

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

---

Papers in Natural Resources

Natural Resources, School of

---

1998

## Using AVHRR Data for Quantitative Estimation of Vegetation Conditions: Calibration and Validation

Anatoly A. Gitelson

*University of Nebraska - Lincoln*, [agitelson2@unl.edu](mailto:agitelson2@unl.edu)

Felix Kogan

*United States National Oceanic and Atmospheric Administration*, [felix.kogan@noaa.gov](mailto:felix.kogan@noaa.gov)

E. Zakarin

*Academy of Sciences of Kazakhstan*

L. Spivak

*Academy of Sciences of Kazakhstan*

L. Lebed

*National Meteorological Administration, Kazakhstan*

Follow this and additional works at: <https://digitalcommons.unl.edu/natrespapers>



Part of the [Natural Resources and Conservation Commons](#)

---

Gitelson, Anatoly A.; Kogan, Felix; Zakarin, E.; Spivak, L.; and Lebed, L., "Using AVHRR Data for Quantitative Estimation of Vegetation Conditions: Calibration and Validation" (1998). *Papers in Natural Resources*. 266.

<https://digitalcommons.unl.edu/natrespapers/266>

This Article is brought to you for free and open access by the Natural Resources, School of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Papers in Natural Resources by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.



## USING AVHRR DATA FOR QUANTITATIVE ESTIMATION OF VEGETATION CONDITIONS: CALIBRATION AND VALIDATION

A. A. Gitelson\*, F. Kogan\*\*, E. Zakarin\*\*\*, L. Spivak\*\*\* and L. Lebed†

\**J. Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, Sede-Boker 84990, Israel*

\*\**NOAA/NESDIS, Room 712, NOAA Science Center, 5200 Auth Road, Camp Spring, MD 20746, U.S.A.*

\*\*\**Institute for Space Research, Academy of Sciences of Kazakhstan*

†*National Meteorological Administration, Kazakhstan*

### ABSTRACT

NDVI-derived Vegetation Condition Index (VCI) was compared with vegetation density, biomass and reflectance measured in the fields. The VCI numerically estimates fluctuation of NDVI related to intra-annual weather change only and is a measure of weather impact on vegetation. Test fields were located in different climatic (annual precipitation 150-700 mm) and ecological zones (semi-desert to steppe-forest) with elevation from 200 to 700 m in Kazakhstan. A range of NDVI variation was from 0.05 to 0.47. The determination coefficient between AVHRR-derived vegetation state and actually measured vegetation density of more than 0.76 was achieved. For the first time it was shown that the VCI-derived vegetation condition data can be effectively used for quantitative assessments of both vegetation state and productivity (density and biomass) over large areas.

©1998 COSPAR. Published by Elsevier Science Ltd.

### INTRODUCTION

In the last 10 years, considerable efforts were undertaken in validating qualitatively the Global Vegetation Index (GVI) product for environmental monitoring purposes (Gutman, 1991; Holben, 1986; Kogan, 1990, 1994; NOAA, 1988; Ohring *et al.* 1989). These work was expanded recently in order to provide quantitative validation of AVHRR-based algorithms (Kogan, 1995, Gitelson *et al.* 1996). In this paper we present the most comprehensive results of quantitative comparison and analysis of data obtained from NOAA operational polar-orbiting satellites and actually measured in the fields in Kazakhstan. Climate of Kazakhstan is arid and semi-arid. Annual precipitation changes mostly from less than 50 mm in the desert zone to 300-400 mm in step zone in the North and 1000 mm in the small area of the south-east. These amount of precipitation are negligible for thermal resources. Annual evapotranspiration in the North is between 500 and 700 mm, which is twice exceeded the amount of precipitation. In the south it is 700-900 mm exceeding annual precipitation four to seven times. Vegetation zones change from desert in the South to step and forest in the North.

### DATA

**Satellite data** Radiance measured by the Advanced Very High Resolution Radiometer (AVHRR) on board NOAA 9, 11, and 14 polar orbiting satellites were used in the study. These data were collected from the Global Vegetation Index (GVI) data set. The GVI includes radiance in visible (Ch1), near infra-red (Ch2) and two thermal bands (Ch4 and Ch5), the NDVI, solar and satellite angles. The GVI was sampled from one to 16 km spatial resolution and from daily to one week temporal composite resolution for the period from April 1985 to the end of 1994.

