JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 12 2004

SCS CURVE NUMBER ESTIMATION USING REMOTE SENSING NDVI IN A GIS ENVIRONMENT

M.L. Gandini Facultad de Agronomía de Azul.
UNCPBA, Azul, Argentina
E.J. Usunoff Instituto de Hidrología de Llanuras
UNCPBA-CIC-MA, Azul, Argentina

The Soil Conservation Service Curve Number (SCS-CN) method is a simple, widely used and efficient procedure for determining the expected amount of runoff from rainfall in a particular area. Its use, however, requires a detailed knowledge of several important properties of the watershed namely soil permeability, land use and antecedent soil water conditions, which may not be readily available. The large amount of spatially detailed information derived from digital images offers new opportunities for SCS-CN estimates, particularly those parameters related to land use and vegetation coverage. This paper address the use of the Normalized Difference Vegetation Index (NDVI) and its combination with land use classes as well as soil type data to derive SCS-CN estimates within a GIS environment. The results are quite encouraging in terms of providing refined spatial information for input to rainfall-runoff models currently used for flood forecasting in the Azul River Basin, Argentina.

INTRODUCTION

The modified Soil Conservation Service - Curve Number (SCS-CN) method (USDA, 1973) is used to estimate the amount of precipitation which becomes runoff, and the amount which infiltrates into the soil. Curve numbers vary from fallow conditions to full crop cover, depending on canopy cover, and automatic adjustments for wet and dry antecedent conditions (conditions I and III) depending on estimated soil water in the top soil layer. If the moisture of layer 2 is below 60% of field capacity (antecedent condition I) the curve number is adjusted down, and if the moisture of layer 2 is above field capacity (antecedent condition III) the curve number is adjusted up.

Remote sensing can help in estimating land use types for CN determination (Ragan and Jackson, 1980; Tiwari et al., 1991), but is not yet used for evaluating land use conditions. In emergency situations it is necessary to have an estimation of the spatial distribution of land use and the status of the vegetal coverage in order to calculate basin runoff in as unbiased a manner as possible.

The Normalized Difference Vegetation Index (NDVI), a widely used remote sensing index, can be interpreted as an estimator of vegetative land coverage (Tucker and Sellers, 1986). NDVI has become a standard for band ratio applications, having a long history of use in remote sensing, ecology, and geography to study characteristics of vegetation including biomass, type, and condition (Griffith et al., 2002)

Several attempts have been made to interpret time series of the NDVI in order to estimate the productivity, leaf area index or absorption of atmospheric or terrestrial surface CO_2 based on the increase of vegetal cover (Tucker and Sellers, 1986; Sellers et al., 1992; Ludecke et al., 1996), or to classify covering types at the regional scale (Derrien et al., 1992). However, no attempts have been made to use NDVI or another indicator of vegetative cover to classify land into biomass cover classes.

SAC-C images have been shown to be useful for regional NDVI calculations (Gandini et al., 2002.) because of their resolution and path overlapping (they have a 6-day frequency for the Azul creek basin).

The aim of this paper is to build a method capable of evaluating ranges of probable curve number values for Azul creek sub-basins. These values can be used in emergency plans to calculate basin runoff and ranges of flooding areas in Azul city, Buenos Aires Province, Argentina.

MATERIAL AND METHODS

The Azul creek basin (Figure 1) covers 7000 km^2 and is located in a humid temperate zone with seasonal peaks of rainfall. The main production is crop cultures in the south and livestock in the northern sector.

Eight windows of SAC-C images covering this area were obtained for a period between April 2001-May 2002. The images were geometrically corrected at the sub-pixel level (mean RMS=0.879).

The NDVI of each scene was calculated using channels 3 (red) and 4 (near infrared) (Table 1) using ERDAS software, and reclassified into three vegetative cover classes with IDRISI GIS.

Land use was estimated by combining visual and automatic classification using a wide classification rule as used in curve number tables (USDA, 1973). The basin surface was classified into six classes, namely: urban, open water bodies, forest, natural grasslands and pastures, winter crops, and summer crops.

