Monitoring Wheat Rust Epidemics With the Landsat-2 Satellite

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ABSTRACT

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In 1978, serious epidemics of yellow rust and leaf rust occurred in the major wheat growing plains of Pakistan while similar areas in adjacent India were free from these diseases. Analysis of Landsat-2 multispectral scanner negatives for April 1977 and 1978 channels 6 (wavelength range 0.7–0.8 μm) and 7 (wavelength range 0.8–1.1 μm), that covered both the disease-affected and unaffected areas, revealed that crop plant stress caused by disease can be monitored. Data recorded by channels 6 and 7 during the disease-free years of 1977 and 1978 in India had overlapping values, indicating a similar status of health; while the 1978 wheat crop in Pakistan was seriously diseased and reflected more of the infrared (wavelength range 0.7–0.8 μm). This difference was due to disease, because soil, crop, and weather conditions were almost identical on both sides of the border. Although channel 7 data showed similar differences, these were not conspicuous. These studies established the possible utility of Landsat-2 in assessing crop health.

Additional key word: epidemiology.

Both *Triticum aestivum* and *Triticum durum* are grown extensively in the northwestern part of the Indian subcontinent. Yellow rust (caused by *Puccinia striiformis* West.) and leaf rust (caused by *Puccinia recondita* f. sp. *tritici* Rob. ex. Desm.) are the main biological constraints on wheat yield in this relatively cool area (7). During 1978, although these two diseases reached epidemic proportions in the Punjab of Pakistan (3) and caused serious losses (6), the wheat crop on the Indian side of the border yielded a record harvest (1). This situation offers the possibility of learning whether epidemics can be monitored from a resource satellite as the ultimate aim of the Indian space program is to help assess the production of wheat over vast areas (4). A complete analysis of weather during these epidemics and the methods of monitoring it have been made (9–11).

We present here results from a continuation of previous work on the use of satellites to monitor epidemics (8–11) with emphasis on

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Landsat-2 imagery for differentiation of diseased and healthy wheat fields.

MATERIALS AND METHODS

Landsat-2, a satellite launched by the USA, orbits the earth at an altitude of 918 km and has a scan area of 185 × 185 km along its path. Each scanned area is examined approximately every 18 days. The satellite carries a powerful multispectral scanner (MSS) that senses the reflectance of features on the earth at several wavelengths. The wavelength range from 0.7 to 1.1 μm (infrared [IR]) is useful for the correlation of plant and geographic factors (12). We analyzed data sampled by MSS channels 6 (wavelength 0.7–0.8 μm) and 7 (wavelength 0.8–1.1 μm) for 16 April 1977 and 11 April 1978. Areas of similar cropping pattern of approximately 7 mm^2 area of the Landsat-2 negatives were selected and optical densities were measured by a scanning-microscope-photometer (SMP) (Zeiss-SMPO5, Oberkochen, West Germany) and processed by a model PDP-12 computer (Digital Equipment, Maynard, MA 01754) by a special software system. Field 3 from the lighter side of the different control grey levels given in the MSS negatives was selected as a check (100% transmission). Both the areas were scanned by the SMP in one procedure and the optical density (OD) was measured at 460 μm. The resolution of the measuring field was 80 μm^2 in the negative.

Comparisons of Landsat-2 negatives with the digital computer output revealed that each pixel represented the OD value of ~80 m^2 of cropped area on the ground. These data fields were evaluated for OD value to assess differences in their spectral signature. In digital output, characteristic features such as rivers or irrigation channels can be recognized clearly and were used as local references for selecting uniform areas represented by 400 OD values. On the basis of six samples, frequency distributions of the OD values were evaluated and used to check the possible significant differences due to the epidemics.

The ground truth data were supplied by the Wheat Diseases Survey Team of the Indian Agricultural Research Institute, New Delhi. Data from the Indo-Pakistan border were used (9). Climatic and soil conditions on either side of the border are alike (9); hence, severities recorded on a vulnerable host along the Indo-Pakistan border has been plotted over time and serve as ground truth (Fig. 1A and B). Disease progress curves reached their peaks around early dough stage, ie, around the first week of April. We therefore chose Landsat-2 imageries from a period just beyond that peak.

RESULTS AND DISCUSSION

In the computer output on the relative values of spectral signature, lesser values denote darker parts of the negative, which implies lesser reflectance of IR. In data obtained via channel 6 there were no conspicuous differences in the mean values between 1977 and 1978 on the Indian side of the border. Transmission values of Pakistan for 1978 were much greater than for 1977. For the sampled areas the mean frequency OD value remained around 45 during both the years in the epidemic-free areas of the Indian side, while the areas in Pakistan had a OD value of 40 in 1977 and 60 in 1978, the epidemic year (Fig. 2A and B).

