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Use of a Chromogenic Film for Aerial Photography of Erosion Features

The exceptionally wide exposure latitude of Ilford XP1 is highly beneficial to photography under conditions of low sun angles.

INTRODUCTION

ASSESSMENT OF RILL EROSION is important to evaluate the effectiveness and application of Best Management Practices to prevent nonpoint source pollution. Aerial photography with color and color infrared (CIR) film has provided useful information about rill erosion at 1:2000 and larger scales. Sufficient detail was recorded on 70-mm aerial films to rank eroding areas according to rill density and to inventory soil movement on rangeland (Frazier and McCool, 1981; Tueller and Booth, 1975).

ABSTRACT: *The potential of Ilford XP1 photographic film in 35-mm format for aerial photo assessment of erosion was investigated. A wide exposure latitude (ASA 50 to ASA 1600) makes this film attractive for aerial photography where lighting conditions are variable and rapid shutter speeds are required. The film was field tested for image quality using exposures equivalent to ASA 100 to ASA 1000. A D-log E curve was developed by photographing a gray card from ASA 40 to ASA 128,000. The D-log E curve from negatives has a long straight portion with 0.5 gamma and a toe that is barely perceptible beginning at ASA 1600. Acceptable prints were obtained throughout the range ASA 100 to ASA 1000. A bar chart photographed at ASA 1000 showed separable line pairs 25.4 mm in width, equivalent to 35 line pairs/mm on the negative. Examples show that the film is useful for documenting the effects of erosion after cultivation and for measuring rills or soil slips.*

In this study we evaluated a chromogenic film, Ilford XP1, for 35-mm, low oblique photography of erosion features. The film has an unusually wide exposure latitude, can be processed by any photo lab, is inexpensive, and is easy to enlarge. It requires no special camera equipment, so the techniques that we have developed with it should be useful elsewhere. Most importantly, this film has a considerable margin for error by the photographer, which is an advantage in adopting new techniques. We are using it to develop techniques for quantifying rill erosion, but our evaluation should also prove useful to others doing environmental assessment work with aerial photography.

BACKGROUND

The geographic area that we need to assess for erosion is known as the Palouse region. It is a large area of silty, loessial soils on steep (30 to 45 percent) north, northeast, and northwest-facing slopes and on 0 to 30 percent south and west-facing slopes (USDA, 1978). Most water-caused soil erosion occurs between November and April. The erosion features that need to be photographed (primarily rills) are highly visible during February, March, and April. An assessment of the soil surface condition prior to the season of erosion must be made after the fall planting but before snowfall occurs, which is late October to mid-November.

This timing creates difficult conditions for aerial photography. The period when major cloud cover begins is in November and it extends well into April. The "Aerial Photographer's Clear Day Map" shows 1 to 3 days in February and 3 to 6

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 49, No. 8, August 1983, pp. 1211-1217.
0099-1112/4908/-1211$02.25/0

in March and April (Cravat, 1968). The period from November to January shows less than 30° solar altitude, a condition when photography is not recommended. In spite of this, we must record the uneroded soil surface condition before the winter precipitation starts in November.

Requirements

Most of the rills range in width from 30 to 250 mm. If we are to accurately represent these on film, image motion must be reduced to a minimum and by techniques which require no special equipment. We used rapid shutter speeds, 1/1000 second or faster, to minimize image motion as most 35-mm SLR cameras have this capability. At a ground speed of 129 km/hr, and with a 135-mm lens, a 1:2000 scale image will have 18 μm of image motion. A rapid shutter speed increases the lighting problem caused by low solar angles and demands fast film speeds or larger aperature openings or both. Larger aperature openings provide less than maximum resolution, and high speed films are well known for having large grain sizes; both situations produce lower quality images.

Characteristics of Ilford XP1

Ilford XP1 is a black-and-white (B & W) negative film which possesses a combination of B & W and color image forming techniques. The emulsion is composed of two silver layers which are activated by light. They, in turn, activate color couplers during development, and the silver is completely removed to leave an image formed by dyes. Hence, the term chromogenic or "color producing" is applied.

