

ASSESSMENT OF GRASSLAND PRODUCTION USING INFORMATION FROM SATELLITE REMOTE SENSING

K. DABROWSKA-ZIELINSKA, A. CIOLKOSZ, M. GRUSZCZYNSKA, ST. LEWIKSKI

Remote Sensing and Spatial Information Center
Institute of Geodesy and Cartography
Jasna 2/4, 00-950 Warsaw, Poland

ABSTRACT:

The paper presents the methodology for determination of evapotranspiration for the grassland using surface temperature recorded by NOAA/AVHRR images and meteorological data. Evapotranspiration assessed from NOAA data was applied for Leaf Area Index (LAI) and biomass determination. Both factors are indicators of forage production. For LAI and biomass prediction linear model was performed using Normalized Vegetation Index (NDVI) and evapotranspiration. To calculate NDVI the visible channels of NOAA satellite were used. Normalized Vegetation Index (NDVI) was used as an indicator of the height of the grass. The method presents a possibility to assess spatial information about grassland condition over large area with very high frequency including the actual state of meadows productivity derived from biomass.

Keywords: accuracy, hydrology, remote sensing application, renewable resource, thermal, grassland, evapotranspiration.

1. INTRODUCTION

The project has been carried out at Remote Sensing and Spatial Information Centre and has been sponsored by UNDP/FAO and Polish Academy of Sciences. The objective of the project has been to develop a methodology for determination of evapotranspiration using information from NOAA/AVHRR images for assessment of grassland parameters LAI and biomass which are production's indicators.

The study area which is a grassland located South-West of the city of Poznań (Poland) in Obra Valley (52° 52' 10" N and 16° 20' - 16° 20' E) is occasionally flooded. The area of the test site is 15 km² which corresponds approximately to 15 NOAA images pixels. The area is characterized by three types of soil: peat-muck, mineral muck and mucky soil. Both soil water condition and vegetation cover are not homogeneous showing wide spatial variability. This is the reason why vegetation cover produces different signals in the visible and thermal regions registered by AVHRR installed on the board of NOAA satellite. The studies were carried out during vegetation seasons of 1989, 1990 and 1991.

2. METHODS

2.1 Ground truth data collection

At the ground following meteorological parameters were measured at two sites at five heights as hourly data: wind speed, air temperature, air humidity, solar and net radiation and soil heat flux. Evapotranspiration was calculated by means of aerodynamic method. These values were ground references for assessment of evapotranspiration assessed using remotely sensed and meteorological data.

Each time vegetation's parameters such as height, LAI and biomass were measured at the twenty ground points. LAI measurements were performed using LAI-2000 Plant Canopy Analyzer.

2.2 Remotely sensed data

NOAA/AVHRR data are easily available from NOAA receiving station located in Kraków. Because of unfavorable atmosphere condition during experiment it was possible to receive only seven NOAA cloud-free images. They were registered on: 16 May 1989 at 14:40h, 23 July 1989 at 12:20 h, 23 May 1990 at 12:08 h, 3 August 1990 at 12:27 h, 8 July 1991 at 12:57 h, 24 July 1991 at 11:35 h and 7 August 1991 at 12:11 h (GMT).

Geometric and radiometric correction of NOAA/AVHRR images have been achieved by procedures applied in ERDAS image processing software. Surface temperature values were obtained from channel 4 and 5 of NOAA/AVHRR images. These values were corrected for absorption by atmospheric water vapor using Split Window Technique (SWT). The best coefficients for Poland were those derived by Dalu and Liberti (1987) according to the formula:

$$T_s = T_4 + A(T_4 - T_5) + B \quad (1)$$

where:

T_s - surface temperature [°C]
 T_4 - temperature from AVHRR channel 4 [°C]
 T_5 - temperature from AVHRR channel 5 [°C]
 $A = 2.68$
 $B = -0.4$

The digital values of the first two channels of NOAA images were used to calculate the Normalized Vegetation Index (NDVI). NDVI values were calibrated according to the formula (S.N. Goward et al, 1991):

$$NDVI = (Y_2 - Y_1)/(Y_2 + Y_1) \quad (2)$$

where:

$Y_1 = G_1 * DN_1 + I_1$
 $Y_2 = G_2 * DN_2 + I_2$
 G_i, I_i - gain and intercept for channel i
 DN_1, DN_2 - spectral response for channel 1, 2 respectively.