The negative on MSS channel 7 for 1977 was darker than the negative for 1978. In this wavelength range, green crop absorbs IR. Although the 1978 crop in India reflected more IR than that in Pakistan, sharp peaks such as those indicated by channel 6 data were not observed. There was only a very weak signal in channel 7, possibly due to the epidemic. Thus, channel 6 of Landsat-2 was found to differentiate healthy and diseased crops. The signature differences arising due to disease were quite conspicuous. At that range, the area affected by the epidemic reflected more IR than did the areas of healthy wheat on the Indian side. In both locations, wheat occupies more than 85% of the area sown, with barley (*Hordeum vulgare* L.) on marginal areas. The non-cereal winter crops occupy a very small proportion of the cropped area and hence

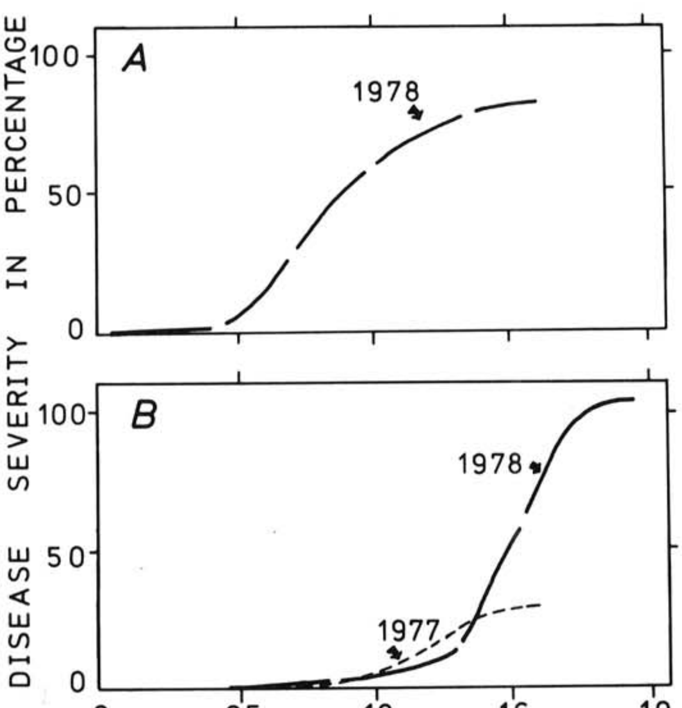

Fig. 1. Ground truth data for development of **A**, yellow rust at Jammu (no yellow rust developed in 1977) and **B**, leaf rust at Pantnagar, India, during epidemic (1978) and nonepidemic (1977) years.

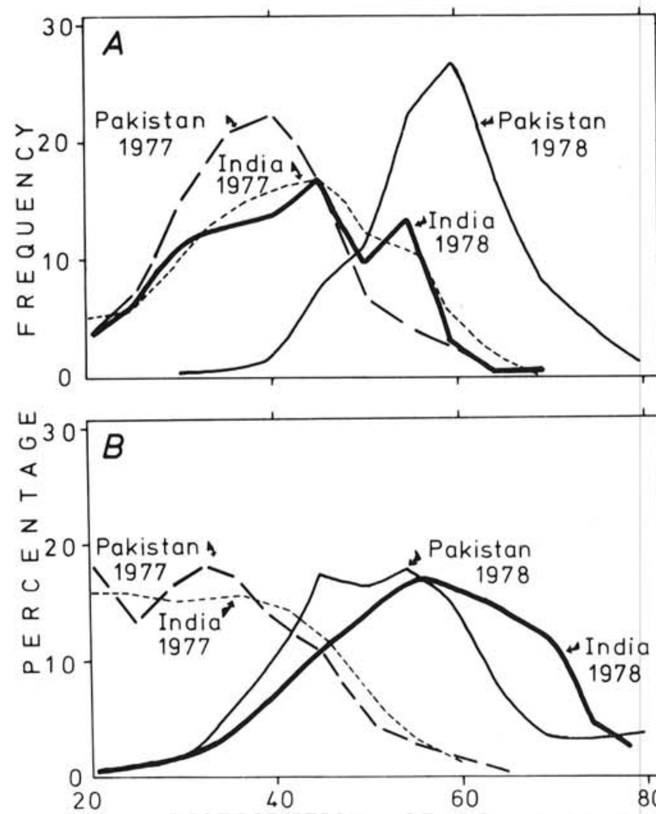

Fig. 2. Frequency distribution of optical density (OD) data for adjacent areas studied in India and Pakistan for the years 1977 and 1978 by the Landsat-2 multispectral scanner on **A**, channel 6 and **B**, channel 7. On the Indian side of the border the wheat crop was healthy and there were similar frequency distributions during both years. Note that in Pakistan (**A**) marked spectral differences were observed between nonepidemic (1977) and epidemic (1978) years.

can not account for the spectral signature differences observed. Based upon experiments of Teng and Close (12), and upon the fact that in Pakistan wheat was subject to a severe epidemic in 1978, we believe that in this specific case, the higher value indicated by MSS channel 6 is due to the severe yellow rust.

Results of our investigations support those of Colwell (2) and Kanemasu et al (5) who showed that IR can differentiate the state of health of the crop as well as aid in yield loss estimation. We believe that the Landsat-2 MSS has potential in identifying epidemic areas.

This study shows that technological capability exists which permits the use of satellites in routine crop health monitoring. Further experiments with CCT tapes and generating false color pictures in computer-interacted image analysis would clarify many points.

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