According to literature supplied with this film, XP1 can be exposed over a range of 50 to 1600 ASA and, in addition, film speed can be varied from exposure to exposure within any roll without altering the development process. Optimum exposure is ASA 400. Overexposure is supposed to produce finer grain. Schwalberg (1980) reported that finer grain is produced because added exposure permits activation of more color couplers which fill in dye patterns that separate light from dark images. The film literature calls for processing with Ilford chemicals or C-41. We have used both satisfactorily. According to Schwalberg (1980), the base density increases with temperature and the Ilford process should be used at 104°F, which is 4° higher than with C-41. Negatives developed in Ilford chemicals have a darker brown tone than those developed by the C-41 process.

These characteristics are very important for our purposes. We can set the shutter speed at 1/1000 sec to reduce image motion, the *f*/stop at 8 to use the center of the lens, and then adjust the camera ASA to balance the light meter. This

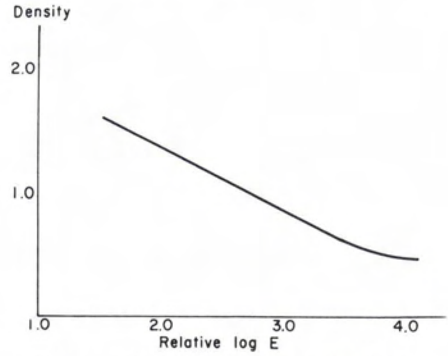

Fig. 1. D-log E curve for Ilford XP1.

balance provides assurance that exposures are within the allowable range of the film. Most of our aerial exposures using this technique have balanced at ASA 400, but the range has been from ASA 100 to ASA 1000.

We have also investigated the film characteristics by photographing an 18 percent gray card placed in full sunlight and in open shade. Camera shutter speeds and lenses were the same as used for the aerial work. A D-log E curve was developed from the negatives (Figure 1). Two lenses were used, a Zuiko 135 mm from *f*22 (D = 0.46) to the maximum opening of *f*3.5 and a 50 mm to extend the curve to *f*1.8 (D = 1.6). All exposures were for 1/1000 sec. The curve has a long straight-line portion with a toe that is barely perceptible and no shoulder—at least, not within the range of exposures we have used. Essentially, this means that we are not likely to overexpose the film at 1/1000 sec and will underexpose it only at openings of *f*11 or smaller.

The tradeoff with a film that has wide exposure latitude is that it has low contrast. The slope of the D-log E curve (gamma) in Figure 1 is about 0.5. This has not been a problem for erosion work because we can print the enlarge-

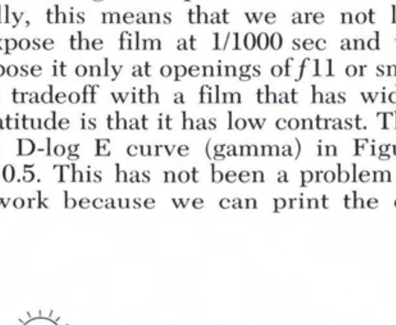

Fig. 2. Position of plane for hand-held photography of hillslope erosion.