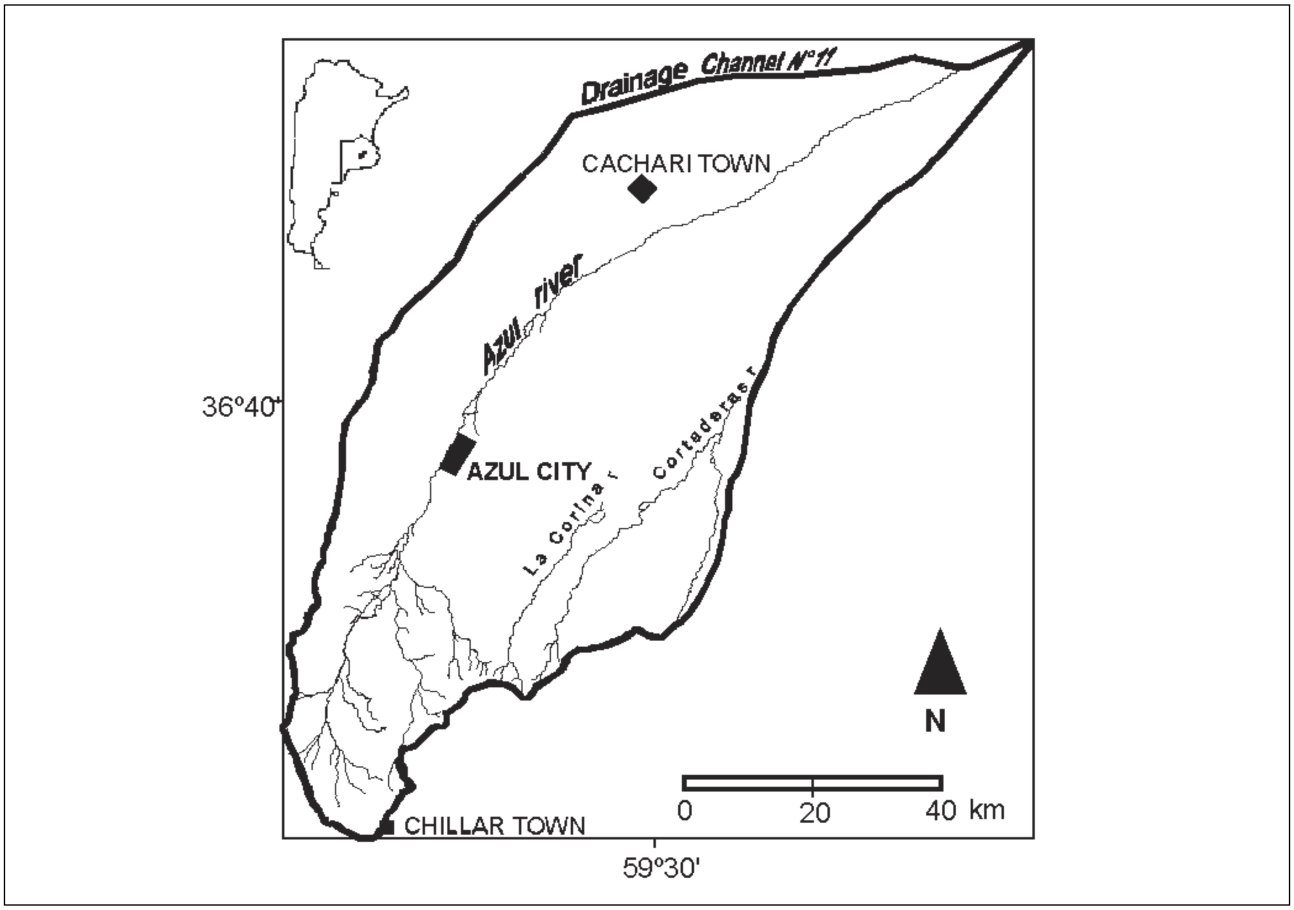

Figure 1. Azul creek basin and its location in Argentina.

