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DIFFERENCES IN ONSET OF GREENNESS: A MULTITEMPORAL ANALYSIS OF GRASS AND WHEAT IN KANSAS*

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ABSTRACT

The time when vegetation emerges (begins active photosynthesis) each year can be monitored using remotely sensed data obtained from Earth observation satellites. This measurement, called the onset of greenness, can be calculated using time series data sets of the Normalized Difference Vegetation Index (NDVI), a ratio of red and near infra-red (NIR) light that is strongly correlated to plant biomass. The date at which the onset of greenness occurs varies depending on the region, type of vegetation present, weather conditions, land management practices, and other factors. Time series NDVI data are proving useful for a wide variety of applications including vegetation mapping, crop monitoring, and yield modeling.

The onset of greenness metric values were extracted from bi-weekly AVHRR satellite data over the state of Kansas from 1989 through 2000. Four different locations in Kansas were sampled: 1) winter wheat from Sumner County, 2) winter wheat from Thomas County, 3) tall grass rangeland from Chase County, and 4) short grass rangeland from Logan County. The onset date was recorded from 20 AVHRR pixels from each location for each year of data. Samples from the same location were analyzed to detect differences in onset date between years and samples from different locations were compared to identify differences in onset date within the same year.

Results show a significant difference in the onset of greenness date between cover types and a significant difference in onset dates between years for the same cover type at the same location. Regression analysis shows that the grasslands and wheat of northwestern Kansas have a negative slope (earlier onset), while the lines of best fit for grasslands and wheat in south central Kansas did not indicate a substantial change in onset date.

INTRODUCTION

The time vegetation emerges (begins active photosynthesis) each year can be monitored using remotely sensed data obtained from Earth observation satellites. The onset of greenness metric is calculated through analysis of time series Normalized Difference Vegetation Index (NDVI) values derived from the Advanced Very High Resolution Radiometer (AVHRR) satellite (Reed et al. 1994). In North America, vegetation generally begins growing in the spring with a low NDVI (onset of greenness)

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and continues to accumulate biomass until the time of maximum greenness (peak NDVI value). At this point NDVI values begin to decrease as the vegetation shifts its resource allocation from producing non-reproductive biomass (i.e. leaves and stems) to reproductive plant parts (i.e. flowers and seeds). This decrease in NDVI continues until plant photosynthesis ceases or the plant becomes dormant; this time of minimum NDVI is referred to as the end of greenness. The date these phenological stages occur varies depending on the region, type of vegetation present, weather conditions, land management practices, and other factors (Badhwar and Henderson 1981, Reed et al. 1994).

The need to accurately identify and delineate different land covers types is well known and widely studied. Multi-date NDVI data has been very useful for vegetation mapping and agriculture surveys (Lloyd 1990, Price et al.1997, Tucker et al. 1985, Tennakoon et al. 1992), but often there is confusion between certain vegetation types. New methodologies are needed to identify ways to accurately separate these classes (i.e. grassland from cropland), and the use of vegetation phenology metrics may be one solution. This analysis was designed to investigate four aspects of the onset date phenology metric: 1) are there significant differences in onset date between rangeland grasses and winter wheat? 2) are there significant differences in the onset date of a particular land cover type from different locations? 3) are there significant differences in the onset date of a given cover type between years? 4) is there a linear trend visible in the onset date?