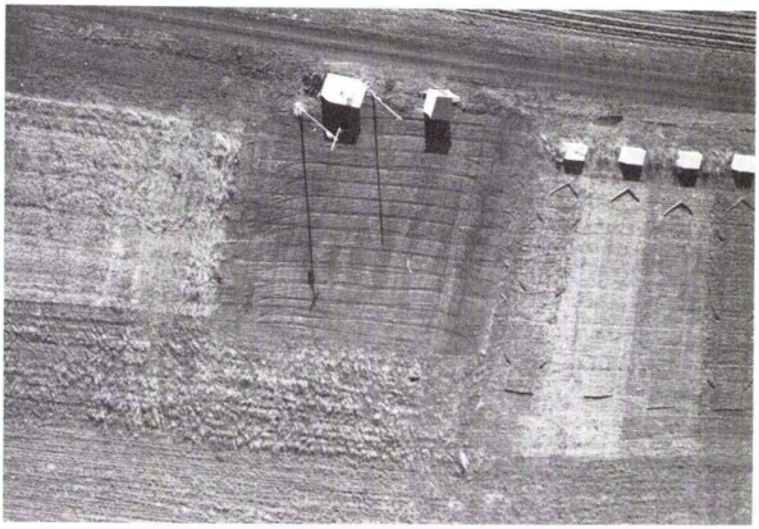

FIG. 3. Erosion test plot area photographed on 1 November 1981 at $f3.5$ and 1/1000 sec, ASA 100.

ments on high contrast paper (Kodak 1594, contrast 5, plastic coated) and there is ample contrast to distinguish features. Rills are photographed when filled with shadow and the soil surface adjoining the rills usually has high enough reflectance to provide good separation.

APPLICATION PROCEDURES AND RESULTS

Normally, negatives are acquired from a camera position about 300 m above ground level off the lower end of an eroded slope (Figure 2). This position allows the photographer using a hand-held camera to locate ground measurement stations through the viewfinder and still be roughly perpendicular to the slope. Many photographs are slightly oblique to the surface, but the change in scale over the target area has not caused a problem. A change of ± 150 across a 1:2000 nominal scale negative is acceptable for our purposes.

Prints showing a range of exposure from $f3.5$ to $f8$, some with yellow or polarizing filters, are shown in Figures 3 through 6. All were exposed for 1/1000 sec with an Olympus OM-1 and a Zuiko 135-mm lens. Figures 3 and 4 were taken at 0840 PST, 1 November 1981, with the solar

FIG. 4. Erosion test plot area photographed on 1 November 1981 at $f8$ and 1/1000 sec, ASA 400.

FIG. 5. Erosion test plot area photographed on 16 April 1982 at *f*8, 1/1000 sec, using a Tiffen yellow (Wratten #12) filter, ASA 640.

altitude about 13° over an area of erosion research plots. Slope of the plots is about 9° toward the sun so the effective angle is about 22°. The negative from which Figure 3 was made appeared to be overexposed at *f*3.5 compared to Figure 4 which was exposed at *f*8, at the recommended ASA of 400. Figure 3 was balanced at ASA 100. These photos illustrate a smoothly cultivated field seeded to winter wheat and left exposed to the forces of erosion for the winter. All of the necessary detail is available in either image, although there is better contrast in Figure 4. Micro relief is enhanced by the low sun angle, which makes assessment of the pre-erosion condition an easy task.

Post-erosion photography of the same plot was obtained on 16 April 1982 at 0830 PST, effective solar altitude about 44° (Figures 5 and 6). Filters were used to study their effects on image quality. Figure 5 was taken with a Tiffen yellow (Wratten #12) at *f*8 and required an ASA of 640. Figure 6 was taken with a Toshiba polarizing filter and, at *f*8, required an ASA of 1000. The negative for Figure 6 was underexposed relative to Figure 4 but not to the extent that information was lost. Rills of about 38 mm in width are mea-

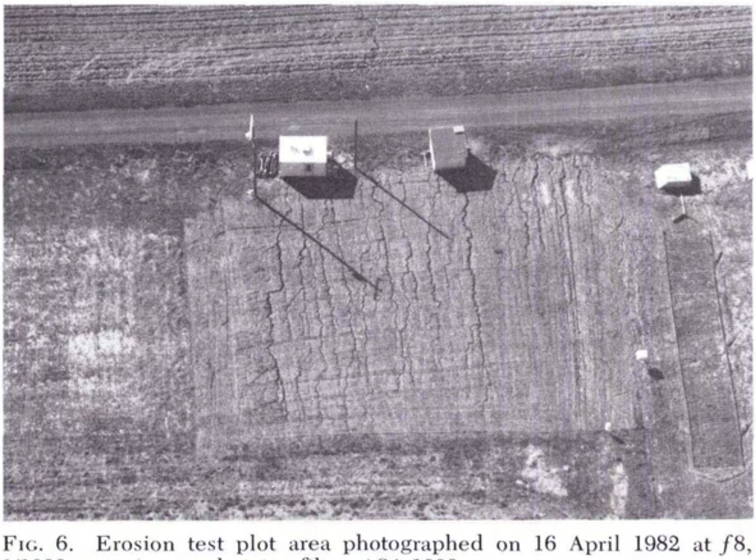

FIG. 6. Erosion test plot area photographed on 16 April 1982 at *f*8, 1/1000 sec using a polarizing filter, ASA 1000.