NDVI values calculated using equation (2) and corrected due to the effect of solar zenith angle according to S.M.Singh (1988):

$$NDVI_c = NDVI * (\theta_s) / (1 - \gamma) \quad (3)$$

where:

$$\theta_s - \text{solar zenith angle [Rad]}$$

$$\gamma = 0.739 \theta_s^{1.602}$$

$$\theta_s = (\theta_s - 176)$$

For the study area aerial infrared (IR) photographs were taken for the same days as NOAA images. From these photographs taken from the altitude of 1600 m photomosaics were created using density slicing method. The photomosaics were overlaid with the grid of NOAA pixels and for each pixel one value of LAI, biomass and height of the grass were calculated as weighted averages.

2.3 Methodology for evapotranspiration computation.

Instantaneous evapotranspiration values were assessed as a residual from the energy budget equation:

$$LE = RN - H - G \quad (4)$$

where:

- LE - the rate of loss of latent heat by evapotranspiration (named as E) [W/m²]
- RN - the rate of net gain of heat from radiation (measured at the study area) [W/m²]
- H - the rate of loss of sensible heat by convection [W/m²]
- G - the rate of loss heat into the ground (measured at the study area) [W/m²]

The values of the rate of loss of sensible heat by convection (H) were calculated as follows:

$$H = [\rho * Cp * (Ts - Ta)] / ra \quad (5)$$

where:

- ρ - air density [kg/m³]
- Cp - specific heat of air [J/kg*K]
- Ts - surface temperature extracted from NOAA/AVHRR images and corrected due to atmospheric water vapor [°C]
- Ta - air temperature measured at the study area [°C]
- ra - air resistance [s/m]

The values of air resistance (ra) were calculated as follows:

$$ra = [\ln(z-d)/zo] / K * u \quad (6)$$

where:

- z - height of measurements above the ground [m]
- d - zero-plane displacement level [m]
- zo - roughness length [m]
- K - Von Karman's constant equal to 0.41
- u - wind speed [m/s]

The values of roughness length (zo) and zero-plane displacement level (d) were calculated in the function of the height

of the grass (h) according to the Monteith (1973) as follows:

$$zo = 0.13 * h \quad (7)$$

and

$$d = 0.66 * h \quad (8)$$

Air resistance values were corrected for air stability using method of R.D.Jackson et al (1987).

For estimating roughness length and zero plane displacement the height of the grass should be known. It is possible to deduce these values from the Normalized Vegetation Index (NDVI). It was found a good linear relation between the height of the grass measured at the test site and NDVI derived from NOAA images (r = 0.86). Equation (9) presents this relationship.

$$h = 0.4 * NDVI + 0.04 \quad (9)$$

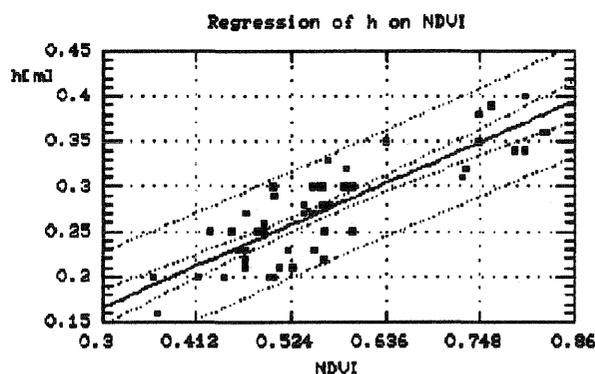


Fig.1 The relation between the height of grass (h) and NDVI.

3. RESULTS

Values of evapotranspiration for the study area calculated using aerodynamic method (Em) were compared to these obtained using equation (4) (Ec). Values of Em were taken as the ground references. The small discrepancies (about 10%) between evapotranspiration measured (Em) and calculated (Ec) are caused mostly by the differences between time of measurements and satellite overpass. Evapotranspiration (Ec) assessed from NOAA/AVHRR images was used for LAI and biomass prediction. The sensible heat (H) was calculated from equation (5) and evapotranspiration from equation (4) where surface temperature (Ts) was derived from NOAA/AVHRR data.

LAI was estimated applying NDVI values calculated from equation (3) and index H/E and Rn. Equations (10) presents this relationship (r = 0.91).

$$LAI = 19.6 * NDVI + 1.09 * H/E + 0.01 * Rn - 11.21 \quad (10)$$

From these results we can state that the multiple relationships between LAI and NDVI, index H/E and Rn are stronger than only with the index H/E.