METHODS

Onset of greenness metric values were extracted from AVHRR satellite date over the state of Kansas from 1989 through 2000. Two different cover types were sampled from locations in northwestern and south central Kansas 1) winter wheat from Sumner County and Thomas County, and 2) native grasses from Chase (tall grass) and Logan (short grass) counties. Figure 1 shows the location of these counties on a map depicting the 12 year average onset of greenness date for Kansas along with a hypothetical NDVI response curve for vegetation typical of Kansas. The onset date was extracted from 20 pixels per year for a sample size of 240 for each cover type and location. The extracted values were then entered into a spreadsheet and analyzed using SPSS statistical software

The Kolmogrov-Smirnov test was used to test that the data was normally distributed, then the mean and standard deviation of each sample was calculated. A t test was conducted to compare the mean onset dates, and an analysis of variance (ANOVA) test was used to identify significant differences from the average onset date within a given cover type (ie. wheat 1989 vs. average wheat). In order to identify which years were significantly different from average, it was necessary to use a post-hoc pairwise multiple comparison test. By including the average onset for each cover type as year 0, the Bonferroni method identified which years were significantly different from the mean. Linear regression analysis was then performed to identify the slope of the line to identify any linear trend in the onset of greenness date.

RESULTS

Analysis of the twelve years of data showed that the data was normally distributed and that the mean onset of greenness occurred in weeks 8 and10 (early/mid Mach) for wheat in Sumner and Thomas Counties, and during weeks 14 and 15 (mid/late April) for grasses in Chase and Logan Counties respectively (Figure 2). A T-test revealed that there was a significant difference between the mean onset date of range grasses and the onset date of winter wheat ($P = 0.000$). Additionally, while there was no significant difference in the onset date of grasses from Logan and Chase Counties ($P = 0.126$), the onset date of wheat in Sumner County was significantly earlier than for wheat in Thomas County ($P = 0.006$).

The variation in onset date proved to be another interesting case for analysis, as the standard deviation appeared to be closely related to both the geographic region and the vegetation type. The grass and wheat samples from northwestern Kansas had larger standard deviations (3.4 and 3.7 respectively) then the grass and wheat samples from south central Kansas which tended to have less year to year variability (1.7 and 2.6 respectively). In both regions, however, the grasses had lower standard deviations than did the wheat from the corresponding region.

The ANOVA test results showed that there were significant differences in the onset date of all samples when compared to the twelve year average onset date ($P = 0.000$). Post Hoc analysis showed that the onset date for wheat was significantly earlier than average in Sumner county in 1991 and 1992, and significantly later in Thomas County in 1989 and 1996. Post Hoc analysis also found that the onset date for grasses in Logan County were significantly earlier in 2000, while the onset date for grasses in Chase County did not differ significantly from average in any year (Table 1).

When the mean onset date for the twelve years of observations were analyzed using linear regression techniques, it became apparent that there were some linear trends in the data. The grass and wheat in northwest Kansas both exhibited negative slopes (-1.67 and -1.04 respectively) indicating that the date of onset was getting earlier for both of these vegetation types. On the other hand, the average onset date for grass and wheat in south central Kansas showed a slope of nearly zero (0.51 and -0.09 respectively), indicating a less substantial change in the onset of greenness over the twelve years.

DISCUSSION

Timing is everything. This phrase is also applicable to the study of vegetation where scientists must select the optimal date(s) for observing the phenomena they are interested in. Single dates of imagery must be carefully selected and multitemporal images should be spaced to show phenological differences in the vegetation. This research shows that the onset of greenness phenology metric can be used to identify different vegetation communities based on their unique growing cycles. Analysis of the data showed that there were significant differences in the onset of greenness date between range grasses and winter wheat in Kansas. This ability to separate cover types by their phenology can aid in the accurate identification and delineation of land cover classes. Additionally, onset date phenology metrics can be used to monitor regional and temporal climate variations. This study showed that the onset date for winter wheat varied significantly from different regions of Kansas and appeared to be getting earlier in northwestern Kansas and not in south central Kansas over the last twelve years. Similar research using the onset of greenness metric in the Mongolian Plateau of eastern Asia also found the metric useful for monitoring vegetation shifts as a response to changing climate patterns (Yu et al. 2000).

