoscope, a visual estimate was made of the amount of cropland devoted to each combination of seasonal plowing and residue management. This procedure was performed for each of the 18 randomly distributed sample sites and, when taken collectively, provided accurate up-to-date information on the land management in Pheasant Branch Creek watershed.

RESULTS AND DISCUSSION

A comparison of the results obtained from manual airphoto interpretation of color and

TABLE 3. INTERPRETIVE KEY TO PLOWING AND RESIDUE PATTERNS IN PHEASANT BRANCH CREEK WATERSHED

Land Use Management	Land Cover Characteristics	Photo Image Characteristics: Color Photos (August 1977)	Color Photos (March 1978)	CIR Photos (March 1978)
Cropland	Row Crops	Dull Bluegreen Tones	N/A*	N/A
Fall-Plowed/Residue-Removed	Bare Soil	N/A	Dark Brown Tones	Dark Green Color
Fall-Plowed/Residue-Left	Bare Soil	N/A	Dark Brown Tones	Dark Green Color
Spring-Plowed/Residue Removed	Bare Soil & Crop Rows	N/A	Lt. Yellow Tones, Striated	Lt. Green Striated
Spring-Plowed/Residue-Left	Residue Cover	N/A	Lt. Yellow Smooth Texture	Lt. Green Smooth Tex.

* N/A = Not Applicable

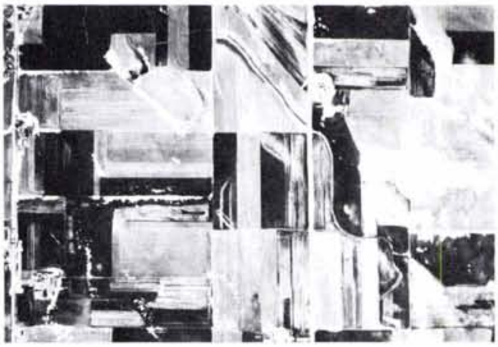

FIG. 5. Black-and-white copy of CIR photo taken in March 1978 showing the seasonal plowing and residue management operations in a portion of Pheasant Branch Creek watershed (scale, 1:38,000).

color infrared photos (scale 1:60,000) taken in March 1978 and a field study conducted simultaneously in Pheasant Branch Creek watershed is presented in Table 4. The results demonstrate the usefulness of small-scale color and CIR photography for evaluating plowing practices in a watershed that is subjected to conventional tillage operations. This cultivation practice is the standard practice for corn in the eastern Corn Belt States—Illinois, Indiana, Wisconsin, Ohio, and Michigan (Griffith *et al.*, 1977). Moldboard plowing is performed in the fall or spring with crop residues removed or left.

In our study area, fields that were spring-plowed, with residues removed or left, were easily discernable on the airphotos. However, because of the thoroughness of Wisconsin farmers in turning the soil over in the fall, our manual interpretive procedures could not distinguish between fall-plowed/residue-removed and fall-plowed/residue-left conditions. In Table 4, the two fall management practices are combined into a single category—fall-plowed.

The findings from both airphoto interpretation and the field study indicate the predominance of conventionally tilled fall-plowing in Pheasant Branch Creek watershed. Almost two-thirds of the cropland in the study area has exposed bare soil conditions throughout the winter and early spring seasons. Unfortunately, this situation is conducive to erosion from snowmelt runoff and heavy spring rains which can impair water quality and reduce cropland productivity. Spring-plowed/residue-left conditions offer the most soil protection for cultivated fields but, as indicated by our airphoto interpretation and field study results, this practice is used on less than 25 percent of the conventionally tilled land in Pheasant Branch.

When compared with the field study, our airphoto technique required approximately 50 percent fewer work-hours to complete. This represents a considerable time savings to agencies responsible for monitoring soil conservation programs on agricultural land in many watersheds.

CONCLUSIONS

Determining plowing practices on cropland is important to agencies involved in soil conservation and watershed planning. Vital to many of the agencies is the ability to quantify soil loss, to encourage necessary conservation practices, and to develop ongoing management plans for nonpoint pollution programs. Obtaining this data is difficult because extensive areas are involved and land management practices are constantly changing. Results from our study indicate that remote sensing can be useful in solving these problems of areawide erosion analysis.

In our study, 70 mm color and color infrared photography at a scale of 1:60,000 provided up-to-date total coverage of Pheasant Branch Creek watershed in Dane County, Wisconsin. When compared with a field study, manual airphoto interpretation provided accurate information about current

TABLE 4. COMPARISON OF FIELD STUDY AND PHOTO INTERPRETATION RESULTS SHOWING PERCENT OF SEASONAL PLOWING AND RESIDUE MANAGEMENT ON CROPLAND IN PHEASANT BRANCH CREEK WATERSHED IN DANE COUNTY, WISCONSIN

Management Practice	Field Study Results (%)*	Photo Interpretation Results (%)*
Fall-Plowed	64.0	64.6
Spring-Plowed/Residue-Removed	13.0	13.9
Spring-Plowed/Residue-Left	23.0	21.5
	100.0	100.0

* Expressed as a percent of the total agricultural land in cultivation in Pheasant Branch Creek Watershed.

plowing practices and residue management on conventionally tilled cropland.

As illustrated by our research, remote sensing is an effective tool for estimating USLE *C*-factor values, providing a permanent record of cultivation practices on conventionally tilled agricultural land, and reducing the time required for data collection. If performed on a regular basis, airphoto analysis can be used for continuous assessment of cropland management in watersheds.

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