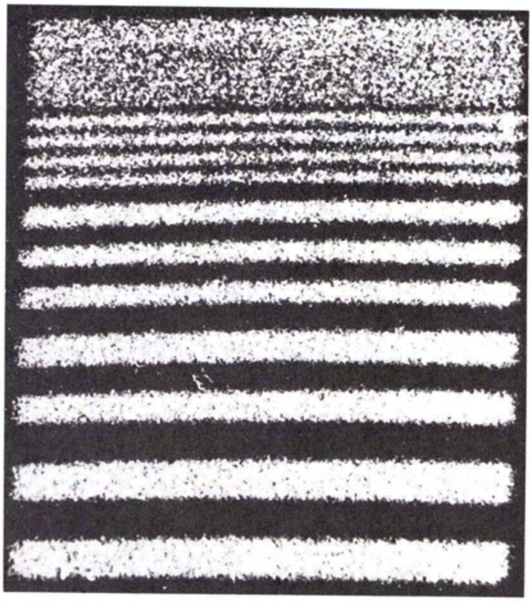

FIG. 7. Resolution target magnified 100×. Minimum separable line pairs are 25.4 mm.

sureable on either negative but are more easily measured on Figure 5 which has better exposure and contrast. This is comparable to measurements reported earlier with CIR film (Frazier and McCool, 1981).

A resolution target was photographed on one frame at *f*8 with the polarizing filter. Four pairs of black and white lines, 25.4 mm in width, represent the minimum line separation visible on the negative (seen enlarged to 100× in Figure 7). This is equivalent to 35 line pairs/mm on the negative.

Documentation of erosion under rigorous photographic conditions is illustrated in Figures 8 through 10. A soil slip was photographed in the shadows of a very steep north-facing slope on 6 March 1982 at 1230 PST with the solar altitude at about 35° (Figure 8). The negative was exposed for 1/1000 sec at *f*5.6, ASA 640. The field above the slip was left in a rough condition over winter and only minor rills are evident. The soil was probably saturated from melting snow banks and rainfall, causing it to slide and flow down the slope and into the forest zone. Sunlit areas are properly exposed while the tongue of the flow is underexposed in the deep shadow. Despite this underexposure, the path of the flow may be traced to where it enters the brush.

Photographs taken over open areas are better because most of the scene is sunlit and exposures may be set for the whole scene. The soil slip and rill pattern in Figure 9 are on a steep N 75°W slope. At 0950 PST the sun is nearly op-

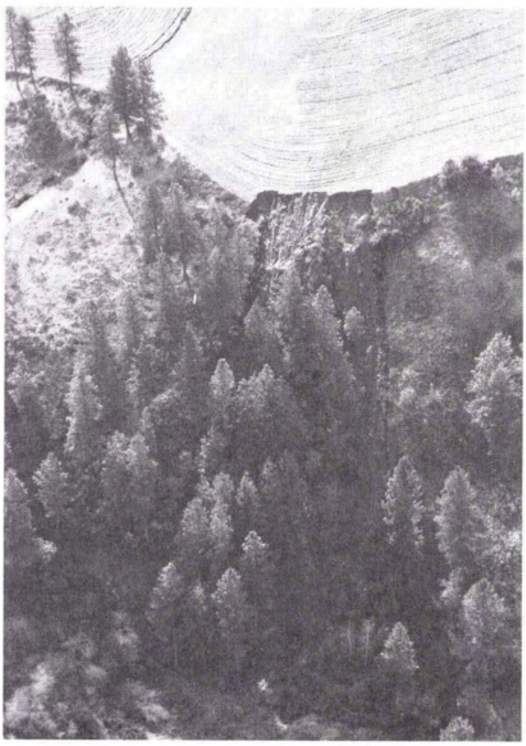

FIG. 8. Soil slip on north-facing slope, ASA 1000.