**Ground data** included vegetation density, measured in spring wheat fields at six meteorological stations during 1985 through 1994. These stations were located in very different ecological and climatic zones, from semi-desert in the South to steppe and the steppe-forest in the North.

## METHODS

The proceeding of satellite data included: calibration of Ch1 and Ch2 radiance using past launch calibration to eliminate noise related to sensor degradation and, partially, to satellite orbit drift; noise reduction in order to eliminate high frequency temporal variations from NDVI time series; calculation of Vegetation Condition Index (VCI). The VCI was calculated as multiyear (1985-1994) variation from minimal values of NDVI, normalized to difference between maximal and minimal values for this period (Kogan, 1987; 1990):

$$VCI = (NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min}) \quad (1)$$

It is invariant of ecological background (soil type, geology, and so on) and estimates response of vegetation state to weather in very different ecological and climatic conditions. For comparison to ground data, mean VCI was calculated from 3 by 3 GVI pixels around selected weather stations. We calculated the highest ( $NDVI_{max}$ ) and the lowest ( $NDVI_{min}$ ) values of the NDVI during 1985-1994 for each of the 52 weeks of the year and for each pixel. The resulting maximum and minimum NDVI were used as the criteria for estimating the upper (favorable weather) and the lower (unfavorable weather) limits of the ecosystem resources. These limits characterize the "carrying capacity" of each selected station ecosystem. Since the minimum and maximum NDVI curves delineate the contribution of ecosystem component in the NDVI value for the cases with the most extreme weather, the area between these curves largely approximates the weather-driven component of the NDVI.

In 1985-1994, density of vegetation ( $D$ ) was measured every ten to twenty days during growing period as number of plants (spring wheat) per square meter. To compare to VCI, density of vegetation was expressed as a deviation of  $D$  from multi-year median value ( $D_{med}$ ), normalized to difference between 1985-1994 maximal ( $D_{max}$ ) and minimal ( $D_{min}$ ) densities:

$$DD = (D - D_{med}) / (D_{max} - D_{min}) \quad (2)$$

## RESULTS AND DISCUSSIONS

The 1991 and 1992 growing seasons were quite similar in some locations and different in others. At the general background of NDVI similarity for 1991 and 1992 growing seasons, the VCI were extremely different (Figure 1). The VCI is more sensitive to change in vegetation conditions compare to NDVI. The density deviations (DD) were compared with VCI dynamics during 1991 and 1992 for the selected stations (Figures 2). There is a very good match between the VCI and DD, although the dynamics of vegetation conditions was quite different between years, stations, and period of vegetation development. Analysis of temporal variations in Figure 2 shows that there is a strong correlation between the VCI-derived vegetation condition and change in density of wheat per unit area. Determination coefficient ( $r^2$ ) for individual stations changes from 0.72 to 0.92 with an estimating error of density between 11 to 15. However, the strongest correlation is observed for VCI values between 0 and 80. For higher VCI values, there is a tendency towards decrease in a slope of VCI versus DD relationship. This supports previous findings of NDVI saturation for high chlorophyll content, leaf area index and canopy cover (e.g., Gitelson and Merzlyak, 1994).

The correlation between the VCI and density deviation for all six stations used in this research is shown in Figure 3. As seen, VCI values around 50 which characterize near normal vegetation condition corresponds to multi-year median value of vegetation density (DD near zero). VCI values below 30, which was shown specify drought conditions (Kogan, 1995), correspond to the density of vegetation below -20. The lowest density of vegetation observed in this study was around -60 with a matching VCI value around 10. For VCI over 50, density of vegetation exceeds median value, indicating that conditions are favorable for development of healthy vegetation.

Despite of the fact that the selected stations were located in different climatic and ecological zones, all station points were located around the same correlation line (Figure 4). Although there are some differences between the stations, correlation was high ( $r^2 = 0.76$ ) with an estimating error of DD less than 16 for a very high variation of vegetation density (between -60 and 70). This error is less for low density, indicating that in cases of very unfavorable weather (such as drought) the accuracy of VCI-derived estimates is higher.