Soil maps at a scale of 1:50000 were obtained from INTA (1973), digitized using ArcView software, and converted to hydrologic soil groups map (A, B, C, and D) in agreement with USDA definitions (Figure 2).

SCS curve number estimations were performed using mathematical operations such as those in Ferrer et al. (1995) in a GIS environment that took into account soil maps, land use maps, and vegetal coverage estimated by NDVI values, converted to a "cover condition" value (poor, fair, good).

Table 1. Radiometric Characteristics of the Five SAC-C MMRS Bands.

Band Number	Radiometric Range (nm)	Use in NDVI calculation
Band 1	480 - 500	No
Band 2	540 - 560	No
Band 3	630 – 690	Yes
Band 4	795 - 835	Yes
Band 5	1550 - 1700	No

Reference extreme CN values for the Azul creek basin were taken from Gandini et al. (2000).

RESULTS AND DISCUSSION

The land use map (Figure 3) reflects the distribution of the different land use classes for the 2001-2002 period. The percentages and areas of the six classes are presented in Table 2. As given by Figure

2, there exists a concentration of agricultural activities in the south and livestock in the north. The agricultural activities may leave soil uncovered in critical rainfall periods like late summer and near autumn (mainly 20 February-20 May), and contribute most of the runoff responsible for Azul city flooding. Figure 4 shows the NDVI values for March 2002 converted to cover condition, reflecting the facts just mentioned.

A set of eight curve number maps was generated by applying the eight maps of cover condition to the curve number definition. The agricultural zone reveals a high spatial variability according to

