MODELING THE RIPARIAN ZONE

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ABSTRACT

The relation between riparian vegetation and streamflow is complex. Furthermore, the present state-of-the art in modeling the link between riparian vegetation and flows in the river is rudimentary. Two simple models are presented in this paper. The first links streamflows to the potential for establishment of cottonwood trees and is applied to the Bosque del Apache reach of the Rio Grande in central New Mexico. The second model links herbaceous species composition at a point on an elevational gradient to the frequency that the point is inundated. This model is applied to the canyon bottom of the Black Canyon of the Gunnision River in western Colorado.
Keywords: Riparian vegetation, cottonwood, streamflow

COTTONWOOD ESTABLISHMENT INDEX

Over the last 150 years the riparian cottonwood forests of the Middle Rio Grande Valley have changed significantly. The native cottonwoods are adapted to the natural pattern of a snow melt hydrograph characterized by spring floods in late May or early June, followed by gradually receding streamflows throughout the remainder of the summer. The natural pattern of streamflows has been significantly modified by water management activities in the Rio Grande basin and reduction in peak flows have been suggested as a cause of changes in riparian forest.

An index model of establishment suitability was developed to test the potential importance of flow alterations on cottonwood regeneration in the Bosque del Apache reach of the Rio Grande between San Acacia and San Marcial, NM, using streamflow data from gages near San Marcial (Milhous, 1994). Suitable conditions for cottonwood seedling establishment include a bare, moist substrate during the time the seeds disperse, followed by flows that do not destroy (usually by erosion or overtopping) the small plants. The first assumption of the index model is that the clean substrate results if flows cover an area during the period 1 April thru 15 July. The next assumption is that young seedlings survive if subsequent flows during the rest of the water year and through the next year do not exceed the flows during the initial germination window. If the flows during the rest of the water year or during the following water year are greater than the cleansing flow, the establishment index is zero. The model determines areas suitable for establishment by assuming the width of a river can be calculated using the simple power law, $W = A*(Q**B)$, (1)

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where W is width, Q is streamflow, and A and B constants. If the streamflow available to prepare an area for cottonwood establishment is QEST, and the flow following the establishment period limiting the area available for establishment is QDES, then the width available for establishment (WEST) is

$$WEST = A*((QEST**B) - (QDST**B)). \quad (2)$$

The objective is an index to establishment; therefore, we assume the value of A is 1. The establishment index (ESTI) is thus

$$ESTI = (QEST**B) - (QDST**B). \quad (3)$$

The width versus discharge relation (discharge in cms, width in meters) for the San Marcial gage is

$$W = 18.75\ Q^{0.34}\ . \quad (4)$$

QEST is the maximum average 5-day discharge in the period 1 April thru 15 July. QDST is the maximum average daily discharge in the rest of the water year and the following water year. The results are given in Fig. 1. Note that there have been periods available for cottonwood establishment during all of the record, although the construction of upstream reservoirs has probably caused a reduction in the amount and the frequency. Thus, the establishment index model suggests that a moderate increase in peak flows would not improve the establishment of cottonwood in the Bosque del Apache reach.

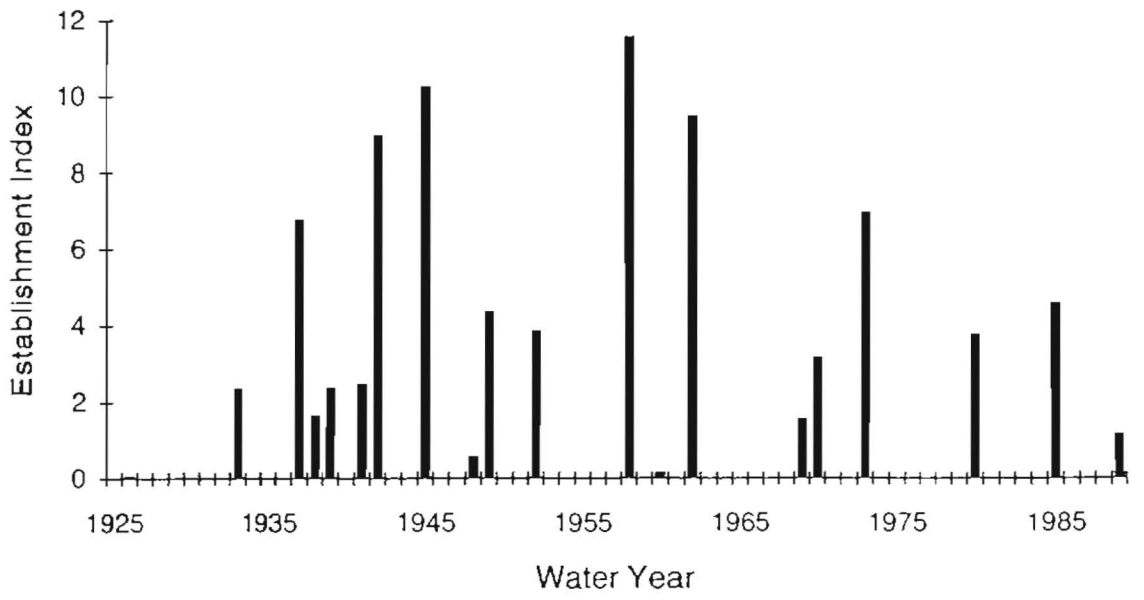

Figure 1. Annual Establishment Index based on seedling survival for the Rio Grande River near San Marcial, New Mexico. Water years 1925 thru 1989. Streamflow data from the records of the U.S. Geological Survey.