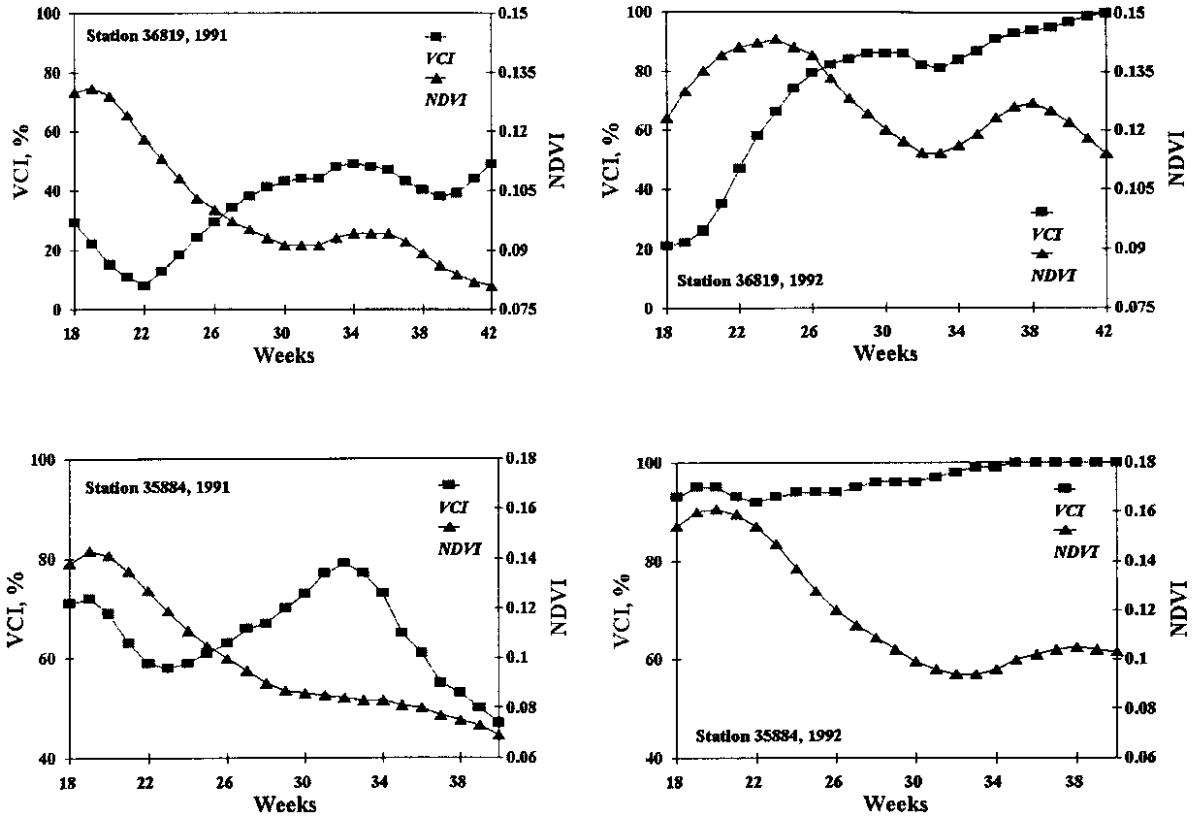


Fig. 1. NDVI and VCI dynamics at three stations during 1991 (dry) and 1992 (favorable) conditions

The main causes for scattering of the VCI versus variation of vegetation density relationship are: (a) the difference between large-scale estimate of VCI from AVHRR data (3 by 3 GVI pixels) and field scale (1 by 1 km) measurements of vegetation density; (b) reduced sensitivity of NDVI and VCI to high values of vegetation biomass and density; (c) limited period of NDVI and vegetation density observations for accurate retrieval of ecosystem resources.