The best results for calculating wet biomass were obtained using values of NDVI assessed from equation (3) and Rn and E

values from equation (4). Equation (11) presents this relationship ($r = 0.76$)

$$Bw = 1735 * NDVI + 0.93 * Rn - 1.54 * E + 102 \quad (11)$$

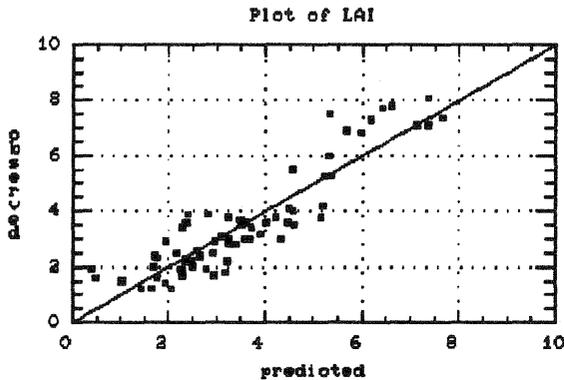


Fig.2 The relation between LAI observed and predicted.

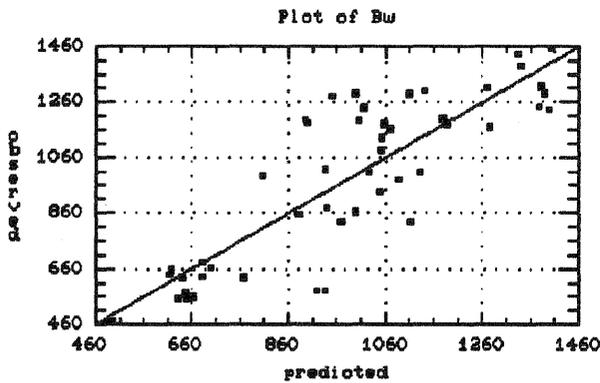


Fig.3 The relation between biomass observed and predicted.

Discrepancies between evapotranspiration obtained applying aerodynamic method (ground reference) and evapotranspiration assessed using temperature derived from NOAA/AVHRR images and meteorological data were small. Considering the results of this study it is possible to conclude that there is a relationship between LAI and the ratio of sensible heat to latent heat (H/E). The same relationship was obtained for biomass. For LAI and biomass prediction the linear model should be used using data registered in all channels of NOAA images as more complete for production forecasting. The advantage of this method is a possibility to assess spatial and temporal variables such as evapotranspiration, LAI and biomass which are very difficult to quantify at the large scale using field measurements.

For prediction of grass yield for the whole country a subject oriented geographic information system was established. Its data base was fed with information about distribution of grassland in Poland extracted from NOAA/AVHRR images. The next coverage was a map of administration division of the country with location of meteorological

stations. Another layers of the system's data base were NOAA/AVHRR images which were used for calculation of NDVI and evapotranspiration. This information was applied for creation the layer comprising values of LAI and biomass for each NOAA pixel which represents grassland.

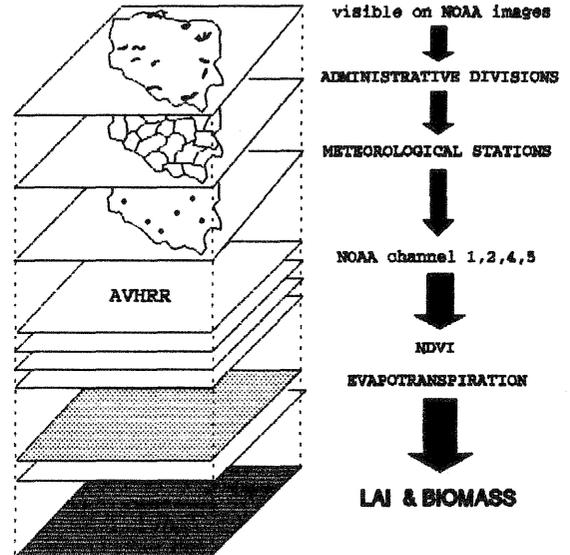


Fig.4 GIS coverages.

Information obtained from this geographic information system will be applied for refining the existing simulation models based only on meteorological data.

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