PREDICTING FLOODPLAIN VEGETATION STATE FROM REMOTE SENSING-DERIVED HYDROLOGICAL HISTORY

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1. INTRODUCTION.

Remote Sensing (RS) is an increasingly important tool for monitoring and management of wetland environments, particularly in the context of change in climate and catchment characteristics. For large wetlands in developing countries with limited management resources, RS-based assessments are clearly a first-choice approach. The application of RS to wetland management problems, however, is subject to a number of constraints, which significantly include a paucity of continuous historical records, cost, and resolution (spatial, temporal and spectral).

The relationships between hydrology and floodplain ecology in Botswana's flood-pulsed Okavango Delta are poorly understood, but are critical inputs to national and international policy development, and to management decisions for both the Delta and indeed the whole basin, which lies predominantly in Angola and passes through Namibia en route to the endorheic Delta. Regional climate change and land-use change are inevitable sources of hydrological change in the catchment and the Delta, with equally inevitable ecological effects. This paper describes an approach to developing ecological management tools by seeking relationships between various disparate archival RS data and floodplain vegetation community data.

2. FLOODPLAIN HYDROLOGY AND VEGETATION IN THE OKAVANGO DELTA.

Hydrological conditions in the Okavango Delta are determined by the combination of local rains and the magnitude of the annual flood originating from the Okavango River catchment. The seasonal and inter-annual variability of hydrological inputs to the Delta translates into spatial heterogeneity and temporal variability of hydroperiod conditions taking place at various spatial and temporal scales. Successional processes in floodplain vegetation communities in the Delta are driven by the prevalent hydroperiod conditions, and extant communities are thus a reflection of (recent) past and present hydroperiod dynamics. Could this relationship be used to establish extant vegetation state (~sere) spatially under different hydrological regimes?

The various different vegetation communities on the Delta floodplains support very different trophic networks, both terrestrial and aquatic. The arrangement and interdependence of these ecological networks in space and time forms the basis of the low-impact, high-return eco-tourism industry in the Delta. Detailed understanding of how these networks and their relationships respond to hydrological change superimposed on their natural variability is an essential step in formulating management strategy.

3. ESTABLISHING HISTORICAL HYDROPERIOD.

The classical approach to RS use for assessment of relationships between hydrology and floodplain ecology faces two difficulties in the Delta. Firstly, there are spectral resolution problems in discriminating vegetation with subtly different signatures but radically different ecological functions. Secondly, spectral responses are dynamic in time, resulting from superposition of effects arising from emerging and increasingly denser vegetation with those resulting from varying water levels (dry-inundated). These were overcome by limiting RS interpretation to a simple two-class system, wet or dry, and derivation of hydroperiod conditions from time series of RS images at annual and intra-annual scales. This was achieved with satisfactory consistency from Landsat, ASTER and MODIS imagery. Hiatuses in the RS records were filled by using data from multiple platforms, between which there is sufficient temporal overlap to ensure agreement across platforms.

The initial step [1] was the careful interpretation of Landsat images of annual maximum flood extent in the year 2002 against a reference set of large-scale aerial photography; this study developed an objective routine for discriminating floodplain vegetation from active riparian vegetation, and for distinguishing dry and wet fire scars. This allowed the identification of areas not prone to flooding in the medium to long term, as well as a system for mapping annual maximum flood extent in a time-series of Landsat images from 1989 to 2007. There are, however, 3 hiatuses in this series: 1991, 2003 and 2004. For the latter two years, partial coverage is available from archival ASTER imagery, while full coverage of the time series 2000-2007 is available from MODIS. In addition, in order to derive flood duration, numerous images from within each flood cycle are needed; Landsat or other high-spatial resolution imagery (SPOT, ASTER) becomes cost-prohibitive for such analysis.

A second time series of maximum flood extent was derived from MODIS 8-day composite imagery at 250m resolution and a temporal resolution of 1 month, using the Landsat and ASTER interpretations for reference. The annual flood history, and flood duration at a monthly time step, of landscape units at the scale of individual floodplains, was thus established for a continuous 8-year sequence from 2000-2007.

4. ESTABLISHING EXTANT FLOODPLAIN VEGETATION STATE

Two distributaries in the Delta were selected for detailed study: the Boro and neighboring Xudum systems. These systems are characterized by pronounced seasonal fluctuations in response to the annual pulse, and thus exhibit a wide range of hydroperiod variation. A stratified (to represent the full spectrum of possible flooding frequencies) random set of 30 floodplain vegetation communities across these distributaries was selected and sampled for species composition and relative cover in 2007, using quadrats on transects oriented across the long axis of the floodplains. Ordination of these data from a sub-sample of 25 sites (5 sites were withheld for accuracy assessment) produced a set of floodplain communities and classes, defined in terms of extant vegetation. Multi-variate regression relationships identified between hydrological characteristics and vegetation communities were then translated into spatial distribution maps of current vegetation state, and validated using the sites withheld from analysis.

5. CONCLUSIONS

By combining independent RS dry-wet interpretation and vegetation survey techniques to identify relationships between vegetation state and hydroperiod in floodplains, the problems of spectral overlap in space and time, which have dogged the application of RS to vegetation mapping in the Okavango Delta floodplains, were overcome. The results from this study will be used to develop a spatial hydrology-driven vegetation model.

[1] Wolski, P. and M. Murray-Hudson (2006). “Reconstruction of 1989-2005 inundation history in the Okavango Delta, Botswana, from archival Landsat imagery.” Globwetland Symposium, Frascati, Italy. ESA-ESRIN.