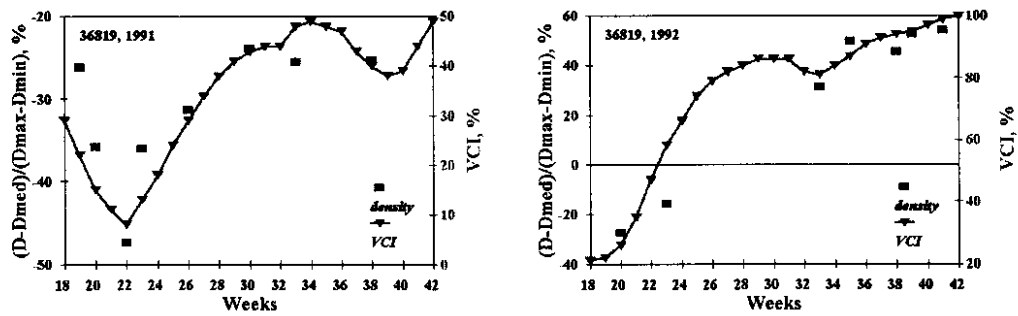


Fig. 2. Comparison of the VCI and multi-year density variation from median values in 1991 and 1992.

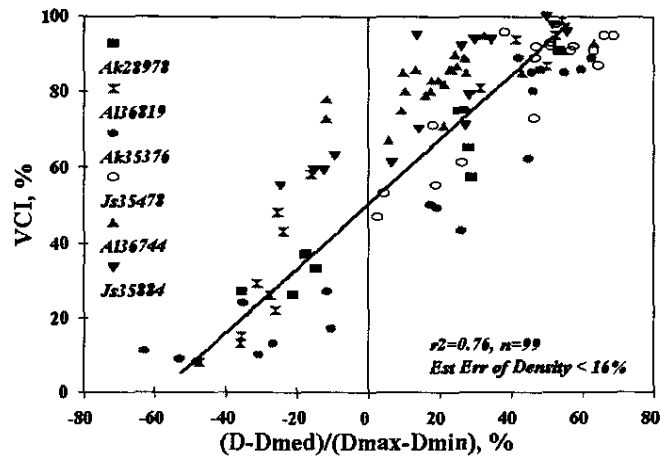


Fig. 3. The VCI-derived and actually measured density of vegetation for six stations in 1991 and 1992.

## CONCLUSIONS

1. For the first time a comprehensive validation of NDVI derived from operational satellite data with ground measurements of vegetation characteristics was fulfilled over large areas with diversified ecosystem resources.
2. The VCI showed to be a good indicator of weather impact on vegetation and, correspondingly, vegetation condition and health. The VCI provides fairly accurate assessment of unfavorable vegetation condition, especially those related to drought impact.

## ACKNOWLEDGMENTS

This research was funded by US Agency for International Development (Us-Israel AID/CDR/CAD program, Grant No. TA-MOU-CA13-056).

## REFERENCES

- Gitelson, A.A. and M.N. Merzlyak, Spectral reflectance changes associated with autumn senescence of *Asculus hippocastanum* and *Acer platanoides* leaves. Spectral features and relation to chlorophyll estimation. *J. Plant Physiol.* 143, 286-292 (1994).
- Gitelson, A., Kogan, F., Spivak, L., Zakarin, E., and Lebed, L., Estimation of Seasonal Dynamics of Pasture and Crop Productivity Using NOAA/AVHRR data, in *1996 International Geoscience and Remote Sensing Symposium*, Vol. 1, pp. 209-211, IEEE, Lincoln, Nebraska, (1996).
- Gutman, G.G., Vegetation Indices from AVHRR Data: An Update and Future Prospects, *Remote Sens. Environ.*, 35, 121-136, (1991).
- Holben, B.N., Characteristics of maximum-value composite images from temporal AVHRR data. *Int. J. Remote Sensing*, 7, 1417-1434 (1986).
- Kogan, F.N., Remote sensing of weather impacts on vegetation in non-homogeneous areas. *Int. Journal of Remote Sensing*, 11, 1405-1419 (1990).
- Kogan, F.N., NOAA plays leadership role in developing satellite technology for drought watch. *Earth Observation Magazine*, September 1994, 18-21 (1994).
- Kogan, F.N., Drought of the late 1980s in the United States as derived from NOAA polar-orbiting satellite data. *Bul. of the Amer. Met. Soc.*, 76, 655-668 (1995).
- NOAA, NOAA polar orbiter data users guide. NOAA-11 update. Edited by K.B. Kidwell (1988).
- Ohring, G., K. Gallo, A. Gruber, W. Planet, L. Stowe, J.D. Tarpley, Climate and Global Change: Characteristics of NOAA Satellite Data. *Eos. Trans., Amer. Geophysical Union*, 70, 889-901 (1989).