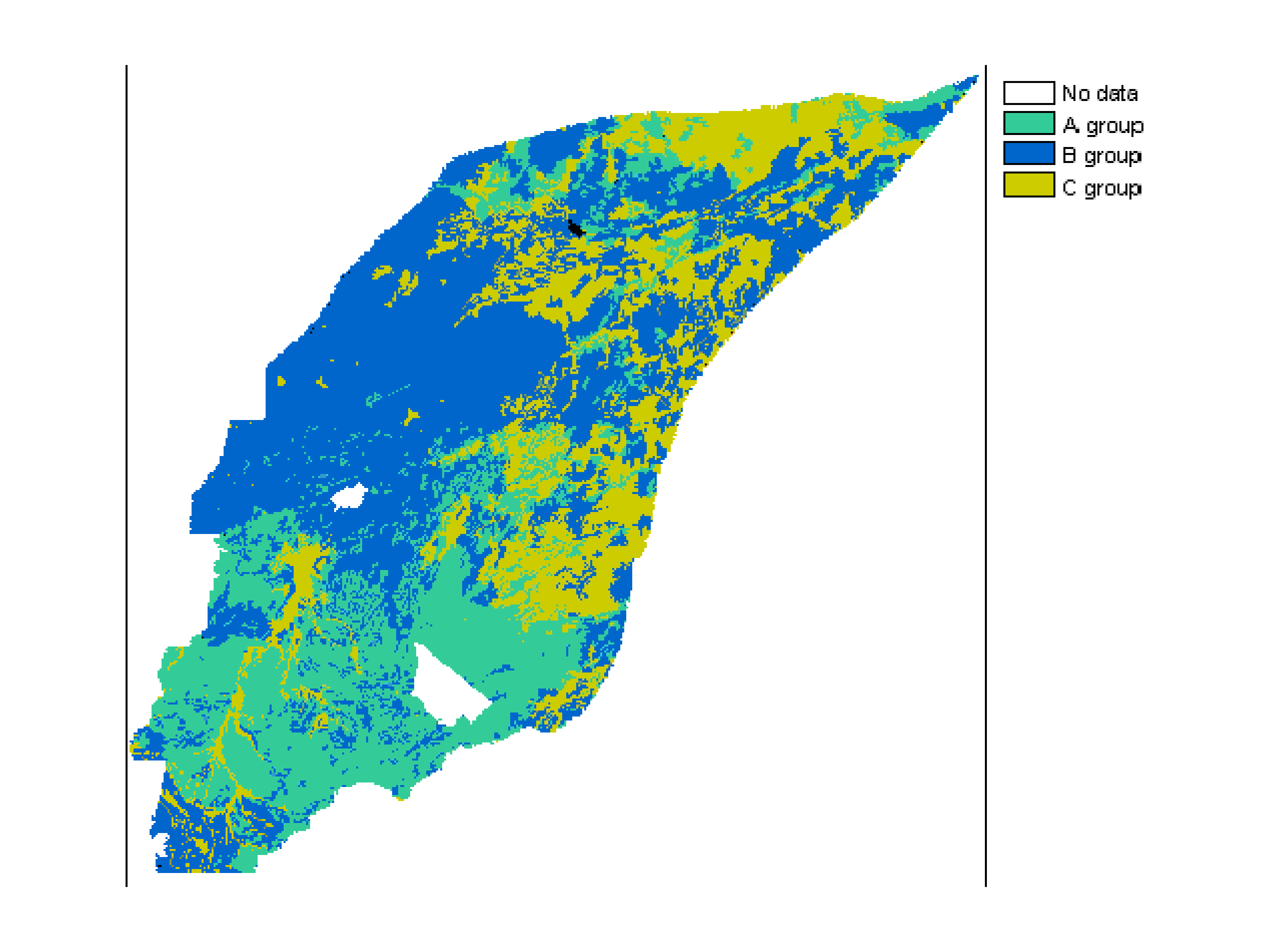

Figure 2: Hydrologic soil groups in Azul creek basin. Green: A; Blue: B; Yellow: C. Azul city was considered as no data.

the various uses. Medium and low cover areas are in the south coinciding with agricultural land use, reflecting soil plowing or low cover crop status (Figures 4c and 4d), although February 2002 (Figure 4g) shows dominant medium values in all the basin. This fact is coincident with an unusually dry period (Confallone, 2002 per. com.), with recovery in May 2002 (Figure 4h) due to rain events in autumn.

Table 2: Percent Cover Area of Different Classes of Land use/Land Cover and Possible Curve Number Values from SCS Tables.

Use/cover	Winter crops	Summer crops	Water	Forest	Urban	Grassland
Percent	27.03	27.53	1.46	2.38	0.02	41.49
Area (Km^2)	199461	203151	10773	17562	14.758	306165
CN range	65 - 82	72 - 81	100	45 – 77	74 - 92	68 - 79