Several interesting things can be seen in the graphs showing the average yearly onset date. The grasses of south central and northwestern Kansas, while showing a fairly wide range of onset dates for any given year, tended to have less year to year variability then wheat. Contrastingly, the wheat from south central and northwest Kansas showed a much higher degree of year to year variability. Looking at figure 2, it can be seen that the grasses in the Flint Hills (Chase County) behaved similarly in most years, while the wheat belt reacted with the same general trend, but to much greater extremes. These observations could be the result of the inherent strengths of natural vegetation as compared to the highly sensitive nature of hybrid agricultural crops.

The onset of greenness data analyzed here contains a lot of information, and this brief look at the general data trends and differences only scratches the surface. A more detailed examination of a particular aspect of the vegetation phenology data would probably reveal some interesting relationships. Future research that includes temperature and precipitation data for the region may help to explain why in 1995 the wheat was late greening up, and the grasses greened up earlier than average, or what led to the late green up of all samples in 1996. Additional information such as crop yield or grazing conditions may

also add valuable insight into what impacts these fluctuations in onset date may be having on the agricultural community.

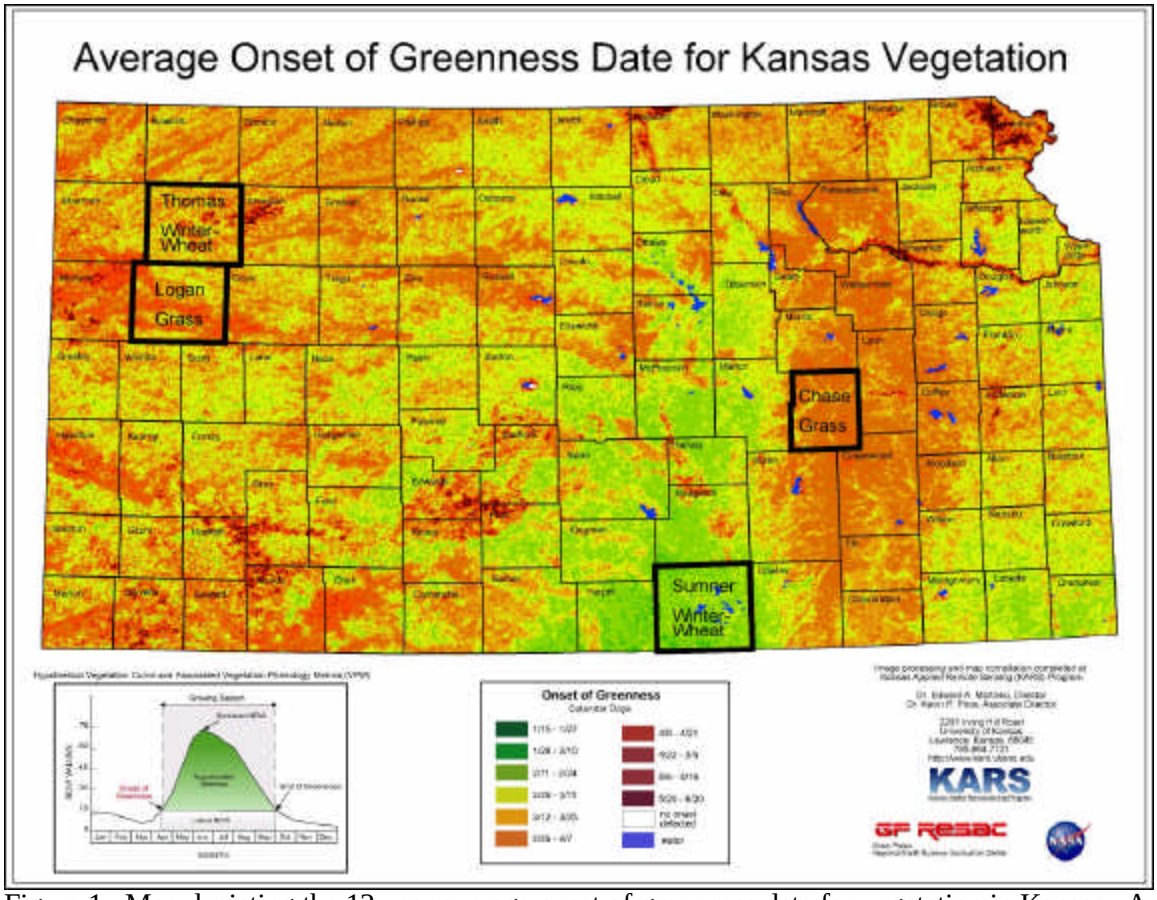
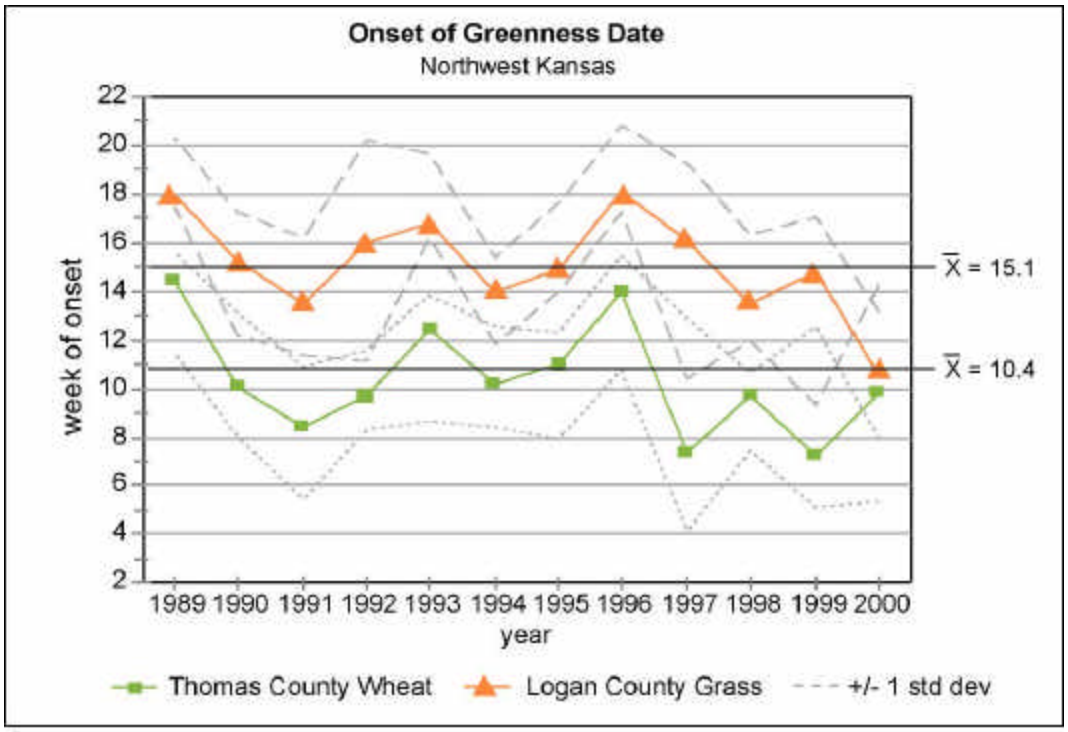


Figure 1. Map depicting the 12 year average onset of greenness date for vegetation in Kansas. Areas depicted in green and yellow begin their growing season earlier, while orange and red areas have a later onset date. The large area of green in south central Kansas is dominated by winter wheat and the large band of orange in the eastern third of the state shows the extent of the tall grass prairie in the Flint Hills. In the western portion of the state, Thomas County is dominated by winter wheat and Logan County has large tracts of short grass rangeland. Similarly, in south central Kansas, Sumner County is in the heart of the wheat belt and Chase County is dominated by the grasses of the Flint Hills.



