Landsat Data From Two Forest Sites in Indiana Reflect Impact of Summer Drought[1]

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Introduction

With the successful launch of LANDSAT-1 in July 1972, many exploratory research studies were initiated. A study entitled "Phenology Satellite Experiment" was initiated by the North Eastern Regional Agricultural Research Committee (NE-69) (Atmospheric Influences on Ecosystems and Satellite Sensing).

The study was designed to scan forest canopies in fourteen areas in the eastern half of the country, from Orono, Maine, to College Station, Texas and ten locations in the Rocky Mountain states (4).

Included in the eastern area were two locations in Indiana, one near West Lafayette which included McCormick Woods and adjacent areas, and the second near Princeton where U.S. 41 intersects the White River. Data and methods are included in the final report of the original report, which was undertaken to study the comparative progression of the Green and Brown wave (1).

These two locations in Indiana were of particular interest because a severe drought condition developed in July 1973 at Princeton while Lafayette, 210 km to the north, had favorable weather and production conditions for both corn and soybeans, and they lie in the area of east-west overlap between two successive days of LANDSAT passes. During the 1973 season more data were collected at these locations than any of the other fourteen sites and thus provided an opportunity for this investigation.

Differences in reflectance of the two canopies prompted a more detailed evaluation of data collected.

Review of Literature

Differences in seasonality, over broad areas of the United States as detected annually between different plant cultivars, have been reported by Caprio and Hopp and Blair (2,5). Most of these studies have been on limited species which are confined to phenophase observations which terminate in the early spring. Similar studies are in progress using cultivars which hopefully will make possible use of phenophase observations beyond flowering, i.e., fruit development, ripening and maturation (3). These data hopefully will provide additional phenophase information over more of the growing season and relate to the influence of seasonal climatic patterns over broad areas of the U.S. which relate to crop production.

Recent analysis of lilac phenology data from the Ontario and Quebec Provinces of Canada for over 300 stations has demonstrated that with four years data new areas have been located not now in economic crop production. Agriculturists feel these areas can be successfully developed into needed crop production. Thus at least in marginal production areas above 50° N latitude, phenology observations have demonstrated a means of locating areas that may hopefully be shifted from timber to economic crop production (6).

Without the need for developing extensive meteorological instrumentation, the hypothesis of using phenophase evaluation, which can be observed on selected species adapted to broad marginal areas of the humid subtropics, may have similar potential and application.

Material and Methods

After analysis of multispectral data collected from fourteen locations from Orono, Maine, to College Station, Texas, it was demonstrated that variations in spectral reflectance measured by bands 5 and 7 occur at the extremes and also at a mid-latitude location for both the green and brown wave. A more indepth evaluation of the two Indiana locations was undertaken. This was prompted for

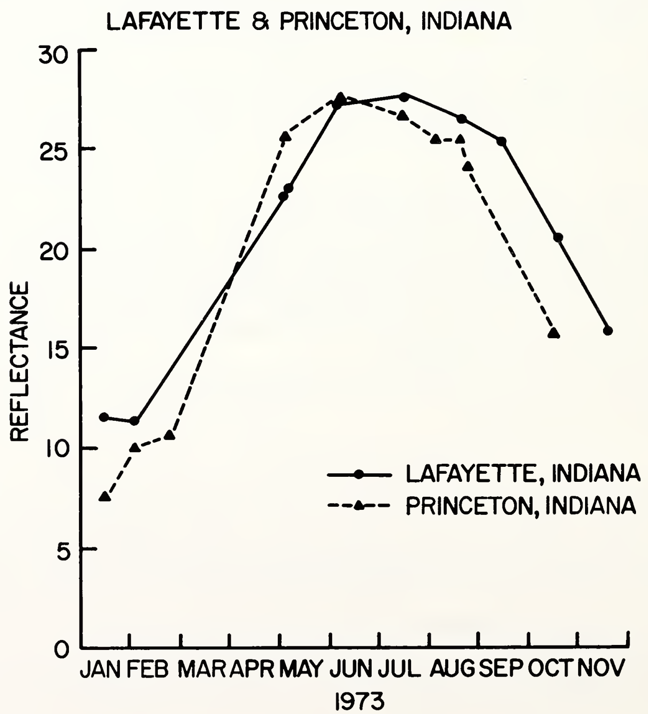

FIGURE 1. *Mean relative canopy reflectance from wave band (.8-1.1 μ m) in percent of the total possible reflectance at two locations in Indiana during the growing season of 1973.*

TABLE 1. *Precipitation and temperature data of Lafayette and Princeton, Indiana, 1973.*

	Lafayette (Tippecanoe County)				Princeton (Gibson County)			
	Rainfall	Temperature C°		Evap.	Rainfall	Temperature C°		Evap.
Month	in cm	Max	Min	in cm	in cm	Max	Min	in cm
May	8.7	19.9	8.7	13.8	19.5	22.6	10.8	14.5
June	15.3	27.7	16.7	19.9	19.1	30.4	18.3	20.5
July	13.9	29.2	17.7	18.6	6.3	31.8	20.0	20.8
August	7.4	28.2	17.1	16.2	10.0	31.4	18.6	18.0

	Growing Degree Days	
Month	Lafayette (Tippecanoe County)	Princeton (Gibson County)
May	238.7	372.0
June	657.0	777.0
July	921.3	1078.2
August	705.25	838.55
TOTAL	2522.25	3065.75

Difference in Locations—Total 543.5 growing degree days

TABLE 2. *The influence of 1973 climate on crop yields (kg/ha) at two Indiana locations.*