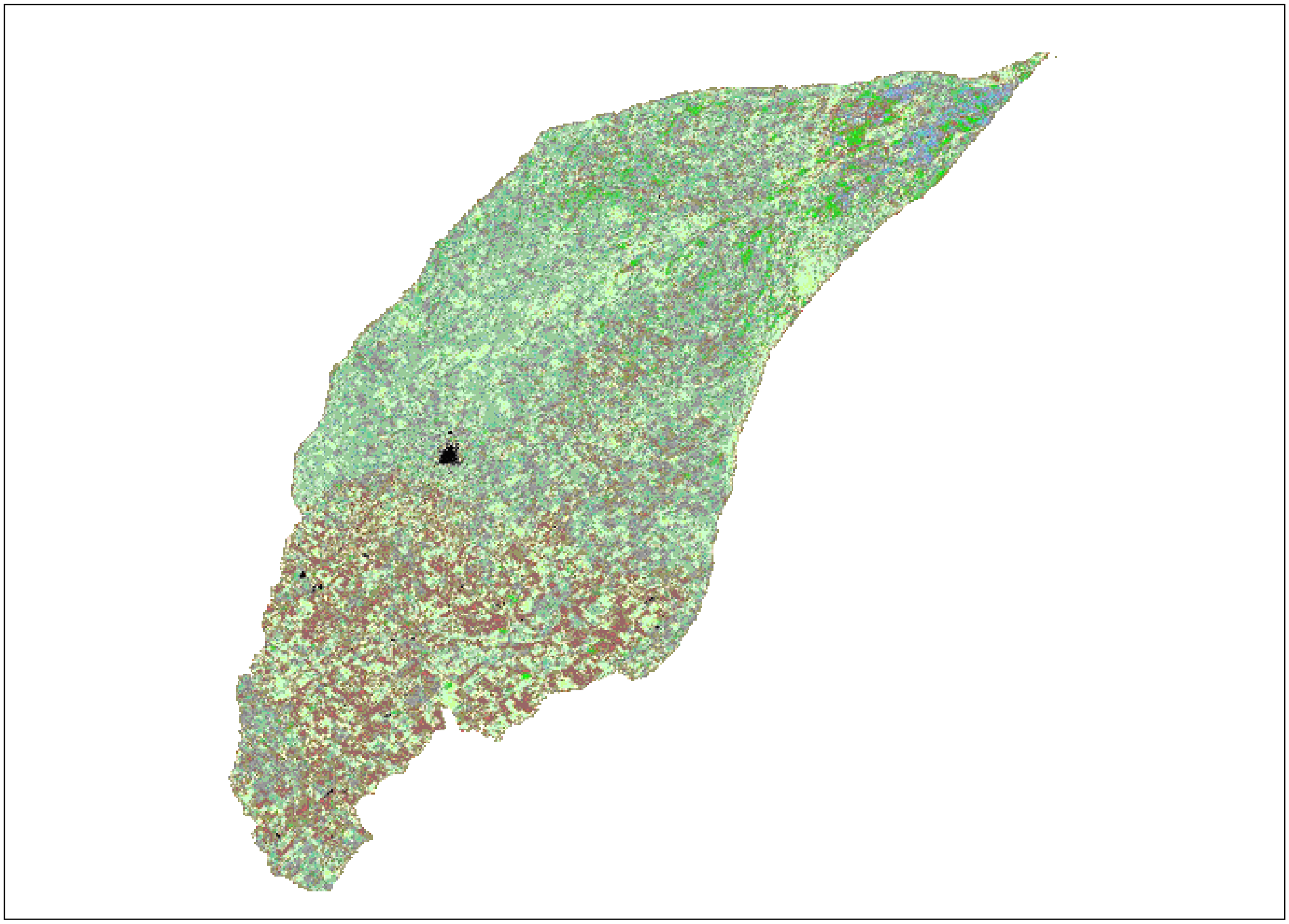

Figure 3. Land Use/Land cover map for Azul creek Basin. Black: Urban; Brown: winter crops; Yellow: summer crops; Dark green: grasslands; Green: forest; Blue: open water bodies.

Mean NDVI values varied in the study period with seasonal peaks near spring and late summer for all vegetation classes (Figure 5) justifying the NDVI approach for curve number calculations. Later response is seen for summer crops (row crops) and urban classes.

The CN maps are displayed in Figure 6 (a to h). The values varied between 92 (urban) to 45 (forest, good). The cropland zone can be viewed as a mosaic of changing CN values due to differences in land use. On the other hand, grasslands show a more continuous aspect related to their mostly uniform and non-destructive use of vegetative cover. The CN for February 2002 (Figure 6g) matches the low cover values observed (Figure 4g).

The same trend as the NDVI values is observed in CN temporal variations and meanwhile hydrologic soil groups appear as constraints for defining upper and lower limits of CN. A comparison of Figure 2 and Figure 6 (c to g) shows a more important component of hydrologic soil group B leading to lower CN values.

The methodology presented here appears to make good use of general-purpose tools in a novel hydrological application that handles readily available map information input to a GIS. The data can be updated by means of the acquisition of satellite images. In this case SAC-C combines a wide space covering with a half resolution (175 m), with direct application in regional hydrological studies.

The calculated CN may later serve as input to most hydrological models and contribute to rainfall-runoff modeling or be part of hydrological decision support systems.