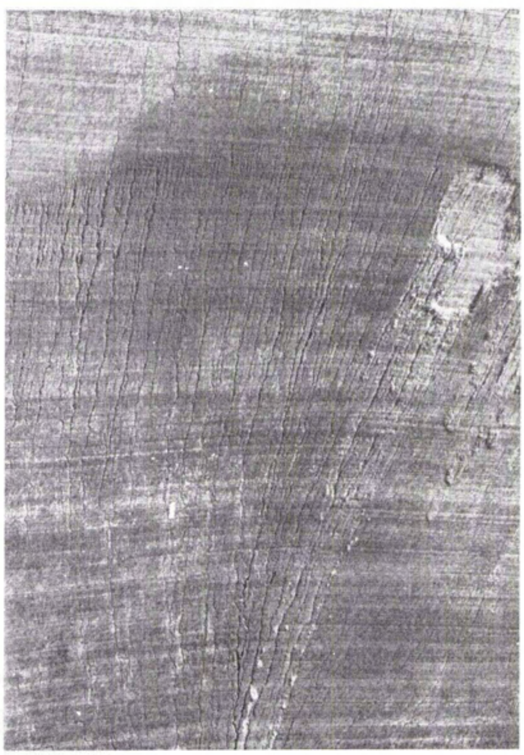

FIG. 9. Rill development on tillage pan after soil slip has occurred, ASA 400.

posite the camera, as illustrated in Figure 2, and its altitude is 36°. The light is sufficient for ASA 400, *f*8 settings to depict rills marked by shadows. The soil slip, in this case, is due to saturation of the soil above a tillage pan. Details of the pan surface and the capability of the film is apparent in this 5× enlargement. Micro-rilling is seen on the gently undulating surface left by a tillage implement.

The azimuth of incoming light has an important effect on the photography of slopes which face the sun as well as on those with north aspects. Because we use oblique photo angles we encounter situations where rills are either not filled with shadows or the photo angle is such that shadows are not seen. This is illustrated in Figure 10 by an east-facing slope photographed at 0930 and 0935 on 22 March 1982. The upper part of Figure 10 was photographed with the sun directly behind the camera (the opposite of Figure 2). Because of the steepness of the slope the effective sun angle is about 50° in spite of the early hour. The lower part of Figure 10 was taken from a lower altitude, flying into the sun, with the camera pointed into the shadows. The effects of the sensor look angle with respect to

FIG. 10. Images of the same slope taken with different look-angles and from different elevations, ASA 400. The sun is behind the camera for the upper image and in front of the camera for the lower image.

the reflectance angle are dramatic and must be taken into account whenever oblique photography is used.

Conclusions

Ilford XP1 film offers a wide latitude in exposures which provides useful prints for assessment of rill erosion. The effects of incorrect exposure settings are minimized by the compensating ability of this film. Exposures equivalent to ASA values of 100 to 1000 have provided the necessary information and detail needed to assess uneroded soil surface conditions as well as eroded surfaces.

Best results are obtained by photographing into the shadows or, at least, at some angle other than parallel to the incident light. This is particularly important on slopes facing the sun. The film is capable of recording the increased reflectance of the surface, but the lack of shadows minimizes detail.

The 35-mm negatives have sufficient resolution and small enough grain to tolerate enlargement 20 to 30 times. This film makes 35-mm format photographs an inexpensive and effective tool for erosion assessment and for other similar environmental assessments under difficult photographic conditions.

Acknowledgment

This is Scientific Paper No. 6323, College of Agriculture Research Center, Washington State University, Pullman. Project Number 0323.

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(Received 8 September 1982; accepted 18 February 1983)