HYDROPERIOD GRADIENT MODEL

This model employs a direct gradient analysis of existing vegetation to locate cover types along a gradient of hydroperiod, or fraction of time inundated as indicated diagrammatically in Fig. 2. The model has been applied to the largely herbaceous riparian vegetation of the Black Canyon of the Gunnison National Monument along the Gunnison River in Colorado (Auble et al., 1994). The model was calibrated by measuring the existing distribution of vegetation along a hydroperiod gradient. Randomly located plots were censused and four cover types were defined. A hydraulic model for the reach was calibrated and used to estimate the hydraulic position or discharge required to inundate each plot. Each plot was assigned to one of the cover types, and the hydroperiod determined for each plot based on the discharge required to inundate the plot and the historical flow exceedance curve. The hydroperiod gradient was broken into 12 classes and the proportion of plots in each cover type was calculated for each hydroperiod class (Fig. 3). These proportions were then used as probabilities to estimate the future cover type of a plot from its future hydroperiod.

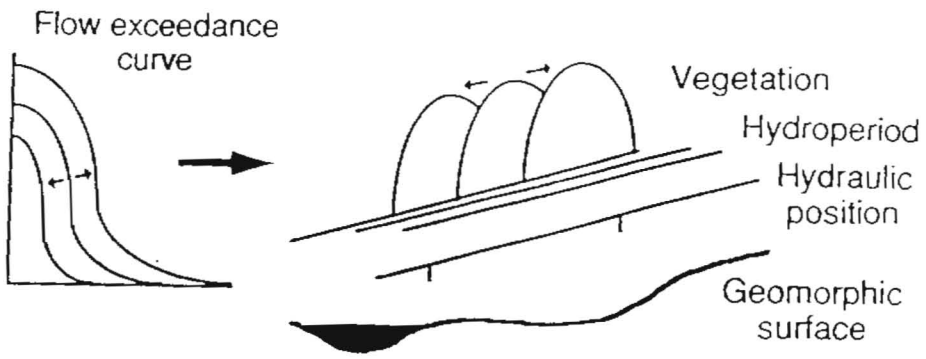

Figure 2. Diagrammatic application of direct gradient model (from Auble et al., 1991).

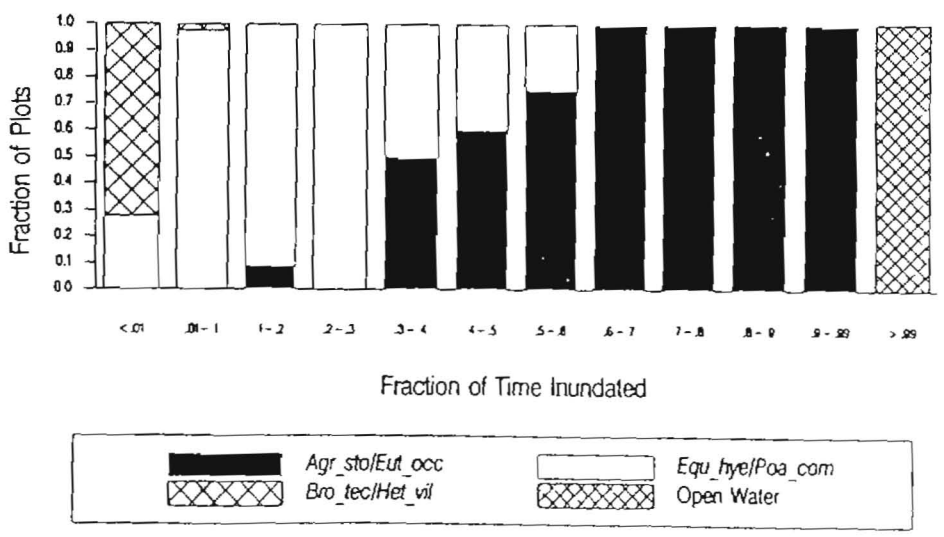

Figure 3. Observed distribution of riparian cover types used to calibrate direct gradient model (from Auble et al., 1991).

Flow exceedance curves describing different hydrologic alternatives were used to produce plot hydroperiods associated with each alternative. Applying the cover-type probabilities to plots with new hydroperiods produced an estimate of the expected value of the new number of plots in each cover type as follows:

$$n(i,j) = P(i,j) * T(j), \qquad (5)$$

where n(i,j) = number of plots in cover type i and hydroperiod class j, P(i,j) = probability that plot in hydroperiod class j is in cover type i, T(j) = total number of plots in hydroperiod class j.

DISCUSSION

The complexity of riparian systems and the current state of the art of models relating streamflow to riparian vegetation do not permit development of a general model that can be reliably applied to a wide range of assessment problems. Rather, we are in the position of carefully matching the restrictive assumptions of available models to answering limited questions about particular riparian systems. The principal advantages of the cottonwood establishment index and direct gradient models are their simplicity and reliance on relatively standard aspects of plant community ecology and hydrology. Their most serious limitations are centered on unrealistic assumptions about stationary channel geometry. The direct gradient model may work reasonably in a bedrock controlled canyon, but where the channel is meandering the hydroperiod of points in the riparian zone is changing as the discharge to inundate those points changes. Likewise, the cottonwood establishment model may be doing poor job of estimating long-term cottonwood regeneration by failing to account for whether or not the suitable area is in the same or different locations over time. Seedlings established in the same location as last year's seedlings do not produce the same replacement of trees as seedlings established on a newly accreting point bar that will be less subject to future disturbance as the river moves away from the establishment site. Effectively incorporating fluvial geomorphic processes into the relation between flow and vegetation is the challenge of the next generation of riparian models.

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