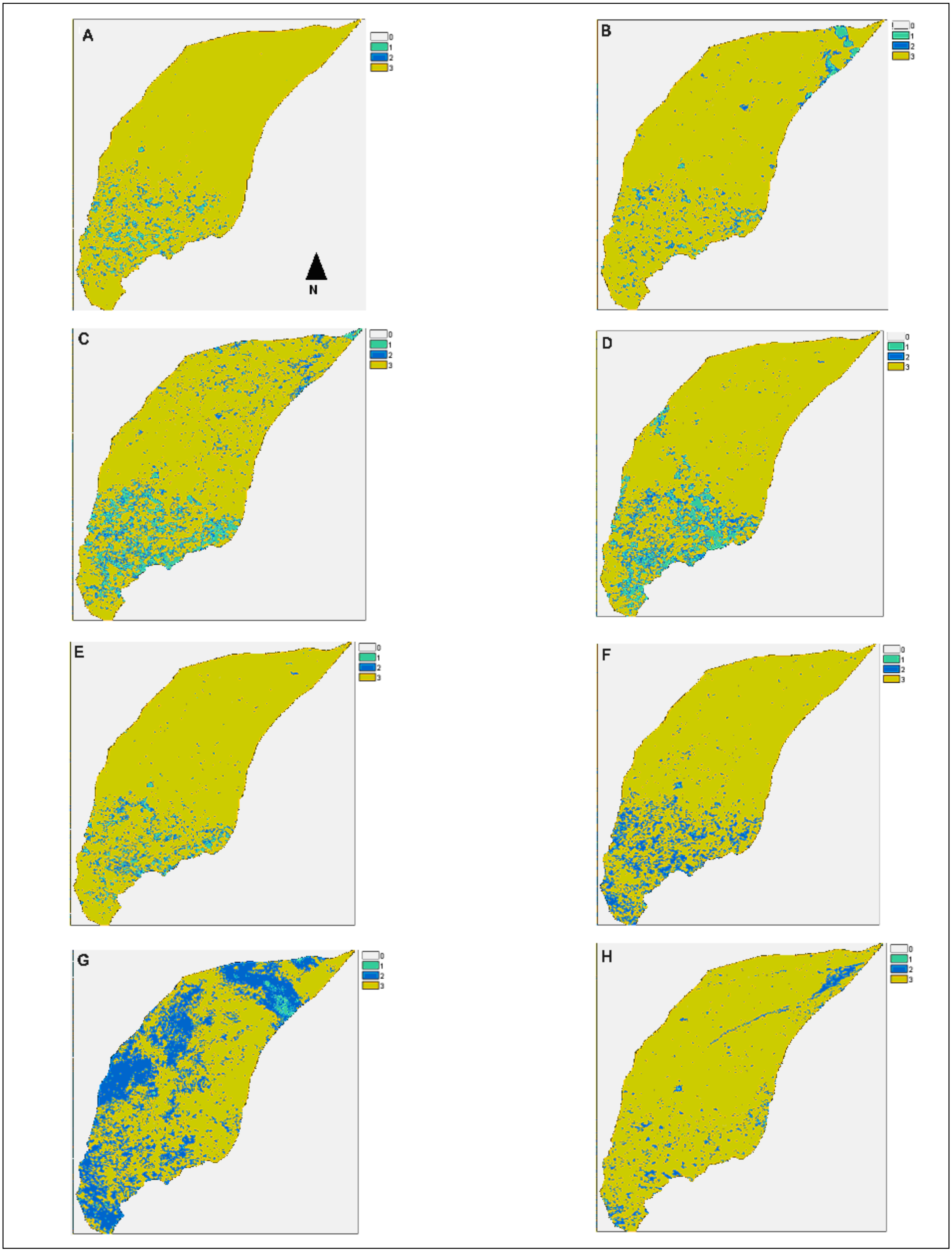

Figure 4. NDVI values for study period converted to cover condition. a) April 2001 b) May 2001 c) June 2001 d) September 2001 e) December 2001 f) January 2002 g) February 2002 h) May 2002. References: 1 (green) Low –Poor cover; 2 (blue) Medium-Fair cover; 3 (yellow) High –Good cover.

