Forest Ecology and Management 281 (2012) 1–11

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Changes in vegetative communities and water table dynamics following timber harvesting in small headwater streams

B. Choi [a,c,*], J.C. Dewey [b], J.A. Hatten [c], A.W. Ezell [c], Z. Fan [c]

[a] Research Center for River Flow Impingement and Debris Flow, Gangneung-Wonju National University, Gangneung 210-702, South Korea
[b] Department of Geology and Geophysics, University of Wyoming, P.O. Box 3006, 1000 E. University Ave., Laramie, WY 82071, USA
[c] Department of Forestry, Mississippi State University, P.O. Box 9681, Mississippi State, MS 39762, USA

ARTICLE INFO

Article history:
Received 22 September 2011
Received in revised form 10 June 2012
Accepted 14 June 2012
Available online 15 July 2012

Keywords:
Ephemeral streams
Riparian zones
Streamside Management Zones
Water table
Prevalence index
Indicator species

ABSTRACT

In order to better understand the relationship between vegetation communities and water table in the uppermost portions (ephemeral–intermittent streams) of headwater systems, seasonal plot-based field characterizations of vegetation were used in conjunction with monthly water table measurements. Vegetation, soils, and water table data were examined to determine potential indicator species of near-surface water that could be used in rapid delineation of Streamside Management Zones (SMZs) by forest managers. Twelve watersheds were instrumented with three hundred screened wells, installed in grids of 25 per sub-watershed. Well locations were used to monitor water table and vegetation communities. Species were classified according to their wetland indicator status for Region 2; communities were evaluated using a prevalence index (PI). As part of a larger study, the uppermost reaches of the headwater systems were treated one of four treatments: (1) removal of all merchantable stems leaving understory intact with minimum surface soil disturbance (BMP1), (2) the same as treatment BMP1with the addition of logging debris in the drainage channel (BMP2), (3) total harvest with no BMPs applied (clearcut) and (4) no harvest (reference). Post-harvest increases in water table ranged from 1.6 cm in BMP1 to 28.2 cm in clearcut treatments during 2008, from 10.5 cm in BMP1 to 54.2 cm in BMP2 during 2009. PI differed significantly between channel and hillslope positions and represent distinctive vegetation communities. Forest clearcutting affected vegetation communities through combined direct and indirect disturbances. PI in the clearcut did not respond directly to changes in water table. In the two treatments where BMPs were employed, changes in vegetative communities corresponded to both changes in water table and changes in the microclimate as a result of harvesting intensity and changing stand heterogeneity. A vegetative indicator analysis, based on the presence of saturated soil conditions and water table elevation, was used to determine potential indicators of the true hydrologic boundaries of the headwater streams. Three potential indicator species (*Viola blanda*, *Ludwigia glandulosa*, and *Arundinaria gigantean Ssp. Tecta*) were more prevalent within "wet" channel positions but exhibited less total frequency of occurrence across the study areas than the fern species *Polystichum acrostichoides*, which is locally used for rapid estimation of intermittent stream extent). The combined use of the strong indicator species identified in this study and the "fern line" used by local industry foresters provides a means for rapid assessment of hydrologically functional SMZs in these headwater streams.

1. Introduction

Headwaters are a critical component of the stream network and represent from 50% to 80% of the total stream length in the US (Leopold et al., 1964; Hansen, 2001; Benda et al., 2005). Headwater streams occupy topographically high positions and a substantial portion of drainage basins at points of stream initiation. They initiate fluvial transport of materials, energy, and nutrients to larger streams. The ecological connection between headwater streams and downstream water quality is of increasing interest to researchers and regulators; however traditional stream assessment tools do not work in temporary streams (Fritz et al., 2008). The ecological role of headwater streams also tends to be underestimated because of their small source areas (Gomi et al., 2002); subsequently they are rarely considered in forest management (Wipfli et al., 2007).

Riparian zones are three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems (Gregory et al., 1991). Most of the scientific information on the functional definition and delineation of riparian areas has been gleaned from

* Corresponding author at: Research Center for River Flow Impingement and Debris Flow, Gangneung-Wonju National University, Gangneung 210-702, South Korea. Tel.: +82 33 640 3037; fax: +82 33 640 3007.
E-mail address: bkchoi@gwnu.ac.kr (B. Choi).

0378-1127/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2012.06.021

studies conducted in higher-order streams (Verry et al., 2004). In higher-order stream systems, repeated fluvial and alluvial events result in the development of distinct geomorphic surfaces that can be linked to subsurface hydrology and geomorphology. These characteristics of higher-order streams are often useful for definition and delineation of the riparian zone. First-order streams are the dominant stream type in most forested headwater systems (Wipfli et al., 2007). Although fluvial and geomorphic processes are at work in first-order headwater streams (Clinton et al., 2010), little research has documented vegetation communities in the uppermost portions of headwater systems (Sheridan and Thomas, 2005). It is not obvious whether the distribution of vegetation communities follow hillslope gradients and whether there are distinct vegetation communities between these drainage channels and surrounding hillslopes (Gemborys and Hodgkins, 1971; Spackman and Hughes, 1995; Hughes and Cass, 1997; Zimmerman et al., 1999).