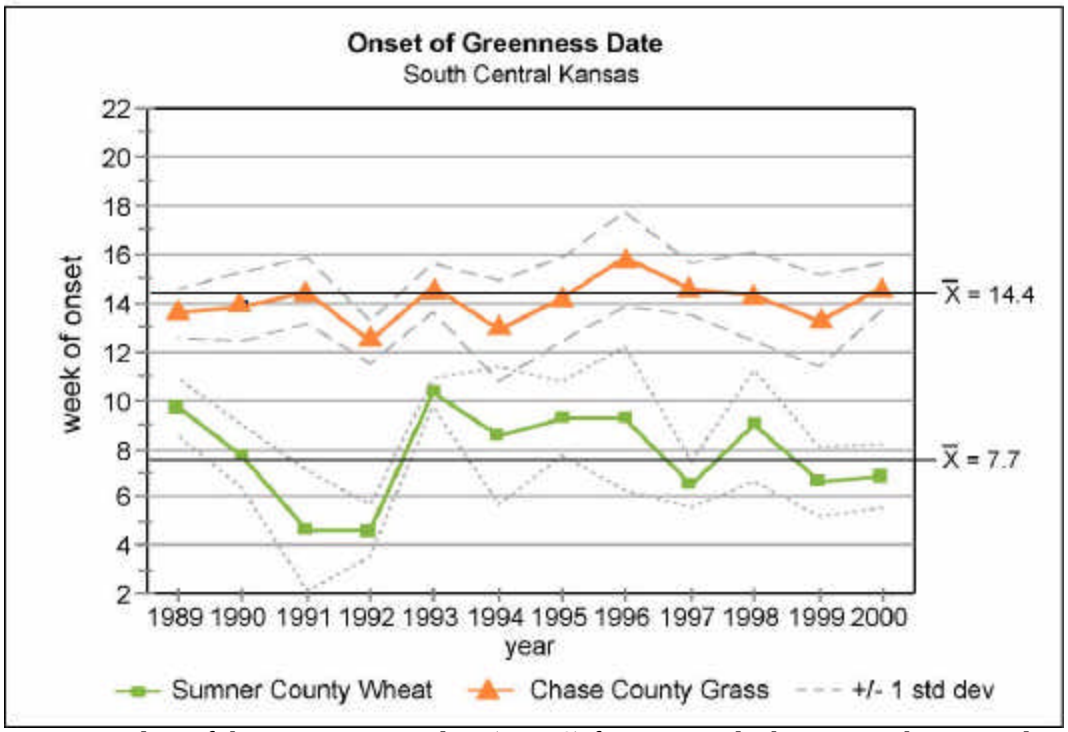


Figure 2. Plots of the average onset date (n = 20) for grass and wheat in north west and south central Kansas. While there are similarities in the trends between the two regions, the grass and wheat in the northwest generally experienced greater fluctuations and larger standard deviations in onset date then grass and wheat located in south central Kansas.

Table 1. Probabilities values from the Post hoc analysis comparing yearly onset dates to the 12 year average to identify in which year the onset date was significantly different than the average. Dark blocks indicate years with later then average onset dates while light blocks indicate earlier than average onset dates. Entries in ***bold italics*** signify onset dates that are significantly different from the average (alpha = 0.05).

Region	**North Western Kansas**		**South Central Kansas**	
County	Thomas (wheat)	Logan (grass)	Sumner (wheat)	Chase (grass)
1989	***0.002***	0.137	0.298	1.000
1990	1.000	1.000	1.000	1.000
1991	1.000	1.000	***0.000***	1.000
1992	1.000	1.000	***0.000***	1.000
1993	1.000	1.000	0.192	1.000
1994	1.000	1.000	1.000	1.000
1995	1.000	1.000	1.000	1.000
1996	***0.014***	0.137	1.000	1.000
1997	0.515	1.000	0.684	1.000
1998	1.000	1.000	1.000	1.000
1999	0.857	1.000	1.000	1.000
2000	1.000	***0.002***	1.000	1.000

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