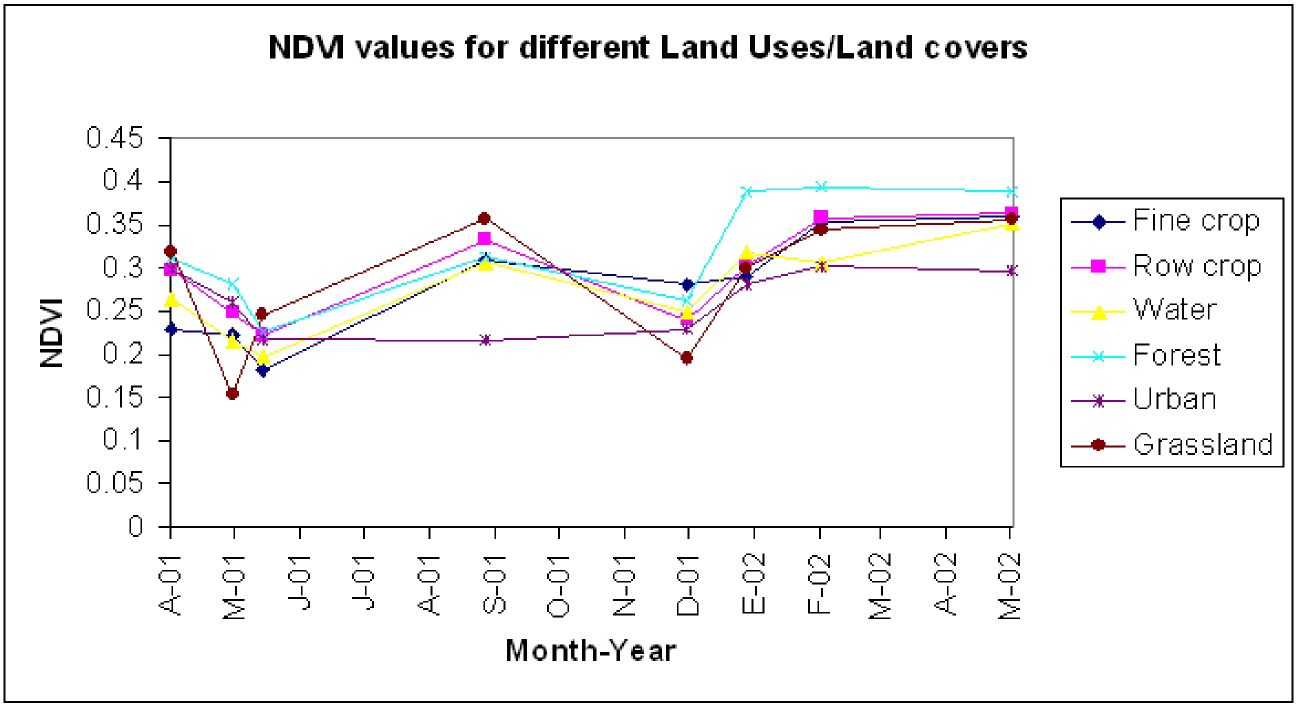

Figure 5. Mean NDVI values for six Land Use/Land cover classes.

ACKNOWLEDGMENTS

This research was supported by the Secretaría de Ciencia, Arte y Tecnología, Universidad Nacional del Centro de la Provincia de Buenos Aires.

SAC-C images were provided at no cost by the Comisión Nacional de Actividades Espaciales (CONAE), República Argentina, project: “Análisis de la variación de la productividad de los ecosistemas y del uso de la tierra como determinantes del comportamiento hidrológico superficial de la cuenca del arroyo del Azul, Buenos Aires, Argentina (ECOAZUL)”

We also thank Leyca Systems for donation of ERDAS 8.7 software, ESRI for donation of ArcView 8.3 Software, and Ing. Carlos Graff for permitting us to use Idrisi GIS in some calculations.