County	Corn	Soybeans
	Lafayette Location	
Tippecanoe*	6,608	2,160
White	6,384	1,980
Warren	6,328	2,160
Clinton	6,664	2,400
Montgomery	6,496	2,340
MEAN YIELD	6,496**	2,208**
	Princeton Location	
Gibson*	5,488	1,680
Warrick	4,816	1,320
Vanderburg	4,928	1,860
Posey	5,264	1,620
Pike	4,928	1,440
MEAN YIELD	5,045**	1,584**

* Yield for county of site location

** Yield average for five county area around location

four reasons: 1) These locations provided more cloud free data than any other locations; 2) An intensive summer drought developed at the southern locations near Princeton which did not occur at Lafayette; 3) These locations were in close enough proximity (210 km) and with similar management practices so that the same crops are produced in both areas and the influence by water stress on forest canopy cover could be expected to be reflected in adjacent crop yields; and 4) The southern location and adjacent areas are residual soils which are more droughty than at the northern location which are a loess soil formed over glacial till and are more drought resistant.

Reflectance data reported in this paper for the two locations for the growing season of 1973 have been summarized and reported (4). Figure 1 shows the canopy reflectance at these two locations. Voids in the data at both locations result from cloud cover which prevented obtaining satellite data on those dates.

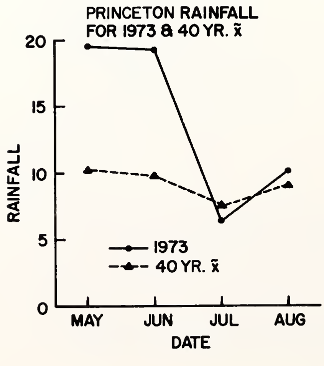

FIGURE 2. *Comparison in cm of the 1973 rainfall pattern with the 40 year mean at Lafayette.*

Comparative climatic and crop yield data are presented in Tables 1 and 2. Differences in rainfall at the two locations are shown in Figures 2 and 3.

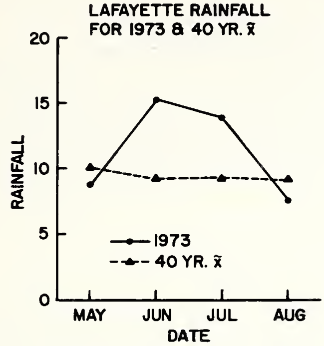

FIGURE 3. *Comparison in cm of the 1973 rainfall pattern with the 40 year mean at Princeton.*

Results and Discussions

These data from canopy reflection which is the percent of total reflectance possible in band 7(.8-1.1 μ m) show that the leaf cover at Princeton developed earlier and ahead of that at Lafayette with Princeton showing maximum reflectance from leaf cover in early June. Maximum reflectance developed at Lafayette in July. In July and until mid-August reflectance dropped appreciably at Princeton. This indicated a loss in canopy by leaf drop, change in metabolic processes or both, that influenced reflectance. The reflectance then continued to decline in a similar pattern at both locations but on a two to three week earlier schedule at Princeton.

The loss in canopy reflectance at Princeton is associated with leaf drop and/or perhaps change in chlorophyll quantities. Rainfall patterns and subsequent comparison of growing degree days at these two locations correlate with the reflectance differences (Table 1 and Figures 2 and 3). As seen in the table and illustrated in the figures, rainfall was much above normal at Princeton during spring and early summer with a marked drop to slightly below normal in July. This dry period extended over 29 days at Princeton with a total of 55 days without measurable precipitation. At Lafayette there were 39 rain free days with 15 occurring in late August.

The high spring precipitation pattern resulted in extensive, and probably above normal, leaf development at Princeton. Leaves began dropping under pressure of limiting water supplied in July. This observed leaf thinning and probable changes in stress was related to the difference in reflectance noted in the multispectral data in both bands 5 and 7.

Precipitation patterns in Lafayette were normal during early spring followed by very favorable rainfall during late spring and summer with a 15-day dry period in late August. These comparative rainfall patterns are further reflected in the temperature differences in monthly and seasonal mean and growing degree days during July and August at these locations (Table 1). Under such different climatic patterns the leaf canopy would be expected to adjust to the stress at Princeton and remain near normal at Lafayette.

The impact of a drought period has been clearly demonstrated between two locations 210 km apart. This climatic pattern is not an uncommon occurrence in Indiana and other areas in the Corn Belt. In 1974 the following year and again in 1977 the reverse climatic pattern between these two areas was noted.

The impact of detecting stress by multispectral scanning should also have similar implications on crop performance in these two areas. Table 2 shows the influence of this differing climatic pattern in 1973 on the yields of corn and soybeans in Tippecanoe, Gibson and four adjacent counties in each area. Results of the favorable conditions at Lafayette compared with the mid-summer drought at Princeton are quite obvious.

Conclusions

Based on analysis of data collected over one season, it would appear that if numerous sites of timber canopies of 50-100 ha over the Corn Belt were selected and could be monitored during the growing season such data would be available and useful in detecting the severity of drought stress over large areas. Its impact on pending productive potential of the crops of the immediate and adjacent areas might also be detected early in the season. Since the multiple scan data from LANDSAT-1 and -2 are available, confirmation and feasibility of using this technique as a tool could be obtained by analysis of data already collected. Further study should be undertaken and would be necessary for using LANDSAT data for relating such information to annual production of food, fiber and timber. Further basic studies on relationship of water stress to leaf drop, chlorophyll changes and metabolism should also be investigated.

Literature Cited

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