Streamside Management Zones (SMZs) are vegetated buffers designated along riparian areas that are a useful Best Management Practice (BMP) for protecting water quality and riparian ecosystem health (Vowell, 2001). SMZs have the ability to reduce excess sediment and nutrients from overland flow, provide shade, moderate water temperatures for aquatic wildlife, decrease erosion, stabilize stream banks, and provide wildlife and aquatic habitat. Most forestry BMP programs in the Southern US contain guidelines for intermittent and perennial streams; however there are few recommendations for small headwater areas characterized by ephemeral streams.

There is growing concern that SMZs should be extended to their upstream limits (e.g. ephemeral streams) in order to maintain hydrologic functions, and to preserve productivity, downstream water quality, and biota within the watershed. However, there is considerable debate surrounding buffer width and extent in forest management. Can ephemeral streams have riparian zones and if so, how far should buffers be extended to maintain hydrologic and ecologic function? Criteria for defining the upstream limits of SMZs are indefinite which makes it difficult for landowners and forest managers to identify and determine functional upstream limits of SMZs. In Webster County, Mississippi, the upper limit is often locally defined by the "fern line" based on the experience of local foresters without corroborating data indicating that the fern line represents the hydrologic and ecologic functional limits of the watershed. In addition, the blue-line streams from US Geological Survey (USGS) topographic contour maps are not reliable tools for determining stream extent and are not designed to represent ephemeral streams (Hansen, 2001). Policy makers and forest managers are faced with the difficulty of making decisions about appropriate riparian zone protection for ephemeral streams based on insufficient information regarding the contributions of ephemeral streams to downstream segments.

In this study, plot-based field characterizations of vegetation were used in conjunction with water table measurements to document changes in vegetation communities and water table in the uppermost portion of small headwater streams and to determine to what extent water table is linked to vegetation communities. The study includes pre- and post-harvest observations documenting two potential best management strategies for headwater areas. Objectives were to (1) detect the transition zone between upland and riparian areas that can be identified based on vegetation communities, (2) determine the effects of timber harvesting on water table and vegetation communities in these transition areas, and (3) determine whether there are plant indicators which can be used in conjunction with geomorphology to infer hydrology.

2. Methods

2.1. Site description

The study area comprises three first-order headwater catchments located in Webster County, Mississippi, within the Sand-Clay Hills subsection of the Hilly Coastal Plain Province. Study sites were chosen based on the presence of intermittent streams, forest land available for research, and similarity of vegetation, topography, and soils. The study area has a humid subtropical climate characterized by long, hot summers and short, mild winters. Precipitation is well distributed throughout the year with a 30 year mean of 1451 mm. Short, high-intensity storms are common and storm precipitation can exceed 100 mm on occasions. Average winter temperature is 7 °C; average summer temperature is 26 °C (US National Weather Service station 222896 Webster, MS). Watershed size ranged from 3.8 to 9.2 ha among the 12 watersheds. Geomorphic setting is similar across watersheds. Stream gradients and hillslope gradients ranged from 2% to 19% and 2% to 26%, respectively, but both were consistent within catchments (Table 1). Two soil types were present: well drained, Fine, mixed, semiactive, thermic Typic Hapludults (Sweatman Series) and moderately well drained Fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs (Providence Series) (McMullen and Ford, 1978). Soils within the rolling to ruggedly hilly area are high in clay content with A-horizons of either loam or silt loam. Streamflow occurs in response to a combination of precipitation and groundwater discharge during wet-season months. Streamflow during the summer months or drought years occurs in response to precipitation; hillslope water table drops to >2 m below the surface in the summer.

Table 1
Physical characteristics of study headwater streams in Webster County, Mississippi.

Watershed	Treatment	Watershed area (ha)	Stream length (m)[a]	Stream gradient (%) mean (min, max)[b]	Hillslope gradient (%) mean (min, max)	Basal area removed (%)[c]
Union	BMP1	2.4	92	5 (4, 6)	26 (13, 39)	8.9
Union	BMP2	3.6	83	4 (3, 5)	22 (3, 42)	32.4
Union	Clearcut	3.8	81	4 (3, 5)	26 (14, 40)	70.1
Union	Reference	1.8	78	5 (4, 5)	21 (3, 39)	–
Congress	BMP1	2.9	117	5 (4, 5)	15 (2, 29)	28.1
Congress	BMP2	2.4	96	13 (6, 19)	14 (3, 31)	53.1
Congress	Clearcut	2.5	95	19 (12, 22)	18 (12, 30)	88.3
Congress	Reference	2.1	102	12 (11, 13)	18 (10, 40)	–
Ingram	BMP1	6.7	73	3 (2, 4)	19 (16, 24)	55.4
Ingram	BMP2	3.3	55	2 (2, 3)	2 (2, 3)	75.1
Ingram	Clearcut	7.1	85	5 (4, 6)	16 (10, 22)	95.2
Ingram	Reference	6.3	116	5 (4, 6)	20 (5, 29)	–

[a] Stream length was a distance from the center well of the first measurement transect to the center well of 5th measurement transect.
[b] Stream gradient was measured within measurement transects.
[c] Values are approximate based on subsample within water table well transects.