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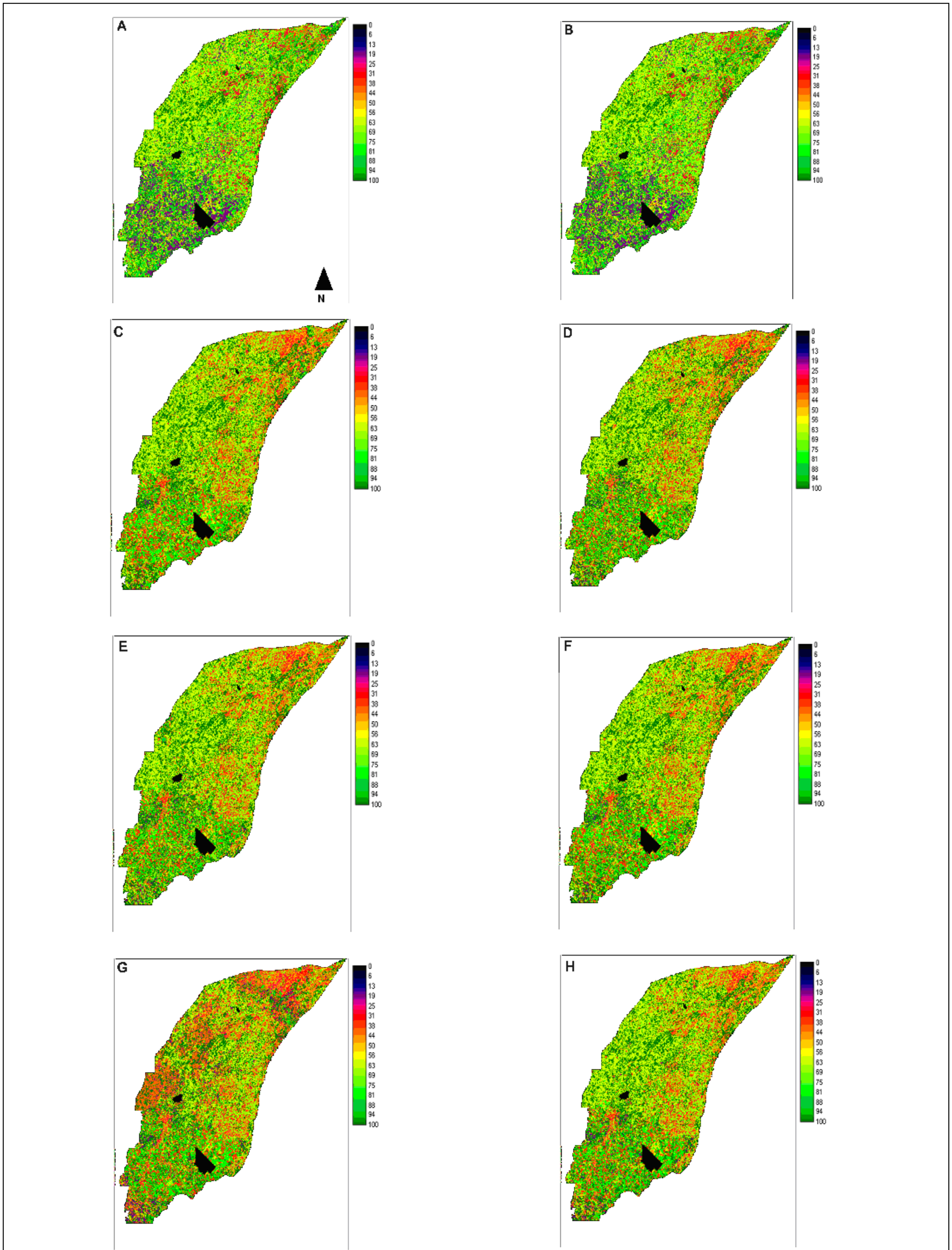

Figure 6 a to h. Curve Number values assigned by mathematical GIS operations for Azul creek basin a) April 2001 b) May 2001 c) June 2001 d) September 2001 e) December 2001 f) January 2002 g) February 2002 h) May 2002

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ADDRESS FOR CORRESPONDENCE
Eduardo J. Usunoff
Instituto de Hidrología de Llanuras
UNCPBA-CIC-MA
Av. República de Italia 780
7300 Azul. Buenos Aires
Argentina

E-mail: eusunoff@faa.unicen.edu.ar